Factors Underlying Phonological Awareness Development in Preschool Children

by

Michelle E. Erskine

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ABSTRACT

Phonological awareness provides an important foundation for learning to read. Children who demonstrate poor phonological awareness skills often experience difficulty learning to read. Research has found that phonological awareness is also among the best predictors of subsequent reading ability in longitudinal studies (Chang, 1995; Bird, Bishop & Freeman, 1995; Wood& Terrell, 1998; Stuart, 1999). However, it is exceedingly difficult to measure phonological awareness in preschool children who are younger than 4-years-old. Some researchers suggest an alternative approach to examine phonological awareness in younger children; this approach involves examining correlates of phonological awareness in preschool children. This study investigates whether individual differences in measures such as vocabulary size and articulatory ability in children as young as 2 ½ to 3 years of age, predict phonological awareness one and two years later. The results of this study show that the best predictors of phonological awareness at age 5 are receptive vocabulary size and a measure of phonological short-term memory. It is vital for clinicians and researchers to understand the mechanisms that underlie phonological awareness development as they continue to encourage and support early intervention. This knowledge will help to eliminate reading deficits among school-age children that can result in poor academic achievement.

CHAPTER ONE

LITERATURE REVIVEW

Phonological Awareness and Early Reading Ability

Reading plays a vital role in children's academic success. Children who read well tend to read more, and as a result acquire more knowledge across multiple content areas. Conversely, children who experience difficulties learning to read often develop negative perceptions of reading that later interfere with their capacity to learn (McBride-Chang, 1995; Cunningham & Stanovich, 1997). Not surprisingly, early success in reading is related to later academic outcomes (Anderson & Cheung, 2003; Robert, 2005; Lawson, 2012).

Research has found that phonological awareness is among the best predictors of subsequent reading ability in longitudinal studies (Bird, Bishop & Freeman, 1995; Wood& Terrell, 1998). A large body of research has shown that phonological awareness skills are causally related to early reading skills (Harm, McCandliss & Seidenberg, 2003; Goswami & Bryant, 1990). In a longitudinal study, Lonigan, Burgess, and Anthony (2000) examined phonological awareness and emergent literacy skills in two groups of preschool children. Structural equation modeling, used to describe the relationships among phonological awareness, emergent literacy and reading ability, showed that 54% of the variance in reading ability was significantly explained solely by measures of phonological awareness and letter knowledge. Similar results were found in studies with bilingual children, where measures of phonological awareness explained a large proportion of the differences between children in reading outcomes (Mediavilla, Buil-Legaz, Perez-Castello, & Rigo-Carratala., 2014).

Intervention studies have also reported improved reading ability when explicit instruction in phonological or phonemic awareness is provided. Torgesen, Alexander, Wagner, Rashotte, Voeller, and Conway (2001) evaluated 60 children with severe reading disabilities using two different instructional programs of phonemic awareness and phonological decoding training. Their results showed that children in both treatment groups improved their ability to manipulate sub-lexical units and their overall reading ability. Moreover, these gains remained stable two years after the treatment period. These findings are analogous to previous studies that also showed that explicit phonological awareness training significantly improved reading ability (Calfee, Lindamood, & Lindamood, 1973; Lundberg, Frost, & Peterson, 1988).

These studies have led to the consensus that there is a causal relationship between phonological awareness and early literacy acquisition. However, there is much less agreement about the underlying mechanisms driving phonological awareness. The literature evaluating these processes has identified several correlates including oral language skills, speech perception, and phonological memory.

Oral Language and Phonological Awareness

Historically, researchers have asserted that oral language skills provide a foundation for metalinguistic awareness more generally, and phonological awareness in particular. These studies measured different aspects of oral language ability including expressive and receptive syntax, morphology, and vocabulary knowledge. Irrespective of the different types of oral language skills investigated, researchers found consistent evidence that oral language skills were related to phonological awareness (Smith & Tager-Flushberg, 1982; Chaney, 1994; Snow, Tabors, Nicholson, & Kurland, 1995; Wagner, Torgesen, Rashotte, Hecht, Barker, Burgess, Donahue & Garon., 1997; Burgess & Lonigan, 1998; Oloffson & Neirdersoe, 1999). More recently, Cooper, Roth, Speece, and Shatschneider (2002) examined whether measures of early reading ability (letter-word knowledge), background factors (including SES and IQ), and oral language skills (encompassing syntax, morphology, and semantic knowledge) predicted phonological awareness skills concurrently (in kindergarten) and longitudinally (in 2nd grade). They found that children's oral language ability, both concurrently and longitudinally, predicted phonological awareness, beyond the influence of early reading knowledge. More specifically, oral language ability uniquely explained 42% of the variance in phonological awareness in second grade, independent of letter-word knowledge. It's important to note that the *language score* in this study was an amalgamation of several different oral language components including syntax, morphology, and semantics. Thus, their oral language measure does not directly inform researchers of the unique contribution of vocabulary knowledge, which some researchers have claimed is the crucial element for developing phonological awareness skills (*cf.* Metsala 1998;1999).

Speech Perception, Speech Production, and Phonological Awareness

Speech perception and phonological awareness rely on similar yet different aspects of phonological processing. Both skills require access to the acoustic-phonetic and phonological representations of words; however, some models of speech perception hypothesize that speech perception has a greater dependence on the acoustic-phonetic representations of words, while phonological awareness relies more heavily on the segmented nature of phonological representations. Speech perception is important for phonological awareness development because children's ability to encode acoustic-phonetic detail about words may affect the quality of phoneme representations comprised within phonological representations, which are subsequently accessed during assessments of phonological awareness (Nittrouer and Bourton, 2005). There is limited *empirical* evidence to support the relationship between speech production and phonological awareness. Studies that have evaluated this relationship focused on children with speech sound delays (Hoffman et al., 1983; Rvachew & Jamieson, 1989; Rvachew, 2006). Rvachew, Ohberg, Grawburg and Heyding (2003) demonstrated that children with speech sound disorders performed poorly on measures of phonological awareness. However, the exact nature of the relationships among speech perception, speech production and phonological awareness remain unclear.

In a longitudinal study of 4-year-old children diagnosed with speech sound disorders, Rvachew (2006) evaluated the degree to which speech perception, speech production, and vocabulary skills accounted for differences in performance on different measures of phonological awareness. There was a significant predictive relationship among receptive vocabulary, speech perception, and phonological awareness, such that receptive vocabulary and speech perception skills at age 4 explained a combined 37% of the variance in phonological awareness at age 5. However, the paper did not specify how much of this variance was uniquely predicted by either receptive vocabulary or speech perception. There was no direct relationship between speech production skills and phonological awareness. Moreover, speech production did not account for additional differences in phonological awareness once the authors controlled for receptive vocabulary size and speech perception skills.

Nonword Repetition and Phonological Awareness

Nonword repetition is a complex phonological processing task that requires phonological encoding of the acoustic signal, temporary storage of the phoneme sequences in phonological short-term memory (or verbal short-term memory), and subsequent articulation of the phonological sequences. Previous studies have used the nonword repetition to evaluate various aspects of phonological processing, including phonological awareness. Previous studies have shown that nonword repetition accuracy is related to the development of reading skills in children, and specifically, measures the quality of children's phonological representations, a critical component for manipulating sub-lexical units within words (Savage, 2006; Snowling, 1981).

Traditional accounts of nonword repetition claim that nonword repetition accuracy solely depends on children's capacity to store phonological information (Gathercole, 2006; Baddeley, 2003; Gathercole and Baddeley, 1993). By contrast, contemporary accounts of nonword repetition hypothesize that successful performance is driven by children's lexical knowledge. With the gradual expansion of the lexicon, children acquire fine-grained phonological representations that promote access to sub-lexical units such as syllables, morphemes, and phonemes. Over time, this increased access to sub-lexical units facilitates children's ability to abstract phonological or morphological regularities (or patterns) across words within their lexicon for subsequent production of nonwords. This account is supported by research demonstrating that vocabulary size explains a significant amount of variance in nonword repetition performance, independent of other phonological memory measures, such as the digit span task (Metsala, 1999). Research that has shown that nonwords that are perceived as more word-like and are produced with greater accuracy further supports the claim that nonword repetition accuracy relies on support from children's lexical knowledge (e.g., Metsala, 1999; Edwards, Munson, and Beckman, 2004).

Extending this work, Edwards, Munson, and Beckman (2004) proposed a novel interpretation for nonword repetition accuracy. They suggest that systematic manipulation of the phonotactic probability of sound sequences facilitates nonword repetition accuracy – the *frequency effect*. Analogous to previous studies that have assessed the relationship between wordlikeness and nonword repetition accuracy, Edwards and colleagues found that nonwords with higher phonotactic probability were produced more accurately than nonwords with lower phonotactic probability. They proposed that the frequency effect could be used as a measure of children's higher-level phonological knowledge, more specifically, the categorical organization of children's phonological representations. This claim is particularly interesting because, if the effect of frequency on nonword repetition accuracy is a measure of higher-level phonological knowledge, it could be used to predict how well children are able to flexibly manipulate and recombine sounds when encountering a new word (i.e., phonological awareness skills) at a relatively young age.

Purpose of this study

Previous research conducted by Edwards et al. (2004, 2008) and Rvachew (2006) suggest that higher-level phonological knowledge, receptive vocabulary, speech perception, and speech production are relevant variables that may predict phonological awareness skills in younger children. Although there is limited evidence to support the relationship between speech production and phonological awareness, speech production was included as a predictor because this study included younger children (2 ½ to 3 year olds) than have been studied previously. Younger children will have more individual differences in articulation accuracy and its possible that these individual differences will be related to phonological awareness at a later age. The purpose of this study was to investigate whether individual differences in these child-level measures in children as young as 2 ½ to 3 years of age, predicted phonological awareness one and two years later.

CHAPTER TWO

METHODS

Participants

186 children (96 boys; 90 girls) participated in this study. Children were a part of a larger, ongoing longitudinal study assessing the relationship between vocabulary growth and phonological acquisition (Citation, when available). Children were 2 ½ to 3 years (range: 28 – 40 months) in the first testing period and 4 ½ to 5 years (range: 51 – 66 months) in the third testing period, two years later. Approximately 45% (n = 64, 30 boys; 34 girls) of the children (who were 4 years old or older) were tested at a second testing period, one year later. The criteria for inclusion in the study included: monolingual speakers of English with typical speech and language skills. Both criteria were assessed by parent report. Furthermore, no children with IEPs were included in the study. All children passed a hearing screening in at least one ear at 25dB for 1000, 2000, and 4000Hz. Children from families with a range of maternal education levels (low/mid/high) were included in this sample. Maternal education level was determined from a background questionnaire that was completed by the primary caregiver for each child. See Table 2.1 for descriptive information on the participants.[1]

The dialect of each child was determined by listening to the speech of the primary caregiver, using a rubric based on observed African American English (AAE) morphological and phonological features (Craig, Thompson, Washington, & Potter, 2003; Craig & Washington, 2002). The caregivers of 22 children met this criterion. Children received the experimental tasks in their native dialect, either AAE or Mainstream American English (MAE). All

[1] [Note. Of the 186 children recorded in the study, 60 were not included in the second set of analyses or in Table 1 because they either did not complete all the tasks of interest for this study or they did not return at the later testing periods].

participants attended between two or three test sessions of about one hour at all three testing periods. The testing periods were approximately one year apart. The measures reported in this paper were a subset of tasks administered during the ongoing longitudinal study. All experimental tasks were presented using E-prime (Schneider, Eschman, & Zuccolotto, 2012). The test sessions for each time period were completed within one month. All reported measures were administered during the first testing period unless otherwise specified.

Table 2.1
Descriptive statistics for study participants

	Age Time 1 (*months*)	Maternal Education Level Time 1[2] **	PPVT-4 Time1 (*standard scores*)	GFTA-2 Time1 (*standard scores*)	CTOPP-2 Blending Subtest (*standard scores*)	CTOPP-2 Elision Subtest (*standard scores*)
Time 2 Study[1]						
Mean (SD)	36 (2)	Low = 4 Mid = 11	116 (17)	95 (11)	10 (3)	11 (3)
Range	28 – 40	High = 49	76 – 153	66 – 117	6 – 18	7 – 16
Time 3 Study						
Mean (SD)	33 (4)	Low = 5 Mid = 18	114 (5)	93 (12)	10 (3)	11 (3)
Range	28 – 40	High = 103	76 - 153	61 – 117	6 – 15	7 - 16

[1] Participants reported in this study (n = 64) are a subset of children from the first testing period. Only children who were at least 4 years old could be administered the subtests from the CTOPP -2. The reported scores for the CTOPP-2 correspond to that specific testing period. Thus, for the Time 2 study, CTOPP-2 scores are reported for children who were 4 years old and older. For the time 3 study, CTOPP-2 scores are reported for children who were 4 ½ to 5 years old. [2] Low = high school diploma, G.E.D., less than high school diploma; Mid = some college, associate's degree, technical school degree; High = college or graduate degree. ** Double star indicates columns that are counts rather than means accompanied by standard deviations.

Materials

Production Measures

Articulation Skills

Children's articulation skills were measured using the *Goldman Fristoe Test of Articulation –Second Edition* (GFTA-2; Goldman & Fristoe, 2000). Children's productions were recorded and transcribed offline. Standard score values were derived from the raw score values (number of errors) and used in the statistical analyses. The standard score expresses the distance of the raw score from the mean in terms of standard deviation units. If children did not produce all words on the GFTA-2 or if words were not intelligible for transcription, then an adjusted raw score was computed (based on the number of items transcribed relative to the total number of test items) and used for computing the standard score.

Nonword repetition

Stimuli. The picture-prompted nonword repetition task was taken from Edwards and Beckman (2008). There were 22 pairs of nonsense words (see Table 2.2), taken from Edwards et al., (2004). Each pair included a biphone sequence that contrasted in phonotactic probability (high [e.g., /tw/ vs. low [e.g., /pw/); the "frames" surrounding this target biphone sequence were similar in transitional probability. The phonotactic probability of the frames was carefully controlled so that differences in phonotactic probability across stimuli items could be attributed to the biphone frequency manipulation. Biphone sequences were consonant-vowel (CV, 7 pairs), vowel-consonant (VC, 7 pairs), or consonant-consonant (CC, 8 pairs). For additional information about the stimuli, cf. Edwards et al. (2004)[2]. Words with both high-and-low phonotactic probability sequences were included to increase the sample range of sound sequence frequencies within the English language. The CC sequences included word-initial onset clusters (e.g., /pw/ as in /pwag6b/), word-final coda clusters (e.g., /mp/ as in /fIk6taemp/), and word-

[2] Edwards, J., & Beckman, M.E. (2008a). Methodological questions in studying phonological acquisition. *Clinical Linguistics and Phonetics*, *22*, 937-956. [PMCID: PMC2728799]
[2] Edwards, J. & Beckman, M.E. (2008b). Some cross-linguistic evidence for modulation of implicational universals by language-specific frequency effects in phonological development. *Language, Learning, and Development*, 4, 122-156. [PMCID: PMC2772077]

medial hetero-syllabic clusters (e.g., /gd/ as in /dogdet/). Approximately half of the nonwords were disyllabic and the other half were tri-syllabic. The stimuli were recorded by a young adult female whose native dialect was Mainstream American English (MAE) and by another young adult female whose native dialect was African American English (AAE). Stimuli in the child's native dialect (either AAE or MAE) were used in this task. The nonwords were normalized for amplitude across the entire stimulus set (within dialect). The stimuli were presented in random order through E-prime. Table 2.2 provides a list of the stimuli with their corresponding calculated phonotactic frequencies.

Table 2.2
Forty-four nonwords taken from Edwards, Munson, and Beckman (2004)[1]. The first and third columns list the nonwords with the biphone target sequences underlined. The second and fourth columns list the log phonotactic frequencies for the embedded target sequences calculated from the Hoosier Mental Lexicon (Pisoni et al., 1985).

Phonetic form of nonwords			
Nonword	Phonotactic Frequency	Nonword	Phonotactic Frequency
/jugoɪn/	-12.92	/bogib/	-10.84
/moɪpəd/	-12.00	/mæbɛp/	-7.81
/vugim/	-12.92	/vɪdæg/	-8.53
/bodəjaʊ/	-14.30	/medəju/	-7.56
/vukɑtɛm/	-12.92	/vitəgɑp/	-8.53
/gaʊnəpek/	-11.82	/gitəmok/	-10.84
/nʊbəmən/	-10.84	/nɪdəbɪp/	-7.79
/motaʊk/	-14.59	/petik/	-9.77
/donug/	-14.59	/bedæg/	-9.62
/tedaʊm/	-14.59	/podaʊd/	-11.81
/aʊptəd/	-14.59	/iptən/	-10.67
/dugnəted/	-14.59	/tʌgnədit/	-10.53
/aʊkpəde/	-14.59	/ikbən/	-9.77
/aʊftəga/	-14.59	/aʊntəko/	-8.96
/nəfæmb/	-15.73	/mɪnæmp/	-11.08
/pwɑgəb/	-13.55	/twɛkɛt/	-10.78
/bufkit/	-15.57	/kiften/	-11.79
/dogdet/	-15.57	/tæktut/	-9.45
/kɜdəwəmb/	-15.73	/fɪkətæmp/	-11.08
/pwɛnətɛp/	-13.55	/twɛdəmɪn/	-10.78
/næfkətu/	-15.57	/gʌftədaɪ/	-11.79
/dɛgdəne/	-15.57	/tiktəpo/	-9.45

[1]See Edwards et al., 2004 for detailed description for the calculation procedure of phonotactic frequency.

Procedure. At the start of each trial, participants were seated in front of a computer screen that displayed an unfamiliar object that was supposed to be the "name" of a target nonword. The experimenter instructed the children to carefully listen to the nonword (a "silly" word) and then repeat it as accurately as possible. Following the elicited response, the experimenter advanced to subsequent trials using a keyboard response. Each successive trial displayed an unfamiliar object that corresponded to the target nonword. All trials proceeded in this manner. The experiment included a total of 51 trials including 7 training items that preceded the 44 experimental trials. Children's productions were recorded for subsequent analysis.

Scoring Analyses. The nonwords were segmented in Praat (Boersma, & Weenink, 2016). Praat: doing phonetics by computer [Computer program]. Version 6.0.16, retrieved 5 April 2016 from http://www.praat.org/) and then all of the biphone sequences (CV, VC, CC) were transcribed by one of two trained native-English speaking phoneticians (i.e., graduate students) who listened to the sequence and reviewed the waveform. Transcribers selected the first response from each child whenever possible. For cases where this was not possible, transcribers selected the second response. This method was applied to reduce the effect of practice for low transitional-probability sound sequences within trials. All responses were transcribed using the International Phonetic Alphabet at the level of careful, broad phonemic transcription. During transcription, the transcription program (Praat) queried the transcriber for each feature in succession. The biphone target sequences were scored on three phonetic features. For consonants, the three features were: place, manner, and voicing. For vowels, the three features were: vowel height (high, mid, low), vowel front/back location (front, central, back), and either tense/lax features for monophthongs or onglide/offglide for diphthongs. In addition to feature accuracy, nonwords were scored for prosodic accuracy. Complete prosodic accuracy required sounds within the biphone sequence to occur in the correct frame position (e.g., for a CV sequence, *did the consonant immediately precede the vowel and did the vowel immediately follow the consonant?*) and for the number of syllables within the entire nonword to be maintained (e.g., for a disyllabic nonword, *does the target nonword have at least two syllables?*). An accuracy count was computed as an aggregate of the feature and prosody categories. For example, in the case of /donug/, the target biphone segment is /ug/. If it is produced as /ik/, then the child would lose 1 point for the incorrect front/back position of the vowel and 1 point for the incorrect voicing of the consonant. In the case of /motaʊk/, the target biphone segment is /aʊk/. If the word-final consonant is produced accurately, but the diphthong /aʊ/ is produced as the monophthong /a/, the child would lose 1 point for not retaining the diphthong offglide. Table 2.3a-c provide detailed examples of the scoring procedure.

Table 2.3a
An example of the segmental accuracy scoring procedure for substitution productions in a VC target segment.

Stimulus	Target Sequence	Child's Production	Features	Child's Production Features	Correct Features
/donug/	/ug/	/donik/	Vowel		
			Height	High	High
			Dimension	Front	Back
			Tense/Lax	Tense	Tense
			Consonant		
			Manner	Stop	Stop
			Place	Velar	Velar
			Voicing	Voiceless	Voiced

Table 2.3b
An example of the segmental accuracy scoring procedure for a monophthong substitution for a diphthong in a VC target segment.

Stimulus	Target Sequence	Child's Production	Features	Child's Production Features	Correct Features
/motaʊk/	/ aʊk/	/motak/	Vowel		
			Height	Low	Low
			Dimension	Back	Back
			Onglide/Offglide	Tense/Monophthong	Diphthong

Table 2.3c
An example of the prosodic scoring for a whole word production.

Stimulus	Target Sequence	Child's Production	Prosodic Scoring	Child's Production Features	Correct Features
/motauk/	/aʊk/	/taʊk/	Is target 1 in the appropriate frame position?	Yes	Yes
			Is target 2 in the appropriate frame position?	Yes	Yes
			Did the child retain the syllable structure (was the entire word frame shortened?)	No (Child deleted the onset and nucleus /mo/, shortening the entire word frame from /motaʊk/ to /taʊk/)	Yes

Inter-transcriber reliability. The productions of the 186 participants were transcribed by one of two transcribers. For the productions of each participant, one of the two transcribers was designated the primary transcriber. For 24% of the nonword repetition files (n = 45), a different transcriber was designated as the secondary transcriber and independently transcribed the productions of each child. I was the primary transcriber for 91 of 186 participants, and the second transcriber was the primary transcriber for the remaining 95 participants. The scored productions for the participants with two independent transcribers were used to evaluate inter-transcriber reliability. Information about the specific details of this analysis and the results can be found in the *Results* section.

Quantitative Analyses. A mixed effects logistic regression analysis was used to quantify children's performance on the nonword repetition task. This model included child-level random intercepts (a measure of overall accuracy) and slope (a measure of the effect of frequency on accuracy). Item-level random intercepts were also included to capture difficulty differences among nonwords that were unrelated to differences in phonotactic probability.

Receptive Vocabulary

For all children, receptive vocabulary was assessed using the *Peabody Picture Vocabulary Test-Fourth Edition* (PPVT-4; Dunn & Dunn, 2007) at the first testing period. Standard scores were derived from the raw scores and used in the statistical analyses.

Speech Perception: Minimal Pairs Discrimination Task.

Stimuli. Twenty-five monosyllable minimal pairs were used in this task. All words were familiar to young children and all word pairs had sounds that were highly confusable, based on Miller and Nicely (1955) perception results at zero dB SNR. Minimal pairs included word-initial consonant (*peas* vs. *keys*), medial vowel (*mouse* vs. *moose*), and word-final consonant (*mouse* vs. *mouth*) contrasts. Table 2.4 provides a complete list of the stimuli.

Table 2.4
Minimal Pair Discrimination Stimuli

Minimal Pair Sounds	Minimal Pair Words
/b/ – /k/	bee – key
/b/ - /p/	big – pig
/k/ - /dʒ/	car – jar
/tʃ/ - /k/	cheese – keys
/k/ - /h/	cold – hold
/g/ - /dʒ/	goose – juice
/h/ - /p/	hen – pen
/ɔr/ - /aʊ/	horse – house
/dʒ/ - /m/	juice – moose
/k/ - /p/	keys – peas
/u/ - /aʊ/	moose – mouse
/s/ - /θ/	mouse – mouth
/k/ - /t/	sick – sit
/sl/ - /sw/	sleep – sweep
/ɑr/ - /ɔr/	star – store

Procedure. This task used a two-alternative forced choice minimal pair identification paradigm (Munson, Baylis, Krause, and Yim, 2010). The procedure differed from many minimal pair discrimination tasks in that a familiarization trial for each item was included because not all words were equally pictureable or familiar. Each member of the minimal pair was presented individually and labeled by the computer for the familiarization trials. Then the two pictures were shown beside each other and the target word was presented. Children were instructed to point to the correct response on a touch screen. Responses were automatically scored as correct or incorrect. Overall percent correct was calculated for each child. Stimuli in the child's native dialect (either AAE or MAE) were used in this task.

Phonological Awareness Tasks

Two phonological awareness measures (Blending and Elision subtests from the *Comprehensive Test of Phonological Processing*, *Second-Edition*, CTOPP-2, [Wagner, Torgesen, & Rashotte, 2013]) were administered to all children at the third testing period and to all children who were 4 years or older at the second testing period. The Blending and Elision subtests were selected as measures of phonological awareness because they require children to explicitly manipulate sub-lexical units within words of gradual complexity, progressing from syllables to individual phonemes. The Blending subtest required children to produce a string of words, syllables, and phonemes in serial order to form a new word. For example, children listened to a digital recording that presented sounds in isolation (/k/, /ae/, /t/) and were instructed to blend the sounds to produce the word "cat." The Elision subtest required children to delete a word, syllable, or phoneme. For example, children listened to the word "base-ball" and were instructed to say the word "base-ball" without "base" to produce "ball." The children's responses were scored according to the instructional manual; scaled scores were derived from the raw scores and used in the statistical analyses.

Table 2.5
The tasks that were used to measure the constructs of interest.

Constructs	Phonological Awareness	Phonological Short-Term Memory	Higher-level Phonological Knowledge	Speech Perception	Speech Production	Receptive Vocabulary
Tasks	Comprehensive Test of Phonological Processing -4 *Elision & Blending (scaled scores)*	Child-level Random Intercept *(from NWR model)*	Child-level Random Slope *(from NWR model)*	Minimal Pair Discrimination Task *(% Correct)*	Goldman Fristoe Test of Articulation -2 *(standard scores)*	Peabody Picture Vocabulary Test -4 *(standard scores)*

Target stimulus: “tweket”

Figure 2.1. Example of a nonword trial with a CC biphone sequence target. The target sequence is underlined.

“peas”	“keys”

Figure 2.2. Example of a minimal pair discrimination task trial. Peas are featured in the left panel. Keys are featured in the right panel.

CHAPTER THREE

RESULTS

Nonword Repetition Analyses.

Children's responses on the nonword repetition task were fit using a mixed effects logistic regression model with the Laplace Approximation method applied for maximum likelihood estimation (Raudenbush, Yang, & Yosef, 2012). The model included fixed effects for centered- Age and centered- Frequency. Age was included in the model as an approximate measure of motor control, which increases with age. The model also included child-level random-intercept and slope. Item-level random intercepts were included to account for differences among items that were unrelated to transitional probability (as mentioned in the *Methods*). The intercept in this model represents the logit-transformed proportion of features accurately produced for a word of average frequency, for children of an average age. In this model, there was a significant effect of intercept, $b = .97$, $se = .09$, $z = 9.75$, $p < .001$. There was a significant effect of centered-Age, $b = .13$, $se = .02$, $z = 5.51$, $p < .001$. Lastly, there was a significant effect of centered-Frequency, $b = .087$, $se = .025$, $z = 3.51$, $p < .001$. The child-level random intercept and slope were extracted and used in the subsequent analysis as independent predictors of phonological awareness performance one and two years later.

Figure 3.1 a-b shows the model fits for the 30 children with the steepest slopes and the 30 children with the shallowest slopes. The child-level random-intercept corresponds to each child's predicted overall accuracy on the nonword repetition task, after controlling for the effects of age and phonotactic probability. In other words, a larger intercept indicates higher overall accuracy on the nonword repetition task. This is observed in Figure 3.1; children with higher intercepts in both plots have greater overall accuracy. The random intercepts were interpreted as an assessment of the quality and capacity of children's phonological short term memory, as in the model proposed by Gathercole and colleagues (e.g., Baddeley, 1998; Gathercole, 2006). The child-level random slope corresponds to each child's sensitivity to the phonotactic probabilities of the biphone sequences. A steeper (positive) slope indicated that the child's performance was sensitive to the phonotactic frequency of the nonword items. That is, the child performed better on more word-like items. Conversely, a shallower random slope indicated that the child's performance was less sensitive to the phonotactic frequency of the nonword item. The random slope was thus interpreted as an inverse measure of the children's higher-level phonological knowledge; children who are more sensitive to phonotactic frequency will have steeper random slopes as observed in Figure 3.1a, and children who are less sensitive to phonotactic frequency will have shallower random slopes as observed in Figure 3.1b. That is, children who are more sensitive to phonotactic frequency are less accurate at producing low-phonotactic probability sequences and are therefore assumed to have less categorical and more holistic phonological representations (i.e., they have less fine-grained phonological representations). By contrast, children who are less sensitive to phonotactic frequency are more accurate at producing low-phonotactic probability sequences and are therefore assumed to have more categorical phonological representations.

Nonword repetition model specification. Below are the level-one and level-two structures for this model. The model included a random intercept and slope by child and a random intercept for the nonword items which are illustrated in the level-two structure below. The subscript i is used to denote each participant and the subscript j is used to denote each item.

Level One Equation:

$$Y_{ij} = \beta^{1}{}_{ij} + \beta_0^{Age} centeredAge_i + \beta_i^{Freq} centeredFrequency_j + \varepsilon_{ij}$$

$$\varepsilon_{ij} \sim N(0, \sigma^2)$$

Level Two Equation:

$$\beta^1{}_{ij} = \beta_0^1 + \beta_j^1 + \beta_i^1$$ [3]

$$\beta^{Frequency}{}_j = \beta_0^{Frequency} + \beta_j^{Frequency}$$ [4]

$$\beta^1{}_j \sim N(0, \sigma_j^1); < \beta^1{}_i, \beta^{Freq}{}_i > \sim N(0, \Sigma_i^{<1,Freq>})$$

Table 3.1
Results of the nonword repetition accuracy logistic mixed effects regression. Child-level random intercept and slope and item-level random intercept were included.

Effect	Variance	*Estimate*	*SE*	*z*	*p*
Fixed Effects					
Intercept		0.97	0.10	9.75	< .001
Frequency[1]		0.09	0.02	3.51	< .001
Age[1]		0.13	0.02	5.51	< .001
Random Effects					
Participants					
Intercept	1.16				
Frequency[1]	0.006				
Correlation (*Intercept*, *Frequency)*	0.16				
Nonword Items					
Intercept	0.15				
df Residual	7920				

Note. [1] Frequency and age are mean-centered in this model.

Inter-transcriber reliability.

Because children's productions were transcribed by one of the two transcribers, two analyses were run to examine whether differences across transcribers could have influenced the results of nonword repetition analysis (described in sections *Nonword Repetition Analysis* and

[3] β_0^1 is the fixed effect for intercept. β_j^1 is the adjustment to the fixed effect of intercept by item. β_i^1 is the adjustment to the intercept for each participant.
[4] $\beta_0^{Frequency}$ is the fixed effect for frequency. $\beta_j^{Frequency}$ is the adjustment to the fixed effect of frequency for each participant.

Table 3.1). For the first analysis, children's nonword repetition accuracy (the same outcome variable modeled in the *Nonword Repetition Analysis)* was fit using a mixed effects logistic regression model that included fixed effects of transcriber (a categorical variable; one transcriber was coded as 0 and the other was coded as 1), centered-age and centered-frequency (as continuous predictors), and two interaction terms: transcriber x centered-age and transcriber x centered- frequency. The model also included child-level random effects for the intercept, effect of frequency, and effect of transcriber. Item-level random effects were included for the intercept only. See table 3.2 for the detailed results of this model. The results showed that there was no effect of transcriber on nonword repetition accuracy, $b = .05$, $se = .05$, $z = 1.07$, $p = .28$.

Because the random slopes and random intercepts were extracted from the original nonword repetition model and used as predictor variables in subsequent analyses, the question of greatest interest was whether differences across transcribers might influence the calculation of these random slopes and intercepts. Therefore, a simulation approach was used to estimate the precision of the random effects of the intercept and the slope from the nonword repetition model described above in the *Nonword Repetition Analysis* section. This simulation was restricted to the productions of the 45 participants who had been independently transcribed by both transcribers. For the 45 participants, one score (of the two available scores) was drawn randomly for each production. The simulation drew a total of 1000 random samples from the scores at the item-level of these participants' productions. From these 1000 iterations, a mean random intercept and random slope (i.e., the effect of frequency) was calculated for each participant. A correlation was run between the mean random effects extracted from the resampling procedure and the random effects from the original nonword repetition accuracy model fit with only the primary transcriber's transcriptions. Both of the random effects were highly correlated, ($r = .98$

for the random intercepts and r =.94 for the random effects of frequency). These correlations suggest that the mean random effects were highly similar across models and that any differences across the two transcribers were unlikely to have influenced the results.

Table 3.2
Results of the inter-transcriber reliability, modeling nonword repetition accuracy using a logistic mixed effects regression. Child-level random intercept and slopes for the effect of frequency and the effect of transcriber, and item-level random intercept were included.

Effect	Variance	*Estimate*	*SE*	*z*	*p*
Fixed Effects					
Intercept		1.37	0.13	10.34	< .001
TranscriberA[1]		0.05	0.05	1.07	.28
Centered-Age		0.15	0.03	4.88	< .001
Centered-Frequency		0.09	0.03	2.71	.006
TranscriberA x Age		0.04	0.01	2.75	.006
TranscriberA x Freq.		0.002	0.01	0.214	.83

Note. [1] Transcriber A was coded as a 1 and transcriber B was coded as 0. The intercept is interpreted as the log-odds of the probability of features correctly produced, for a child who is of average age and was transcribed by transcriber B and for a word of average phonotactic frequency.

Overview of Phonological Awareness Analyses.

Four multiple regression analyses were conducted to evaluate whether the measures of phonological STM, higher-level phonological knowledge, receptive vocabulary size, and speech perception and production abilities, measured at 2 ½ to 3 years of age predicted phonological awareness measured one year later (*time2*) and two years later (*time3*). In all analyses, phonological awareness was quantified as the scaled score from the Blending and Elision subtests from the CTOPP-2 (Wagner et al., 2013). The independent variables included: centered-child-level random intercept, centered-child-level random slope, centered-standard scores from the PPVT-4 and GFTA-2, and centered-percent correct scores from the minimal pair discrimination experiment. Separate regression models were built for each time point for the two outcome variables, Elision and Blending. The independent variables remained the same across all models. The results for the time2 and time3 models are reported below.

Table 3.3
The time2 and time3 model structures for each measure of phonological awareness.[1]

	Model Specification [2]
Time 2 Models	
Elision Blending	$\beta_0 + \beta_1 PhonologicalSTM + \beta_2 Frequency + \beta_3 ReceptiveVocabulary + \beta_4 SpeechPerception + \beta_5 Articulation + \varepsilon$
Time 3 Models	
Elision Blending	$\beta_0 + \beta_1 PhonologicalSTM + \beta_2 Frequency + \beta_3 ReceptiveVocabulary + \beta_4 SpeechPerception + \beta_5 Articulation + \varepsilon$

Notes. [1]Time 2 models predictors at age 3 relative to age 4 phonological awareness. Time 3 models predictors at age 3 relative to age 5 phonological awareness. [2]All predictors are listed in terms of the measured construct. They were entered as centered-variables in every model. Predictors remained constant across all models.

Time 2 models. [5]

For the outcome variable Elision, the spread of the children's scores showed a bimodal distribution. More specifically, at least one-third of the participants (n = 26) had scores near a raw score-equivalent of 0. For the scores of the remaining participants, a second "Gaussian-like" distribution was observed. (See Appendix A for additional information.) Because of the unbalanced distribution of scores, a logistic regression analysis was conducted and children were divided into two subgroups. Children who could elide were assigned a value of 1 and children who could not elide were assigned a value of 0. The results of this analysis are summarized in Table 3.4a. In this model, the intercept represents the log-odds of performing the Elision subtest for a child who received an average standard score on the GFTA-2, PPVT-4, an average percent

[5] The bivariate relationships between phonological awareness across both time points (age 4 and age 5) and phonological short-term memory, receptive language, articulation ability are shown in Figures 3.1c – n.

correct score on the minimal pair discrimination experiment, with an observed average child-level random intercept and slope. There was a significant effect of the minimal pair discrimination task, ($b = 6.01$, $se = 2.6$, $z = 2.33$, $p < .02$). All other effects were not significant in the model.

A typical Gaussian distribution was observed for the scores from the Blending subtest. Thus, a multiple linear regression analysis was conducted. The results of this analysis are summarized in Table 3.4b. The Blending subtest, at time2 (*age 4*), was not significantly predicted by any of the independent variables in the model.

Table 3.4a
Results of the time2 Elision multiple logistic regression analysis with a discrete outcome (0 = children who could not elide; 1 = represents children who could elide).

Effect	*Estimate*	*SE*	*z*	*p*
Intercept	-9.75	5.02	-1.95	.93
Minimal Pair Task	6.02	2.58	2.33	< .02
Frequency	5.86	5.20	1.12	.26
GFTA -2	0.01	0.04	0.24	.81
Child-level random intercept	0.29	0.60	0.48	.63
PPVT-4	0.04	0.03	1.46	.15

Note. All predictors were measured at age 2 ½ to 3. The outcome variable was measured at age 4 or older.

Table 3.4b
Results of the time2 Blending multiple linear regression analysis.

Effect	*Estimate*	*SE*	*z*	*p*
Intercept	9.64	.35	27.23	< .001
Minimal Pair Task	1.27	2.39	0.53	.60
Frequency	4.47	4.65	0.96	.34
GFTA -2	0.46	0.49	0.94	.35
Child-level random intercept	0.05	0.04	1.28	.20
PPVT-4	0.02	0.02	0.95	.35
R^2	.26			

Note. All predictors were measured at age 2 ½ to 3. The outcome variable was measured at age 4 or older.

Time 3 models.

For both the Elision and Blending subtests, multiple linear regression analyses were used with ordinary least squares (OLS). The results for these models are summarized in Table 3.5a-b below. In the model predicting Elision performance, the intercept proved to be significant, *b* = 10.69, *se* = .177, *t* (120) = 60.21, *p* < .001. There was a significant effect of the child-level random intercept, *b* = .80, *se* = .25, *t* (120) = 3.15, *p* < .003. There was a significant effect of PPVT-4, *b* = .035, *se* = .01, *t* (120) = 2.43, *p* < .02. Lastly, there was a marginal effect of GFTA-2, *b* = .032, *p* = .09). The independent predictors accounted for 34% of the variance in Elision subtest.

For the Blending subtest, there was a marginal effect of PPVT-4, *b* = .039, *p* = .051. There were no other significant predictors in this model. 24% of the variance in the Blending subtest was explained by independent variables.

Table 3.5a
Results of the time3 Elision linear regression analysis.

Effect	*Estimate*	*SE*	*t*	*p*
Intercept	10.71	0.18	60.63	< .001
Minimal Pair Task	-0.38	1.29	-0.29	.77
Frequency	-2.57	2.99	-0.86	.39
GFTA-2	0.03	0.02	1.69	.09 †
Child-level random intercept	0.80	0.25	3.15	.002
PPVT-4	0.03	0.01	2.43	.02
R^2 .34				

Note. All predictors were measured at age 2 ½ to 3. The outcome variable was measured at age 4 ½ to 5.

Table 3.5b
Results of the time3 Blending linear regression analysis.

Effect	*Estimate*	*SE*	*t*	*p*
Intercept	0.29	2.69	0.11	.91
Minimal Pair Task	1.53	1.75	0.87	.39
Frequency	0.75	4.07	0.19	.85
GFTA -2	0.51	0.35	1.47	.14
Child-level random intercept	0.04	0.02	1.65	.10
PPVT-4	0.04	0.02	1.97	.051†
R^2 .24				

Note. All predictors were measured at age 2 ½ to 3. The outcome variable was measured at age 4 ½ to 5.

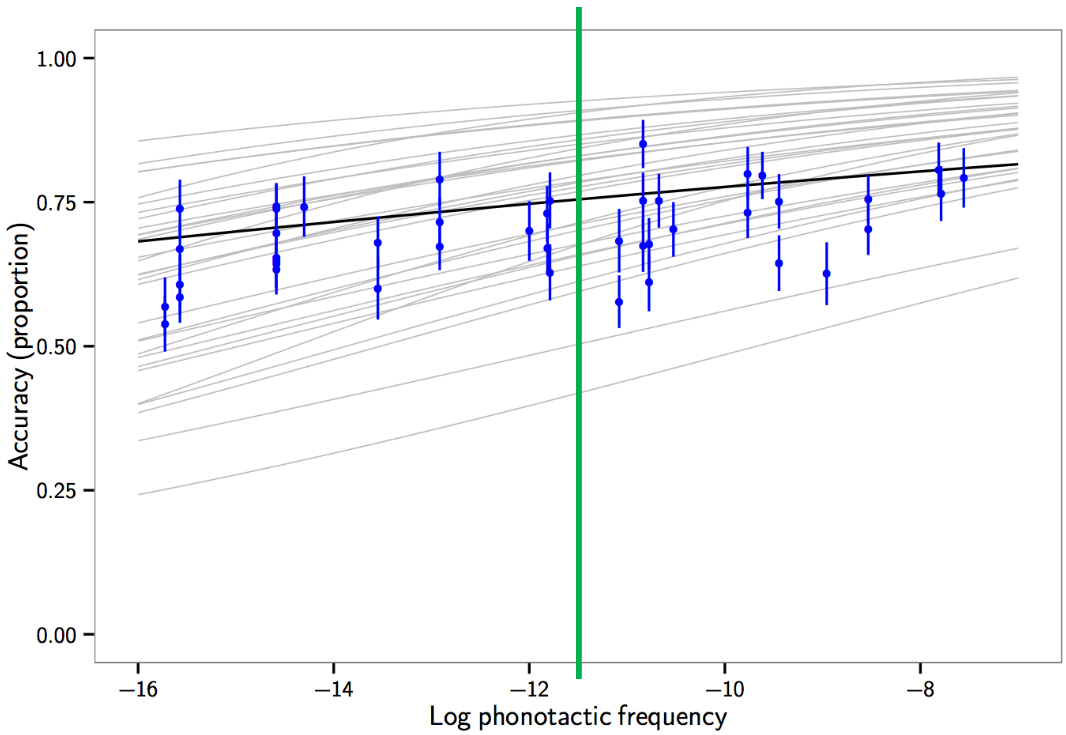


Figure 3.1 a. Individual accuracy curves predicted by the nonword repetition accuracy model. Illustrated in this figure are children with the 30 greatest individual effects of phonotactic frequency. The intercept was centered so child-level intercepts are shown at this point by the vertical green line. The blue points represent the mean accuracy of each item with corresponding standard errors.

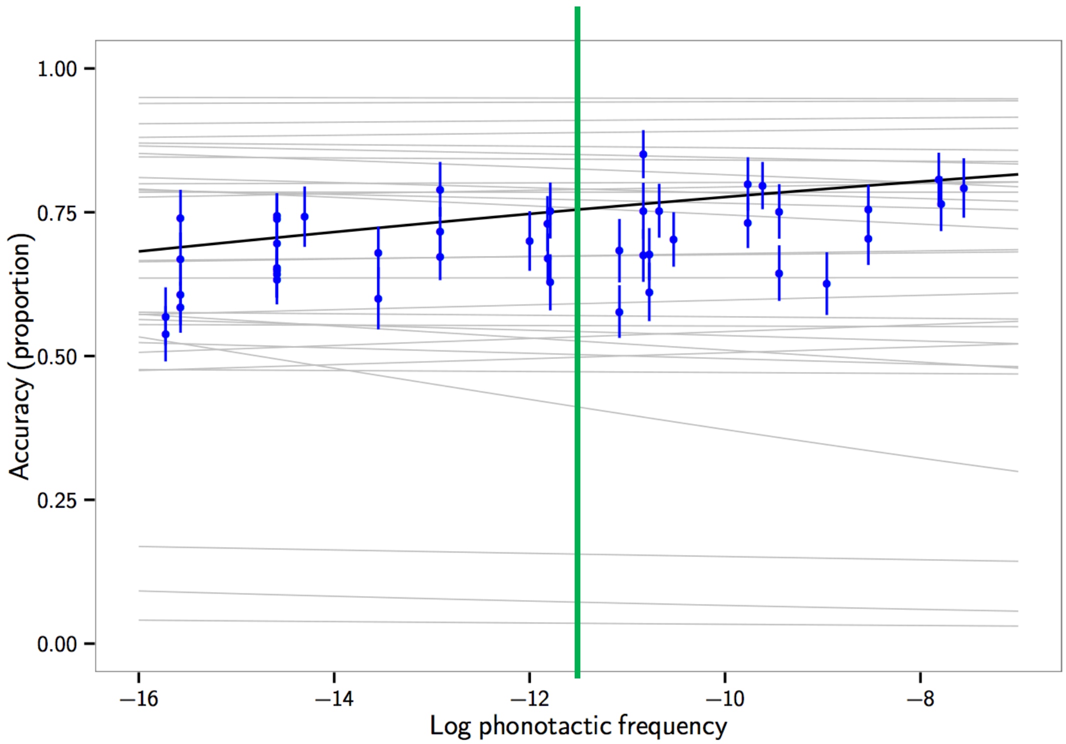


Figure 3.1 b. Individual accuracy curves predicted by the nonword repetition accuracy model for children with the 30 smallest individual effects of phonotactic frequency. The intercept was centered so child-level intercepts are shown at this point by the vertical green line. The blue points represent the mean accuracy of each item with corresponding standard errors.

[Figures 3.1c – g]. The following plots show the relationship between phonological awareness and the predictors that were significant or marginally significant in each of the time point models (time 2 and time 3). For the time 2 study, there were no significant predictors of Blending but Elision was significantly predicted by children's speech perception skills (the minimal pair task). For the time 3 study, Blending was marginally predicted by receptive vocabulary and Elision was significantly predicted by children's phonological short-term memory (the child-level random intercepts from the NWR model) and receptive language (the PPVT-4 standard score) and marginally predicted by children's articulation ability (the GFTA-2 standard score). The shaded grey area shows the standard error about the mean.

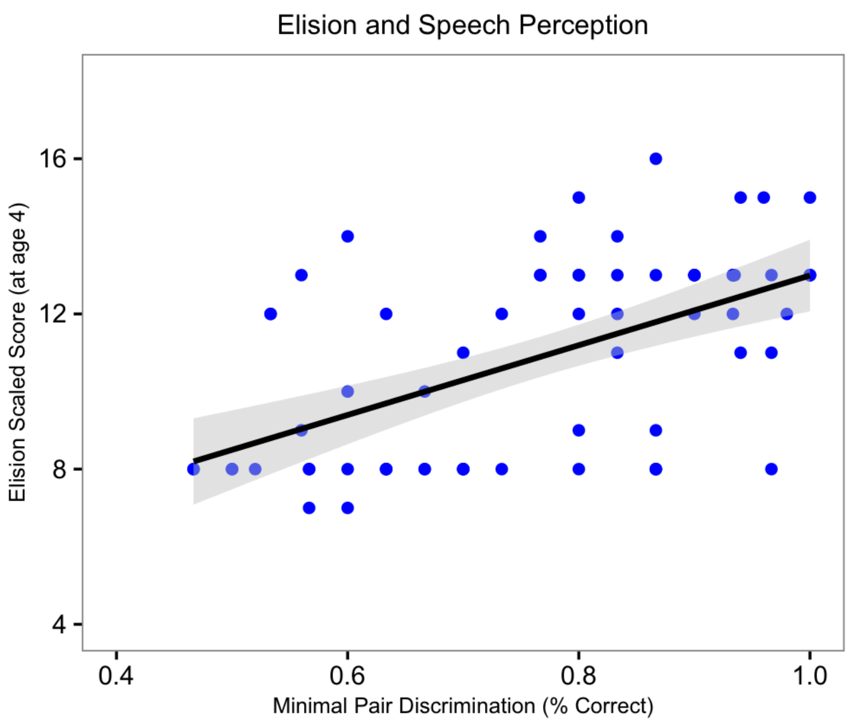


Figure 3.1c The relationship between Elision (age 4) and speech perception.

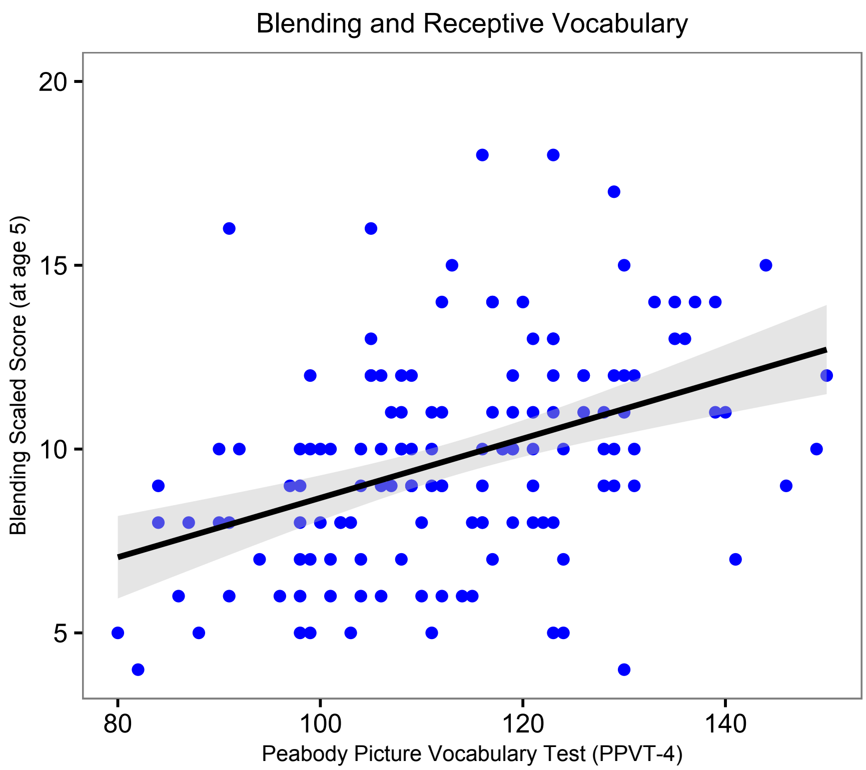


Figure 3.1d The relationship between Blending (age 5) and receptive vocabulary skills.

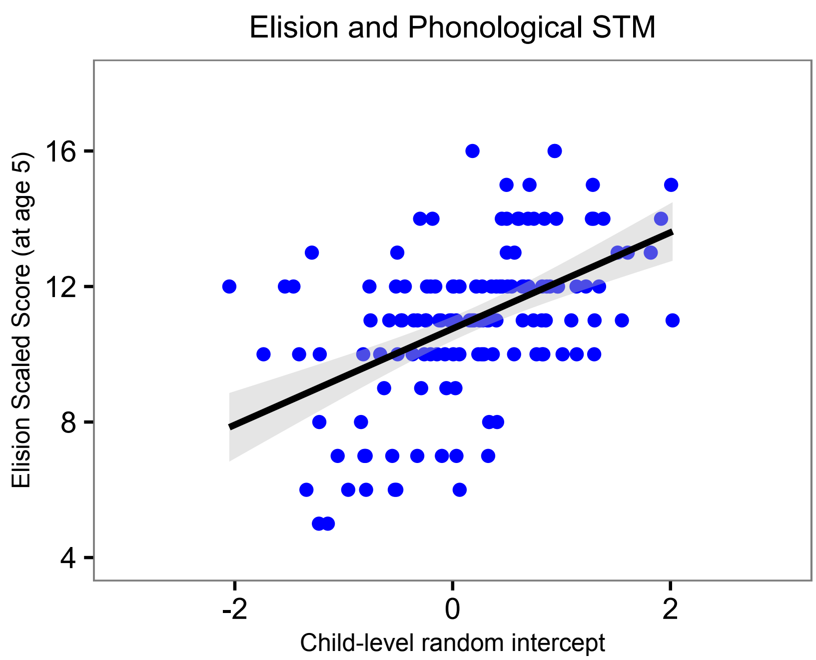


Figure 3.1e The relationship between Elision (age 5) and phonological short-term memory.

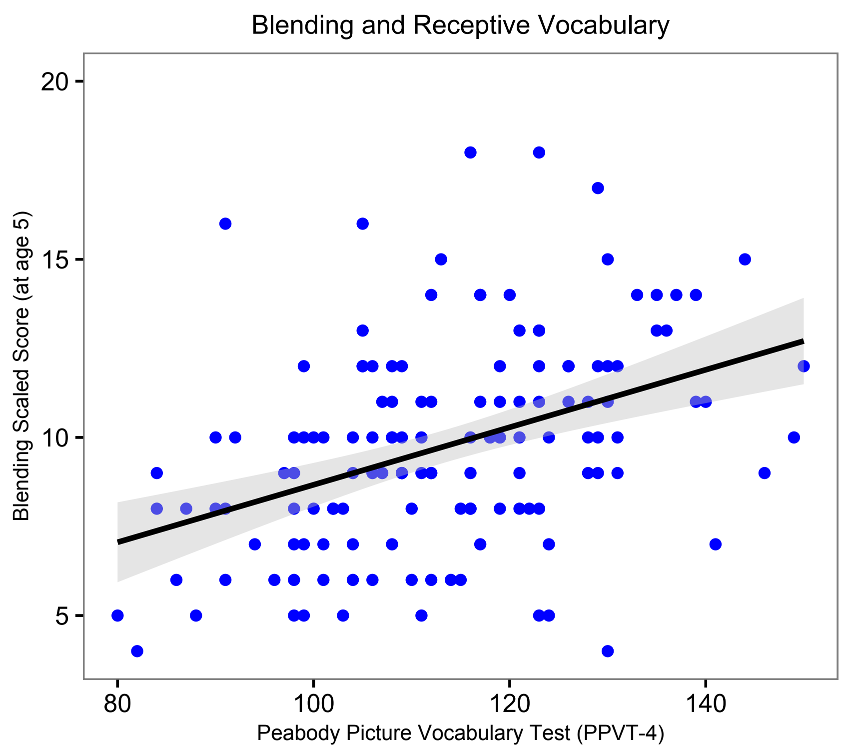


Figure 3.1f The relationship between Blending (age 5) and receptive vocabulary skills.

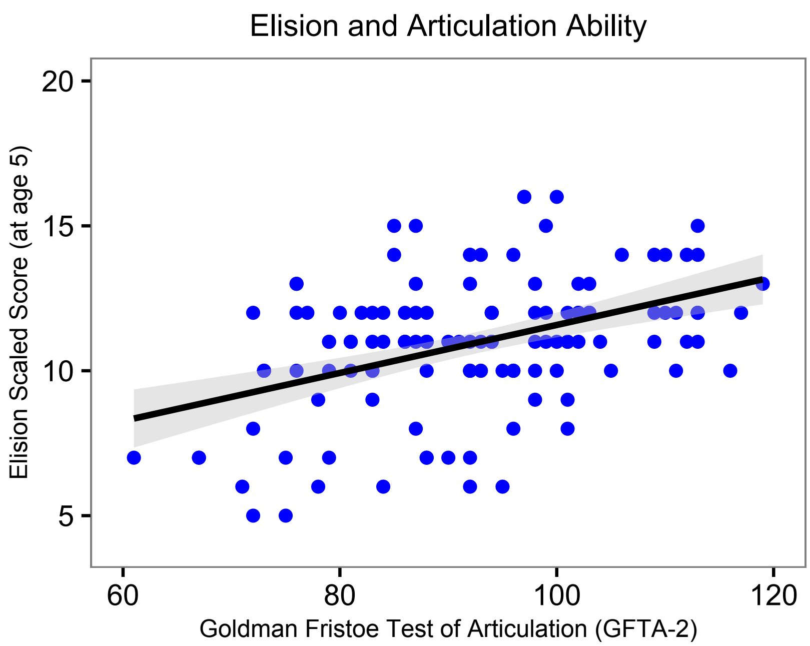


Figure 3.1g The relationship between Elision (age 5) and articulation ability.

CHAPTER FOUR

Discussion

This study extends previous research concerning phonological awareness development in preschool-age children. The current study investigates what child-specific variables at age 2 ½ to 3 predict phonological awareness a year later (age 4) and then two years later (age 5). This study specifically evaluated the relationship among higher-level phonological knowledge, phonological short-term memory, receptive vocabulary, speech perception and speech production, and phonological awareness. The two principal findings from this study suggest: 1) a differential contribution of predictors across individual measures of phonological awareness and across different ages (age 4 *versus* age 5) and 2) children's phonological awareness performance, when measured two years later, is best predicted by their receptive language skills and phonological short-term memory capacity. Further discussion regarding each of these results are provided below.

Age 4 vs Age 5

Age 4 and 5, phonological awareness performance was predicted by different variables. At age 4, the best predictor of phonological awareness was the measure of speech perception (performance on the minimal pair discrimination task). However, this relationship was only found for the Elision subtest and there were no significant predictors of performance on the Blending subtest. At age 5, phonological awareness, as measured by the Elision subtest, was significantly predicted by the measure of phonological short-term memory (child-level random intercept from the nonword repetition accuracy analysis) and receptive vocabulary (PPVT-4 standard score). Receptive vocabulary size was also a marginally significant predictor of performance on the Blending subtest and articulatory accuracy, as assessed by GFTA-2 standard score, was a marginally significant predictor of performance on the Elision subtest.

I speculate that the observed differences across time points were largely due to the fact that it was not possible to reliably evaluate phonological awareness performance at age 4. The most recent revision of the *Comprehensive Test of Phonological Processing-2* (CTOPP – 2) includes norms for children as young as age 4, while the previous edition began at age 5. To my knowledge, no other studies have evaluated whether the age 4 scores are valid. Correlations were run between subtest scores at age 4 and age 5 and it was observed that measures of phonological awareness at age 4 were not significantly correlated with the same measures of phonological awareness at age 5. There was a non-significant positive association between Elision at age 4 and 5, $r = .28$, $p = .29$ and there was a marginally significant positive association between Blending at age 4 and 5, $r = .48$, $p = .06$. An additional problem at age 4 was the unbalanced score distribution on the Elision subtest. As mentioned above, children were separated into subcategories: those who could elide and those who could not. Twenty-six children within this sample received a raw score of 0. The finding that one-third of the participants could not perform the task raises questions as to whether children's elision performance could be measured reliably at age 4. Is their poor performance at age 4 an indication of a "lack" of ability or poor understanding of the task? Another plausible explanation concerns whether the tasks are measuring a different construct such as children's ability to attend to the task or children's ability to comprehend complex language-based instructions (i.e., receptive language ability) when 4-year-olds are tested. Arguably, using a traditional meta-phonological awareness paradigm to assess phonological awareness in older children has proven useful. However, the question of whether phonological awareness can be reliably assessed in 4-year-olds remains unresolved.

Overall, this seems to be a question about the construct validity of the CTOPP-2 for children at age 4. Further research is needed to unpack questions about the validity and reliability surrounding this assessment; especially as researchers and clinicians begin to incorporate the CTOPP-2 in their battery of assessments for younger children.

Significant Predictors of Phonological Awareness at Age 5

Elision versus Blending Performance

Phonological awareness measured by the Blending and Elision subtests at age 5 were also significantly predicted by different age 3 variables. That is, age 5 Elision performance was best predicted by the measures of receptive vocabulary (i.e., PPVT-4) and phonological short-term memory (i.e., child-level random intercept). But, age 5 Blending performance was only marginally predicted by children's receptive vocabulary skills. This differential contribution of predictors to phonological awareness performance at age 5, when assessed by different subtests (i.e., Blending or Elision) is an interesting finding. A typical Gaussian distribution was observed for the children's scores across both measures at age 5. This suggests, that the observed difference in significant predictors across measures is not easily explained by an inability to reliably assess children's phonological awareness performance at age 5. An alternative explanation pertains to the claim that the prerequisite skills for the Elision subtest may be distinct from skills needed for the Blending subtest. A Pearson product correlation coefficient was computed to assess the relationship between the age 5 subtest scores between Elision and Blending. It was observed that these two subtests were only correlated, $r = .59$, $p = .01$. This suggests that while both measures examine phonological awareness, they are also somewhat independent. That is, the phonological processes required for each subtest may be differentially taxed or each subtest may activate different aspects of phonological processing. The Elision subtest requires children to encode a word, delete a constituent word, syllable or phoneme and then reproduce the "newly" formed word. By contrast, the Blending subtest requires children to sequentially order "strings" of verbally presented words, syllables, or phonemes for production of the "newly" formed word. Both subtests require active encoding of the acoustic signal for subsequent transformation to phonetic information, storage of the phonological segments, and verbal reproduction; however, the difference in phonological awareness task expectations may exert different demands on the underlying processes. More specifically, it is possible that children can be successful at blending phonemes by simply relying on their receptive vocabulary skills. However, a similar story cannot be constructed for the Elision subtest, given the finding of this study that even after partialling out the contribution of receptive vocabulary skills, phonological short-term memory remains important. A future consideration that is beyond the scope of this paper should be to investigate which measure of phonological awareness is more indicative of phonological awareness that is necessary for reading readiness. Yopp's (1988) seminal work provided a taxonomy of the complexity of phonological awareness tasks (e.g., the distinction between blending and segmenting). However, this line of research was later abandoned when researchers started to focus on phonological awareness complexity as the size of the linguistic unit to be manipulated (e.g., monosyllable words, onset-rime, and phonemes). Cassidy, Smith and Putman (2008) showed that kindergarten children had greater difficulty on the elision tasks relative to the blending tasks. However, the question remains uncertain as to whether complex phonological awareness tasks are more reliable measures of phonological awareness.

Receptive Vocabulary and Phonological Awareness

Receptive vocabulary skills at age 3 predicted phonological awareness at age 5, although to a greater degree in the Elision subtest than in the Blending subtest. This relationship between receptive vocabulary and phonological awareness is consistent with previous findings (e.g., Cooper et al., 2002, Storch & Whitehurst, 2000; Rvachew, 2003;2006). Receptive vocabulary seems to provide a basis for the acquisition of segmental phonological knowledge which can then be used to repeat and manipulate sub-lexical units within words.

Speech Perception and Phonological Awareness

Speech perception significantly predicted Elision performance at age 4. However, speech perception was neither a significant predictor for Blending at age 4 nor for both the Elision and Blending subtests at age 5. Furthermore, the results for the age 4 Elision subtest should be interpreted with great caution because of the limitations concerning the unbalanced distribution of scores. Because children's phonological awareness performance could not be reliably evaluated at age 4, it is difficult to draw substantive conclusions about what variables reliably predict children's higher-level phonological knowledge at age 4. Previous researchers (e.g., Rvachew & Grawburg, 2006; Rvachew, 2003) have observed that speech perception at age 4 predicts phonological awareness at age 5. The current study differs from the work of Rvachew and colleagues in several important respects. The current study evaluated a sample of typically developing children whereas Rvachew and colleagues evaluated a group of children diagnosed with speech sound disorders. Furthermore, this study used a minimal pair discrimination task to assess speech perception abilities whereas Rvachew and Grawburg (2006) used the Speech

Assessment and Interactive Learning System (SAILS). Finally, the current study evaluated predictors at age 3 relative to age 5 and the Rvachew studies evaluated predictors at age 4 relative to age 5. It may be the case that for typically developing children, phonological awareness measures index top-down perception effects to a lesser degree than for peers with speech sound disorders. It has been established in the literature that at least some children diagnosed with speech sound disorders (SSDs) have difficulty with the perceptual encoding of the acoustic signal (Rvachew &Jamieson, 1989; Rvachew & Grawburg, 2007; Johnson, Pennington, Lowenstein, & Nittrouer, 2011); this difficulty may have consequences for the quality of the phonological representations subsequently accessed for phonological awareness tasks. Thus, it may be the case that there is a stronger relationship between speech perception and phonological awareness in children with SSD's relative to children with typical phonological development.

The second difference highlighted above suggests that different types of speech perception tasks yield different results. The minimal pair discrimination task requires children to discriminate sounds on the basis of a single distinct feature accompanied by the instruction ("What word is this?") whereas the SAILS task requires children to decide ("Is this a good "s" [or other sound] or not?". The stimuli include correct productions and clear substitutions as well as more-fine-grained differences (e.g., distortions of /s/ instead of phoneme substitutions). Thus, it can be argued that SAILS places more metalinguistic demands on children than a minimal pairs task and this difference between tasks could explain why performance on SAILS was a strong predictor of phonological awareness in Rvachew and Grawburg (2006), while the minimal pairs task was not a predictor of phonological awareness in the current study.

Lastly, the current study evaluated children at age 3 relative to age 5 while Rvachew and Grawburg (2006) examined children at age 4 relative to age 5. It is possible that children's speech perception skills at age 3 are less of a predictor of children's phonological awareness than children's speech perception skills at age 4. One possible approach is to evaluate the change in variance explained in the phonological awareness models using age 4 measures instead of age 3. However, in the current study, most children performed at ceiling level on minimal pair discrimination task, suggesting that this task is not demanding enough to be a good measure of speech perception for 4-year-olds. An alternative possibility would be to examine if children's performance on the SAILS paradigm at age 4 predict phonological awareness at age 5 to evaluate whether the results of Rvachew and Grawburg (2006) can be replicated in children with typical phonological development.

Speech Production and Phonological Awareness

There is limited empirical evidence on the influence of speech production ability on phonological awareness. Rvachew and Grawburg (2006) found that speech production did not have a direct predictive influence on phonological awareness. However, they did find that speech perception explained 11% of the variance in speech production ability. This study found that there was a marginal effect of speech production ability at age 3 on phonological awareness at age 5, but this was only for the Elision subtest. Similar to Rvachew and Grawburg (2006), weak correlations were found between the measures of speech production and phonological awareness. These results suggest that further investigation is required to disentangle the relationships among speech perception, speech production, and phonological awareness.

Nonword Repetition and Phonological Awareness

Higher-level Phonological Knowledge: The Frequency Effect

To answer the research question of what child-specific language related factors (at age 3) predicted phonological awareness (at age 5), a variable that measured children's sensitivity to transitional probabilities of sound sequences within the language (i.e., *the frequency-effect*) was included. It was hypothesized that the frequency-effect represented the categorical nature of phonological representations (i.e., *higher-level phonological knowledge*) at age 3 and should therefore predict children's phonological awareness skills at age 5. However, a significant effect of frequency at either age 4 or 5 across all measures of phonological awareness was not observed. This suggests that if there are bootstrapping effects from a level of robustly abstracted categorical representations of sub-lexical structures, these structures are not represented as a frame similar to the sequences of the bi-phone segments that this specific transcription method ascribes to them. This does not mean that higher-level phonological knowledge at age 3 does not influence phonological awareness at age 5, but that child-level slopes were not a good measure of higher-level phonological knowledge. Further research is needed to determine whether any measure derived from this nonword repetition task can be used to quantify higher-level phonological knowledge. This could require rethinking how to score the two-phoneme sequences or reconceptualizing the mixed-effects models from which the slopes are derived. Further analysis is required to answer this question but that is beyond the scope of this paper.

Phonological Short-Term Memory

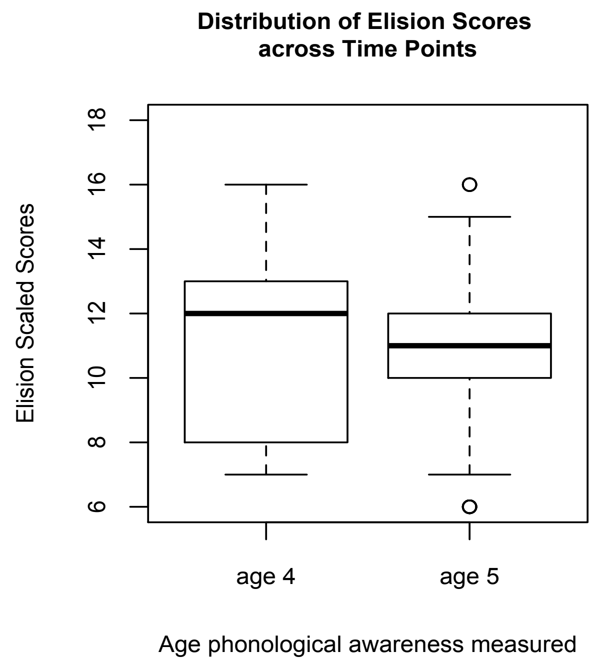
The chosen measure of phonological-short-term memory at age 3 (i.e., *predicted NWR accuracy as quantified by the child-level random intercept)* was a significant predictor of children's phonological awareness at age 5, but again only for the Elision subtest. This suggests that even after the maturity of the articulatory system (via the inclusion of age as a predictor), the potential effect of abstract categorical phonological knowledge (i.e., the frequency effect), and receptive vocabulary size (PPVT-4 standard score), and articulation ability (GFTA-2 standard score) are controlled for, phonological short-term memory continues to explain a significant amount of variance in phonological awareness performance in five-year-old children. In fact, this was the most significant predictor in the model; the random intercepts at age 3 predicted 27% of the variance in phonological awareness at age 5. This result is consistent with Gathercole's (2006) model of short-term phonological memory. In this model, young children's phonological representations and therefore their nonword repetition accuracy rely on their capacity to store phonological information. It should be noted that there is an alternative interpretation of this relationship between nonword repetition accuracy and phonological awareness that avoids having to make the kind of simplistic assumptions about phonological representations being monolithic and non-hierarchical as in Gathercole (2006). It may be that overall nonword repetition accuracy at this very young age (i.e., in 2 ½ to 3-year-old children who are for the most part younger than the youngest children [3-year-olds] in the Edwards et al. [2004] study) is indexing the child's ability to parse a novel form into smaller units that can be recombined in new ways to faithfully reproduce the stimulus, as suggested in work such as Edwards and Lahey (1998) and Gupta (2009).

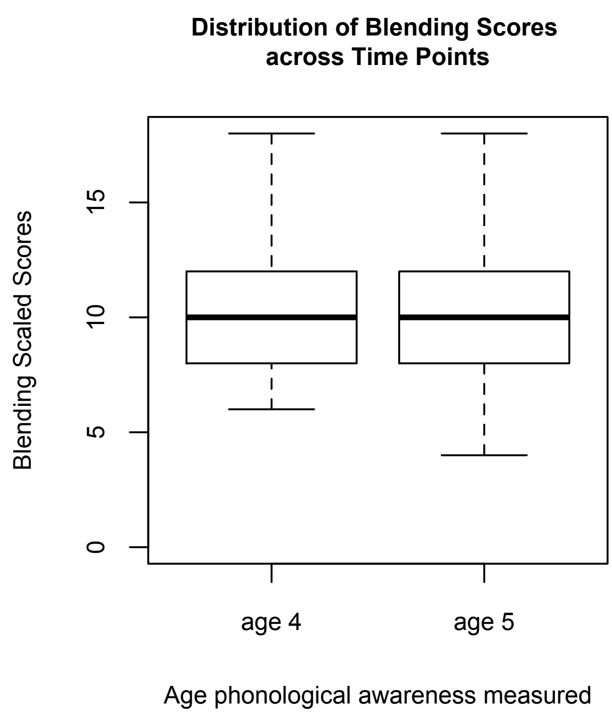
Conclusion

It has been well-established that phonological awareness is one of the best predictors of later reading ability. However, it has been exceedingly difficult to reliably evaluate phonological awareness in children younger than age 5. This study was designed to examine the development of phonological awareness in younger children. It addressed the following research question: *what child-specific measures in children as young as 2 ½ to 3 years of age, predict phonological awareness one and two years later*. The findings of the current study suggest the following: 1) phonological awareness can not be reliably measured in children as young as age 4 and 2) the best predictors at age 3 of phonological awareness at age 5 were receptive vocabulary and phonological short-term memory. Additional research is needed to understand how best to measure higher-level phonological knowledge in children before age 5. Furthermore, the clinical implications of these findings suggest that nonword repetition accuracy at age 3 can be a reliable predictor of phonological awareness at age 5 and could be strategically used for children who are at risk for having poor metalinguistic ability (e.g., children with speech or language disorders). This is useful information because a nonword repetition task can be successfully administered to children as young as age 2 (Dollaghan & Campbell, 1998; Anderson, J., Wagovich, S., & Hall, N., 2006; Shriberg, 2009). The findings of the current study also suggest that building children's receptive vocabulary knowledge in the preschool years will facilitate phonological awareness at age 5.

Appendix A

Distribution of the raw data across time points. The top figure displays the distribution of the scaled scores for the Elision subtest measured at age 4 (the left boxplot) and age 5 (the right boxplot). The bottom figure displays the distribution of the scaled scores for the Blending subtest measured at age 4 (the left boxplot) and age 5 (the right boxplot).





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