The Role of Akshara Knowledge and Phonological Processing Skills in Reading Development among Sri Lankan Children

by

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Abstract

This dissertation consists of three separate papers. The first paper examined predictors of akshara recognition at the symbol-level (akshara type, akshara frequency, visual complexity, number of diacritic markers, grapheme-phoneme sequence matching, and orthographic linearity) and child-level (phonological awareness, phonological memory, RAN, home reading time and socioeconomic status) in a sample of Sinhala-speaking Grade 1 to 6 children (N=300) in Sri Lanka. Generalized linear regression analyses showed that akshara type, akshara frequency, visual complexity, grapheme-phoneme sequence matching and the number of orthographic linearity breaks in akshara accounted for unique variance in how frequently an akshara was recognized correctly. Syllable awareness, phoneme awareness, phonological memory, and home reading time were unique child-level predictors of akshara recognition. The results suggest that the akshara learning process in alphasyllabaries is both prolonged and qualitatively different from letter learning in alphabetic languages due to the large symbol set and symbol-specific characteristics that exact a processing cost. These finding have implications for models of literacy acquisition.

The second paper examined the effects of introducing complex akshara and phoneme-level reading instruction on the development of phoneme awareness and its association with akshara knowledge and word reading accuracy in a sample of Sinhala-speaking children from Grades 3 to 5 (N = 150) in Sri Lanka. Phoneme awareness was slow to emerge and showed a strong relationship with word reading accuracy and akshara knowledge only after children received explicit phoneme-level instruction on akshara formation. Increased exposure to complex akshara itself had a small but significant effect on the development of phoneme awareness. Both word reading accuracy and akshara knowledge predicted phoneme awareness

once children received phoneme-level instruction, but the opposite was not true. The results suggest that phoneme awareness in Sinhala is particularly sensitive to the method of reading instruction. This raises the question whether Sinhala students would benefit from direct phoneme instruction provided to them in earlier grades.

The third paper examined the cognitive correlates (akshara knowledge, phonological awareness, phonological memory, and RAN) of word reading skills in a sample of Sinhala-speaking Grade 1 to 6 children ($N = 300$) in Sri Lanka. Multiple regression analyses showed that akshara knowledge had the strongest unique association with both reading accuracy and fluency across grades. RAN was also uniquely associated with word reading skills in all grades except Grade 4. Phonological memory was uniquely associated with reading accuracy until intermediate stage of reading development and with reading fluency only for the beginning readers. In contrast, neither syllable awareness nor phoneme awareness were uniquely associated with reading skills across grades. These results suggest that learning to read words accurately and fluently in alphasyllabaries is a prolonged process, and akshara knowledge is the most important predictor of success in it. These findings have implications for the literacy acquisition, development, and instruction in alphasyllabaries.

Preface

This thesis is an original work by Deepani K. W. Marasinghe Arachchillage. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "The role of akshara knowledge and phonological processing skills in reading development among Sri Lankan children", No. Pro00053314, February 28, 2015.

All of the research work presented in this dissertation forms part of an international research collaboration with Dr. Sonali Nag at the University of Oxford, and Dr. Rauno Parrila at the University of Alberta. I was the lead investigator and responsible for the areas of literature review, concept formation, data collection as well as manuscript composition. Dr. Rauno Parrila was the dissertation supervisor and involved in concept formation, manuscript composition and editing. Dr. Okan Buluth assisted with data analysis for Study 1 and contributed to manuscript composition. Dr. Tomohiro Inoue assisted with data analysis for Study 2 and 3 and contributed to manuscript composition and edits. Dr. Sonali Nag assisted in data and theory interpretation and manuscript editing.

Dedicated

To

my parents
for their overwhelming support and understanding

and to

my husband and son, Asoka and Madhusara
my eternal gratitude

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INTRODUCTION

Reading is an essential, basic life skill. Reading skills are critical for a child as they pave the way for a successful academic life (Lonigan, Burgess, & Anthony, 2000; Miller, McCardle, & Hernandez, 2010; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001), personal fulfillment and job success throughout life (Cunningham & Stanovich, 1998; Evans, Kelley, Sikora, & Treiman, 2010; Fletcher, Lyon, Fuchs, & Barnes, 2006). Literacy is so deep-rooted in most cultures that the awareness of the importance of early reading development has encouraged parents and teachers to invest in teaching children how to read. While learning to read accurately and fluently is easy for most children, one in three children experience significant difficulties in learning to read (Lonigan et al., 2000) and, if unidentified, slide towards a downward spiral of falling behind in reading and other academic areas, poor grades, low academic motivation, and low self-esteem (Carr, Borkowski, & Maxwell, 1991; Fulk & Montgomery-Grymes, 1994; Lonigan, 2006; Stanovich, 1986). In order to prevent failures in reading and support children to become good readers, it is important to understand the predictors of reading and their influence on reading development.

Reading studies in children and adults have largely focused on alphabetic languages, especially English (Share, 2008) and a large number of longitudinal and intervention studies with children over the last few decades have repeatedly shown that letter knowledge and phonological skills (definitions are provided in appendix) are robust predictors of reading development in languages with alphabetic writing systems (e.g., Caravolas, Lervåg, Defior, Seidlova Malkova, & Hulme, 2013; Hulme, Bowyer-Crane, Carroll, Duff, & Snowling, 2012; Hulme, Caravolas, Malkova, & Brigstocke, 2005; Perfetti, Beck, Bell, & Hughes, 1987; Wagner, Torgesen, &

Rashotte, 1994). However, nonalphabetic writing systems (syllabaries, morphographic orthographies, and alphasyllabaries[1]) are structurally and functionally different compared to alphabetic writing systems (e.g., Nag, 2007, 2014a, 2017; Nag, Caravolas, & Snowling, 2011) and questions have been raised about the applicability of the research findings and theoretical models of reading from alphabetic writing systems to readers of other writing systems (Nag, 2007). For example, the few existing reading studies in alphasyllabaries[2] show that the reading development of young children follows a different developmental pathway compared to the reading development of alphabetic readers (Nag, 2007; Nag & Snowling, 2011, 2012) and reading studies in languages with alphabetic writing systems, especially English, have had limited success in explaining the nature of reading development in other writing systems (Share, 2008, 2014). Only a few studies so far have examined the predictors of reading development in alphasyllabaries (Salomon, 2000; Vaid & Gupta, 2002) and currently we know very little about the impact of symbol-level and child-level characteristics on reading attainment in alphasyllabaries in general. Nothing has so far been published about the factors that influence word reading in Sinhala, the target language of this dissertation, over the primary school years. The purpose of this dissertation is to examine the linguistic (symbol-level and word level properties), cognitive (phonological awareness, RAN, and phonological memory) and environmental (socioeconomic status and home reading time) predictors of word reading development in Sinhala-speaking elementary school children in Sri Lanka.

I suggest that instructional and theoretical advances in understanding reading development in alphasyllabaries require examining the role cognitive, linguistic and

[1] We use this terminology for the present purpose. However, there are disagreements over the terminology. See Share & Daniels (2016) for alternative explanations.
[2] Though 'alphasyllabary' is the most commonly used term, alternative terms have been suggested (see Share & Daniels, 2016).

environmental predictors play in learning to read. Given the differences between alphabetic and alphasyllabic writing systems in how phonemes and syllables map onto orthographic symbols and how many symbols a child has to learn to master decoding, reading studies in alphasyllabaries can significantly contribute to theoretical discussions across languages and will provide a strong contribution to the reading research literature. Sinhala is an alphasyllabary and this study is the first known reading study that examines the predictors of reading in Sinhala. Such examination also has practical importance in guiding reading interventions and general reading instruction in the school system as no such studies exist so far.

Sinhala - an Indic Alphasyllabary

In the contemporary South and Southeast Asia, several languages share common architectural features and use orthographies that descend from the ancient Brahmi writing system. Together they are referred to as alphasyllabaries or Indic alphasyllabaries (Nag, 2007; Nag, 2014a; Nag & Perfetti, 2014). In the classification scheme of writing systems, Sinhala, as a member of Indic scripts, falls in between syllabic and alphabetic writing systems (Bright, 1996; Daniels, 1996) and has overlapping features with both (Gelb, 1952, 1963)[3].

Sinhala is the southernmost Indo-Aryan language and its closest relative is Dhivedi of Maldive Islands, both of whom have been isolated from their relatives in Northern India for over two millennia (De Silva, 1979; Disanayaka, 1991; Gair, 2006). Spoken Sinhala has been exposed to other language families of the region, such as Dravidian and Malayo-Polynesian, as well as to colonial languages (Portuguese, Dutch, and English). For example, Spoken Sinhala shows a heavy influence of Dravidian languages on its phonology (Elizarenkova, 1972; Gair, 1985) and includes numerous lexical borrowings from Malayalam, Portuguese, Dutch, and English

[3] For an alternative view, see Share and Daniels (2016).

(Chandralal, 2010; Hettiaratchi, 1965). Sinhala script started to appear in inscriptions during the 3rd and 2nd centuries B.C., although the visual appearance of the symbols has changed considerably since then (Gair, 1982). The classical Written Sinhala has remained relatively unchanged since the 1300s, resulting in both strong diglossia and in emergence of hybrid texts that combine classical writing and transcription of oral language.

Sinhala Phonology

Sinhala phonology includes 40 consonants and 20 vowels, of which 24 consonants and 14 vowels (seven vowel qualities each with two lengths) are common today (Gair & Paolillo, 1997).

Sinhala Vowels

Phonemically, all Sinhala vowels can occur short or long as shown in Table I-1.

Table I-1

Spoken Sinhala - Vowel Classification

	Front		Central		Back	
	Short	long	Short	long	Short	long
High	i	i:			u	u:
High-mid	e	e:				
Mid			ə	ə:	o	o:
Low-mid	æ	æ:				
Low			a	a:		

Manipulating the vowel length changes the meaning and the pronunciation of a word, and all vowels can be both long and short. Sinhala has a three-way contrast between /ə/, /a/, /aa/, but

there is no separate symbol for /ə/ in Sinhala orthography. However, the contrast between /ə/ and /a/ is limited and it is based largely on the occurrence of /ə/ in the first syllable of a few items, especially the forms of the very frequent verb /kərə/ ‘to do’ in contrast to /karə/ shoulder. Therefore, the distribution of /ə/ and /a/ are largely predictable and the two are in near complementation (Gair, 1998). Long /ə:/ occurs only in loanwords like ‘sir’ /sə:r/ and ‘shirt’ /ʃə:ʈ/. The sound of the vowels /æ/ and /æ:/ (similar to the sounds of the English words - hat and bad, respectively) are distinctive characteristic of Sinhala as these sounds are not present in Indo-Aryan or Dravidian languages (Gunasekara, 1999; Ramanayake, 2006).

Sinhala Consonants

While many of the consonants are similar to neighboring languages, there is a set of four “half nasals” (Chandrallal, 2010) or pre-nasalized voiced stops — ᵐb, ⁿd̪, ᶯɖ, and ᵑg — peculiar to Sinhala (Karunatillake, 2004) and not present in the neighboring Dravidian or North Indian Indo-Aryan languages. These half nasals are sometimes treated as independent phonemes (e.g., Gair & Paolillo, 1997) and sometimes as consonant clusters with an extra short allophone (e.g., Chandrallal, 2010). They contrast with nasal + voiced stop consonant clusters mb, nd, nɖ and ng (Gair, 1970), and are treated as independent phonemes.

Table I-2 below shows the Spoken Sinhala consonant classification. Alveolar nasal /n/ has two phonemically distinct allophones, dental nasal /n̪/ and retroflex nasal /ɳ/. The dental version occurs before dental stops and the retroflex allophone before retroflex stops. While they cannot be clearly identified in speech and the retroflex nasal is sometimes marked by a distinct akshara in writing, they don’t define contrasts in modern Spoken Sinhala and therefore are not included in Table I-2.

Table I-2

Spoken Sinhala – Consonant Classification

	Labial	Dental	Alveolar	Retroflex	Palatal	Velar	Glottal
Stops - Voiceless	p	t̪		ʈ		k	
Voiced	b	d̪		ɖ		g	
Affricates - Voiceless					tʃ		
Voiced					dʒ		
Pre-nasalized voiced stop	ᵐb	ⁿd̪		ⁿɖ		ᵑg	
Nasal	m		n		ɲ	ŋ	
Trill			r				
Lateral			l				
Fricatives	f	s			ʃ		h
Glides/semivowels	w				y		

Fricative /f/ is bilabial and occurs only in borrowed words of English origin, such as /foʈo/. In Spoken Sinhala, speakers regularly substitute it with the bilabial stop /p/ that is native to Sinhala (Chandralal, 2010). Similarly, the palatal fricative /ʃ/ mainly occurs in borrowed Sanskrit words and is sometimes substituted by /s/. The glottal fricative /h/ also has multiple allophones as it adjusts to the following vowel. In Spoken Sinhala, /s/ is commonly replaced by /h/ combined with a vowel change. Thus, Literary Sinhala ‘eye’ /æsə/ and ‘rubbish’ /kasələ/ become / æhæ/ and /kahalə/, respectively, in Spoken Sinhala.

Similar to the vowels, most consonants can be both long and short with the long forms limited to the medial position. The distinction between single and double consonants is critical for distinguishing many common words, as in /atə/ and /attə/ (hand and branch) or /malə/ and /mallə/ (flower and bag). The phonetic length of consonants is indicated most of the time in writing by doubling the consonant symbol. The exception to this is some consonant clusters with a nasal first consonant. Consonant clusters are common in Sinhala and can occur in initial and medial positions. In the initial position, the first consonant is pronounced short but in the medial position the first consonant is usually pronounced long (but orthographically represented by only one consonant letter, creating one of the few opaque features to the Sinhala orthography). Clusters longer than two consonants are also possible, with most of such clusters occurring in Sanskrit loan words.

Finally, syllabification and permissible syllable structure depends on whether the word is of local origin (*nishpanna*), borrowed from other languages in their (near) original form (*thathsama*), or originates from another language, but modified to be incorporated to Sinhala (*thadbhava*; words that mainly originate from Sanskrit and Pali) (Wasala, Weerasinghe, & Gamage, 2005). Though the amount of words in the thathsama and thadbhava categories is about the same as in nishpanna, no separate syllabification rules can be found in literature for these words. However, syllabifications of almost all the words borrowed from languages other than Sanskrit are consistent with the syllabification rules for words in the nishpanna category (Wasala, Weerasinghe, & Gamage, 2005). There are four legal syllable structures – V, VC, CV and CVC – for words in the category of nishpanna. This can also be represented as (C)V(C) (Disanayaka, 1991). Syllabic structures for borrowed Sanskrit words can be represented as (C)(C)(C)V(C)(C)(C). Syllabification of these words will be altered according to the ease of

pronunciation and the existing syllable structures in Sinhala. While oral syllabification is relatively uncomplicated, the written syllable does not always match the oral syllable as we will see below.

Sinhala Orthography

Sinhala can be considered segmental in that all speech segments are represented in the script, yet the fundamental organizing principle of the script is the orthographic syllable[4] (Sproat, 2006) called 'akshara' or 'akuru' (Chandralal, 2010). As a result, a Sinhala akshara represent sounds at the levels of both the phoneme and the syllable simultaneously, allowing visual analysis of them into their constituent consonant and vowel components when the vowel component is present. While the mappings between orthography and phonology in alphabetic languages lie at the level of graphemes and phonemes (e. g., Katz & Frost, 1992; Ziegler & Goswami, 2005; Zhou, Duff, & Hulme, 2015), the mappings between orthography and phonology in alphasyllabaries is defined by context (Nag, 2014b), which is the case in Sinhala as well. An individual akshara is typically an orthographic syllable when it appears alone. However, when an akshara appears in a word, orthography-specific rules delimit their orthographic representation, and thus akshara symbols end up mapping onto multiple levels of phonology.

Sinhala is written from left-to-right with its own distinct, highly cursive semi-syllabic script. Each character of the Sinhala script stands for a distinct sound and there is a high degree of regularity in akshara to phonology correspondences. In this sense, the Sinhala script is highly transparent for reading as the pronunciation of an akshara is almost always clear from its written form. The same is not necessarily true for writing as most syllables can be represented by either a

[4] Note that the fundamental organizing principle of alphasyllabaries is still being debated (see Share & Daniels, 2016).

śuddha akshara or by a *miśra* akshara with only one usually considered correct. The śuddha akshara set is a subset of the miśra akshara set that contains all the akshara necessary to write classical Literary Sinhala (the distinction between Spoken Sinhala and Literary Sinhala will be discussed in detail later in this chapter). The current Spoken Sinhala can be represented fully by the śuddha akshara, but Literary Sinhala retains reference to special Sanskrit and Pali sounds captured by the miśra akshara. This is mostly needed for representing the Middle Indic phonemes, such as aspirates, that have disappeared from Spoken Sinhala over time (Gair & Paolillo, 1997; Paolillo, 1997). The availability of one-to-many mappings between syllables and akshara and the representation of phonemic distinctions in writing not present in spoken language makes Sinhala spelling a considerably more challenging task than reading. In both literate and spoken Sinhala, consonant-vowel (CV) syllable structure is dominant and most words are two to four syllables long. However, complex syllables with consonant clusters (pronounced as blends) are also present and longer multisyllabic words are common. In Sinhala, the inherent vowel /a/ is left unmarked and therefore has no sign.

Table I-3 shows the primary aksharas and the secondary diacritic signs for Sinhala vowels. In turn, Table I-4 shows Sinhala consonants (40). Note that the aspirated sounds in consonants are no longer phonemically present but are preserved in writing.

Table I-3

Sinhala Vowel Primary Akshara and Secondary Diacritics Used in Combination with a Consonant

	Primary Symbol		Secondary Diacritic		Diacritics used in Consonant ɭ /ka/	
Vowel	Short	Long	Short	Long	Short	Long
a	අ	ආ		ා		කා
i	ඉ	ඊ	ි	ී	කි	කී
u	උ	ඌ	ු or ෘ	ූ or ෲ	කු	කූ
e	එ	ඒ	ෙ	ේ	කෙ	කේ
ə						
o	ඔ	ඕ	ො	ෝ	කො	කෝ
æ	ඇ	ඈ	ැ	ෑ	කැ	කෑ
ai		ඓ		ෛ		කෛ
au		ඖ		ෞ		කෞ
ru	ඍ	ඎ	ෘ	ෲ	කෘ	කෲ

Table I-4

Sinhala Consonants with Inherent Vowel /a/ Assumed in Each

		Labial	Dental	Alveolar	Retroflex	Palatal	Velar	Glottal
Stops	Voiceless	/p/ ප	/t̪/ ත		/ʈ/ ට		/k/ ක	
	Aspirated	/p^h/ ඵ	/t̪^{h}/ ථ		/ʈ^h/ ඨ		/k^h/ ඛ	
	Voiced	/b/ බ	/d̪/ ද		/ɖ/ ඩ		/g/ ග	
	Aspirated	/b^h/ භ	/d̪^{h}/ ධ		/ɖ^h/ ඪ		/g^h/ ඝ	
Affricates	Voiceless					/tʃ/ ච		
	Aspirated					/tʃ^h/ ඡ		
	Voiced					/dʒ/ ජ		
	Aspirated					/dʒ^h/ ඣ		
Pre-nasalized	Voiced stops	/^{m}b/ ඹ	/^{n}d̪/ ඳ		/^{n}ɖ/ ඬ		/^{ŋ}g/ ඟ	
Nasal		/m/ ම		/n/ න	/ɳ/ ණ	/ɲ/ ඤ or ඥ	/ŋ/ ඞ or ං	
Trills				/r/ ර				
Lateral				/l/ ල	/ɭ/ ළ			
Fricatives		/f/ ෆ	/s/ ස			/ʃ/ ෂ		/h/ හ or ඃ
						/ʃ/ ශ		
Glides/semi-vowels		/w/ ව				/y/ ය		

Note. /n/ න is identified as dental in some sources. In Sinhala, the inherent vowel /a/ is left unmarked and therefore has no sign.

Similar to other alphasyllabaries (Kannada: Nag, 2007; Bengali: Nag & Sircar, 2008; Malayalam: Tiwari et al., 2011; Telugu: Vasanta, 2004), akshara for consonant clusters in Sinhala are more demanding units to learn (Wijayathilake & Parrila, 2014). Clusters with two consonants (CCV) are the most common form and clusters with more than two consonants, while possible, are rare in Sinhala. Conjunct consonants can appear at the beginning, middle or end of a word and more than one cluster are possible in a word. There are two types of conjuncts in Sinhala script, *combining* and *touching*. Example 1 shows two common combining conjuncts:

Example 1: ප් /p/ + රා /ra:/ = ප්‍රා /pra:/

ක් /k/ + ර /ra/ = ක්‍ර /kra/

A special example of a combining conjunct is when special signs for ්‍ර/r/ and ය /ya/ following a consonant are used as shown in example 2. When /්‍ර/ follows a consonant, it is written as a loop above the consonant, and when ය follows a consonant, it is written with ්‍ය, which is considered as half of ය (half a ය on the right).

Example 2: ක් /k/ + ය /ya/ = ක්‍ය /kya/

ක /ka/ + ්‍ර /r/ = කී /kar/

Example 3 shows two examples of touching akshara.

Example 3: ක් /k/ + ෂ / ša/ = ක්ෂ /kša/

න් /n/ + ද /da/ = න්ද /nda/

In each case, the visual form of the resulting akshara changes, often substantially in the case of combined conjunct aksharas, and it is never visually a pure combination of the two akshara. Furthermore, very frequent combinations are often written in one stroke, like /nda/ (ඳ), /kša/ (ක්ෂ) and /ṭwa/ (ට්ව). Forming the conjunct consonants is rule-governed and covered by instruction in Grade 4. However, children encounter frequently used conjunct consonants in their reading materials well before receiving formal reading instruction on them in school.

Moreover, as the Sinhala orthography signifies distinctions that no longer are phonemically recognized, attention to context is required for choosing the appropriate akshara in writing. For example, there are three pairs of akshara in Sinhala in which the usage is determined by etymology: න and ණ for spoken/na/, ල and ළ for /la/, and ශ and ෂ for /sa/. These akshara pairs sound the same in modern usage but differ in shape and the meaning of a word can change depending on the akshara in use.

Sinhala Diglossia

All Sinhala dialects are mutually intelligible as prominent differences remain restricted to the lexicon while phonological and morphological differences are less prominent between dialects (Chandralal, 2010; De Silva 1979). The most important varietal distinction in Sinhala is diglossia: There are two major functional varieties in Sinhala, the Spoken and the Literary (De Silva, 1967; Gair, 1968; 1986b; Geiger, 1938; Gunasekera, 1891). According to De Silva (1967), current diglossia results from traditionalists resisting changes to Literary Sinhala, whereas Spoken Sinhala has undergone significant changes as a result of contact with other regional and European colonial languages (see also Chandrallal, 2010). As a result, there now is a sharp

distinction between the two varieties that differ in their form, structure, typical use, and functions.

Literary Sinhala is considered the 'higher' variety and generally used for all literary texts and published materials (Dharmadasa, 1967; Weerasinghe, Wasala & Gamage, 2005). Literary Sinhala is no one's first language and children have to learn how to read and write Literacy Sinhala in school. Spoken Sinhala is used by everyone in all societal levels as the language of communication in everyday life (Gair, 1968, 1982, also discusses Formal Spoken Sinhala as a separate variety used in formal situations, such as lectures, public speeches, sermons, and TV and radio news broadcasts). Differences between Literary and Spoken Sinhala exist at all levels of language structure, the most notable being the presence of subject-verb agreement in Literary Sinhala while all spoken varieties lack it (Gair, 1982; Gair & Paolillo, 1988). Literary Sinhala also uses akshara that no longer have phonemic equivalents in Spoken Sinhala as some phonemic contrasts (for example, between aspirated and unaspirated stops) have disappeared from Spoken but are preserved in Literary Sinhala. This, combined with akshara to phoneme consistency, and vocabulary and morphology differences between the two varieties, creates a literacy learning environment where basic word reading skills are relatively easy to acquire, whereas learning to write Literary Sinhala is a prolonged educational process.

Learning to Read and Write in Sinhala

Sri Lanka has provided a free primary, secondary and tertiary education since its independence from Britain in 1948. Compulsory education lasts nine years from age 5 to 13 and practically all children in Sri Lanka attend primary education (UNESCO Institute for Statistics estimates access to primary education at 98.8%). As a result, the average adult literacy rate in 2015 was reported at 93.2% (male literacy rate was 94.1% while female literacy rate was 92.4%;

Central Bank of Sri Lanka Annual Report, 2016). Both youth (98.77%) and adult literacy rate estimates are higher than regional averages (UNESCO Institute for Statistics, 2015), and basic literacy problems are mostly limited to older adults. About 85% of adolescents complete secondary education, but access to tertiary education is limited and only about 21% of young adults access tertiary education (24% for females; 17% males). University access is limited to about 20,000 students per year, a number that equals roughly 15% of those who pass the General Certificate of Education Advanced Level examinations and are thus eligible for universities.

Despite the well-attended basic education system that performs better than most in the region, learning to read and write Sinhala is a prolonged process. Several of the features of Sinhala orthography: akshara-specific characteristics such as the large symbol set, akshara type, visual complexity, phonological complexity, grapheme-phoneme sequence match/mismatch, linearity breaks and akshara frequency, and word-specific characteristics such as the presence of consonant clusters, word length and word frequency can possibly cause literacy learning difficulties similar to other akshara orthographies (e.g., Nag, 2014b; Nag et al., 2014; Nag, Treiman & Snowling, 2010). Further, the strong diglossia and the presence of a highly codified Literary Sinhala create a literacy learning situation where the difference of being able to read and being able to write can be particularly pronounced, as can the differences between levels of writing skills.

Chapter Summary

In summary, a large number of studies have examined the predictors of reading in alphabetic orthographies and indicate that letter knowledge and phonological skills are robust predictors of learning to read. The quantity of reading studies is still very limited in alphasyllabaries and the few available studies show that children's reading development is

particularly affected by the structural and functional differences of the writing system compared to the alphabetic writing systems. Further, very few studies have so far examined the role of symbol-level characteristics in learning the akshara set and none of those studies have examined all of the akshara-specific features (known so far as important in akshara learning) in order to identify their relative importance in learning to read. We know of no published studies of reading acquisition in Sinhala, and more scientific studies are needed to examine the predictors of reading development. The goal of this dissertation is to examine the linguistic, cognitive and environmental predictors of word reading development in Sinhala-speaking elementary school children in Sri Lanka.

Overview of the Present Dissertation

Chapters 2, 3 and 4 report three empirical studies that address gaps in our current understanding of learning to read in Sinhala. They examined the predictors of akshara and word reading in Sinhala and how different cognitive and home characteristics are associated with developing Sinhala reading skills. The purpose of study 1 (Chapter 2) was to examine symbol-level and child-level predictors of akshara recognition in Sinhala-speaking children. In expanding the line of inquiry initiated by Nag et al. (2014), it was hypothesized that akshara-specific features (akshara type, akshara frequency, visual complexity, number of diacritic markers, linearity and grapheme-phoneme sequence matching) and child-level characteristics (phonological awareness, RAN, phonological memory, SES and home reading time) would independently predict akshara recognition in a sample of Grade 1 to 6 children.

The second study in Chapter 3 explored the effects of introducing complex akshara and phoneme-level reading instruction on the development of phoneme awareness and its association with akshara knowledge and word reading accuracy in Sinhala-speaking children from Grades 3

to 5. The first hypothesis was that phoneme awareness will be slower to emerge due to the dominant status of the syllable as the basic orthographic unit in Sinhala. Formal introduction of complex akshara in Grade 4 was expected to boost phoneme awareness, and explicit instruction in akshara decomposition in Grade 5 was expected to further enhance it. Second, it was expected that phoneme awareness correlates only moderately with akshara knowledge and word reading accuracy in Grades 3 and 4, but more strongly in Grade 5 after the instruction on phoneme markers. The third hypothesis was that akshara knowledge (either with or without explicit instruction in diacritics) would predict phoneme awareness that would then predict growth in word reading, marking a bidirectional relationship between reading and phoneme awareness in Sinhala.

Chapter 4 presents Study 3 that examined the variables associated with word reading performance in Sinhala. The first research question was whether akshara knowledge predicts reading rate and accuracy across different stages of reading development in primary school given the crucial role it is claimed to play in learning to read in alphasyllabaries. The hypothesis was that phonological skills (syllable awareness, phoneme awareness, RAN and phonological memory) would predict reading differently for different stages of reading development. Second, it was expected that the effect of explicit phoneme instruction would have an impact on the relative importance of different cognitive skills in predicting reading skills.

Finally, outcomes from these studies and implications for future research are summarized and discussed in Chapter 5 with reference to the current reading literature in alphasyllabaries and other writing systems.

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STUDY 1: THE IMPACT OF SYMBOL AND CHILD CHARACTERISTICS ON AKSHARA RECOGNITION IN ELEMENTARY SCHOOL CHILDREN

One in every four primary school-age children in the world, a total of 168 million children (UNICEF, 2015), live in South Asia and learns to read and write an Indic alphasyllabary. The basic orthographic unit in Indic alphasyllabaries is called an akshara, and it can represent consonants, vowels, consonant-vowel pairs, or clusters of consonants with a vowel. When children learn to read, they need to master a large akshara set that while frequently phonologically transparent, can be orthographically complex (see below for details). Several studies have reported that learning the extended akshara set (roughly 200 to 600 depending on the orthography) is a prolonged process that continues well beyond the primary school years (Nag, 2007; Tiwari, Nair, & Krishnan, 2011). In contrast to alphabetic orthographies where the focus shifts very quickly from symbol learning to decoding, in alphasyllabaries the two processes continue in parallel for a longer period of time. Given the resource demanding nature of akshara learning, it is important to understand the factors that make some akshara difficult and that predict individual differences in akshara recognition. The purpose of this study was to examine simultaneously akshara-level and child-level predictors of akshara recognition in Sinhala-speaking elementary school children in Sri Lanka. We will first describe Sinhala orthography briefly before reviewing the existing literature on akshara recognition.

Sinhala Orthography

Sinhala belongs to the Indo-Aryan branch of Indo-European languages and is written with a unique akshara orthography that is largely consistent in that each akshara stands for the same sound(s) across all words; spelling, however, is complicated by two factors: one-to-many

correspondences from sounds to symbols, and significant differences between the spoken and literate forms of the language. Literate Sinhala includes symbols that no longer have phonemic equivalents in spoken Sinhala, and traditional texts include akshara that are no longer commonly used in modern Sinhala. Sinhala phonology includes about 40 consonants and 20 vowels, of which 27 consonants and 14 vowels (seven vowel qualities each with two lengths) are common today (Gair & Paolillo, 1997).

Similar to other Indic alphasyllabaries, each vowel in Sinhala has a primary symbol, used when the vowel is in the initial position of a word, and a secondary sign (diacritic marker) used in all other instances. Each consonant also has a distinct symbol that is pronounced with an inherent schwa vowel /a/. When a consonant with a vowel other than /a/ is written, the vowel diacritic marker is attached to the consonant symbol and the inherent /a/ is dropped from the pronunciation (for a comprehensive description of alphasyllabic writing systems in general and akshara-specific features in particular, see Nag, 2017). When consonant clusters are formed, the vowel (if not schwa) and the second consonant is ligatured to the first consonant using their secondary diacritic forms, frequently leading to two types of non-linearity: off-the-line location of diacritic markers and sequence mismatches between the phonological and orthographic syllables. The off-the-line arrangement results because the diacritic for the second consonant of the cluster is always attached to the bottom of the first consonant and some vowel diacritics are attached to the top of the first consonant (see example 1).

Example 1. ප /p/ + ර /r/ + ි /i/ = ප්‍රි /pri/

$C_1 + C_2 + V = CCV$

Our count of all individual akshara in Grade 1 to 6 Sinhala Language Arts textbooks identified 332 unique akshara (out of 411 akshara in total) that were consonants with vowel markers (CV) or consonant clusters (CCV). Of these, 194 (58%) included off-the-line markers.

The sequence mismatches between the phonological and orthographic syllables occur also when the orthographic syllable includes linearly placed phoneme markers whose placement does not follow the order of phonemes in the phonological syllable (see example 2).

Example 2. කේ /k/ + ේ /e/ = කෙ /ke/

In total, 246 (74%) of CV and CCV akshara in our akshara pool include non-linear elements. While non-linearity can confuse syllable processing (e.g., Kandhadai & Sproat, 2010), individual diacritics have a designated location in the akshara that is predictable and rule-governed. The predictability of the location of diacritics eases the memory load for the Sinhala readers once they master the ligaturing rules; however, at the time of data collection these rules were taught explicitly only in Grade 5, and the new Sinhala Language Arts curriculum introduced in 2016 moved this instruction to Grade 6.

According to Chandralal (2010), contemporary literate Sinhala can be written with 54 individual symbols (16 primary vowels and 38 primary consonants) combined with 18 diacritics, and 38 symbols (12 primary vowels and 26 primary consonants), combined with the 18 diacritics, are sufficient to represent colloquial Sinhala. Of the 18 diacritics, 16 denote vowels (including two diphthongs), one the syllabic ‘r’ and one (with two different forms), called *hal lakuna* or *hal kirīma*, is used for suppressing the pronunciation of the inherent vowel to make a pure consonant form. In total, Sinhala orthography includes over 600 akshara. In the new curriculum, the akshara are presented to the students as single units roughly in the following order: consonants with an inherent vowel (Ca), vowels (V), consonants with other vowels (CV),

consonants where inherent vowel is nullified with hal lakuna (C), and consonant clusters with a vowel (CCa, CCV) until Grade 6 when the ligaturing rules and the underlying phonological information is explicitly taught.

Akshara Characteristics

There is evidence that akshara-specific characteristics such as frequency, akshara type, visual complexity, consonant clusters, and number of phonological components encoded in an akshara (phonological complexity) directly influence akshara recognition (e.g., Nag, 2007, 2014; Nag et al., 2014). Previous studies in alphasyllabaries show that knowledge of low frequency akshara remain poor even among good readers and the akshara set needed for advanced literacy is not fully mastered by the end of the primary school (Nag, 2007; Nag, Snowling, Quinlan & Hulme, 2014; Nag, Treiman & Snowling, 2010). Learning akshara with diacritic markers, especially consonant clusters, is difficult and takes time because of the dual level of representation of phonological information within the symbol block. Wijayathilake and Parrila (2014) reported that Sinhala words with CCVs were difficult even for Grade 3 good readers, whereas the poor Grade 3 readers struggled also with words made of simpler Ca or CV akshara if they included more than three akshara. Nag (2014) examined reading and spelling of consonant clusters with Grade 3 students and found that both reading and writing consonant clusters were prone to errors. Consonant clusters join together more phonemic markers than the simpler CV akshara and are nonlinear. Similarly, the longer the word, the more likely it is to include diacritic markers that are off-line or that create grapheme-to-phoneme sequence mismatches. Thus, while akshara are read from left-to-right, non-linear placement of diacritic markers can complicate both the visual and the phonological processing of the akshara.

Nag and colleagues (2014) studied the influence of three item-level characteristics – akshara frequency, phonological complexity (defined as the number of phonemes the akshara represents), and visual complexity (defined as how many pixels were needed to print the akshara) – on akshara recognition. Their results showed that all three accounted for variance in akshara recognition both concurrently and longitudinally during the first two years of reading instruction. Nag et al. suggested that cognitive demands are higher when an akshara is visually complex and has more diacritic markers because children have to remember not only the appropriate diacritic markers but also the ligaturing rules on how the diacritic markers can be stacked onto the base consonant. Nag, Treiman and Snowling (2010), in turn, reported that even older children (Grades 4 and 5) had particular difficulty with spelling akshara correctly when the secondary forms of symbols differed from the primary forms in shape and size. Given the similarities in the writing systems, visually distinct secondary forms could be expected to be difficult for Sinhala readers as well.

Child Characteristics

Nag et al. (2014) further examined whether individual differences in age, general ability (Raven's matrices), vocabulary, phoneme awareness, rapid automatized naming (RAN), and visual memory impacted akshara recognition. Age, vocabulary, and RAN predicted akshara recognition concurrently, and age, vocabulary, RAN and phoneme awareness predicted akshara recognition 8-months later after controlling for earlier akshara knowledge. Nag (2007) showed that there was a significant correlation between akshara recognition (specifically, akshara with inherent vowel) and syllable awareness at the beginning phase of reading development (Grades 1-3). By Grade 4, there was a significant association between all akshara types and all types of phonological sensitivity while the relationship between phoneme awareness and akshara

knowledge was particularly pronounced. Nag and Snowling (2011a) confirmed this relationship with Grade 4, 5, and 6 Kannada readers and suggested that the increased akshara knowledge of older children provided a boost to their phoneme processing ability. We could not locate studies directly examining whether phonological memory predicts akshara recognition, but Wijayathilake and Parrila (2014) showed that phonological memory was moderately associated with word reading for both good and the poor Grade 3 Sinhala children. In the study of children from low-income families, Vagh (2010) showed that while the children had little access to rich and diverse print resources at home or in their kindergarten classrooms, their home literacy environments had an impact on children's language and literacy skills. Parents' level of schooling related positively to the richness of the home literacy environment, growth in children's knowledge of akshara and engagement in language and literacy activities.

Current Study

In the current study, we expand the line of inquiry initiated by Nag et al. (2014) and examine what akshara and child characteristics predict akshara recognition in a sample of Sinhala speaking Grade 1 to 6 children. The first purpose of this study was to examine which symbol-level factors (akshara type, frequency, visual complexity, number of diacritic markers, match between phonological and orthographic syllable, and presence of off-the-line markers) have a unique effect on how easy the akshara is to recognize. As many of the factors that possibly make akshara more difficult to learn are correlated (e.g., consonant clusters include more diacritics which increases their visual and phonological complexity and presence of non-linear components), it is important to examine their impact simultaneously. Second, we examine which child characteristics (grade, syllable awareness, phoneme awareness, phonological memory, RAN, SES, and home reading time) predict akshara recognition before combining the

significant predictors from the two levels into a single multi-level model. To our knowledge, this is the first study that includes phonological memory, SES and home reading time as predictors of akshara recognition. SES and home reading have predicted the development of reading across languages (e.g., English: Sénéchal & LeFevre, 2002; Chinese: Shu, Li, Anderson, Ku & Yue, 2002; Korean: Kim, 2009), and Wijaythilake and Parrila (2014) reported that phonological memory was associated significantly with Sinhala word reading. Given the phonological complexity of some of the akshara and possible need to manipulate the orthographic order of phonemes to match the spoken order, we included phonological memory measure to this study as well.

Very little is currently known about the factors that impact akshara learning, and in the absence of such information, Sinhala instructional approaches and experiments are poorly informed by research. We hope that the current study will enhance knowledge of the importance of various symbol-level and child-level factors involved in akshara mastery.

Method

Participants

Three hundred Sinhala-speaking children (148 male, 152 female), in Grades 1 to 6 (between ages 6 years 4 months and 11 years 4 months) from two well-functioning government schools in Kandy and Kegalle districts in Sri Lanka participated in this study. Both schools were suburban schools serving families from middle to upper-middle socioeconomic backgrounds. All teachers had tertiary education and were Government certified. Fifty students with no documented sensory or behavioral disorders from each of the first six grades were randomly selected and assessed. Students' first language and the medium of instruction was Sinhala.

Students additionally received English and Tamil instruction for several periods during the school week from Grade 2 in line with the language education policy of Sri Lanka. English instruction in Grade 2 is limited only to oral English practice. English reading and writing instruction starts in Grade 3.

Materials

Akshara Recognition

Akshara recognition was our dependent variable and the participants were asked to name aloud 80 akshara taken from Grade 1 to 6 Sinhala Language Arts textbooks. The 80 akshara were selected to vary on the following eight dimensions:

1. *Akshara frequency***.** Our count of all individual akshara in Grade 1 to 6 Language Arts textbooks (total number of words was 43 343, and the total number of akshara was 124 132) identified 411 unique akshara whose frequency (number of occurrences in the 124 132 akshara total) varied from 1 to 5293. The 80 akshara used in this study included 40 high-frequency (mean =1361, SD = 1482) and 40 low-frequency (mean = 15, SD = 28) akshara, 10 for each akshara type (see below). Mean frequencies for the different akshara types are as follows: frequent consonants with the inherent vowel (mean = 3532.00, SD = 1178.85), infrequent consonants with the inherent vowel (mean = 26.20, SD = 33.42), frequent vowels (mean = 813.40, SD = 699.42), infrequent vowels (mean = 30.80, SD = 37.16), frequent consonants with vowel diacritics (mean = 1048.80, SD = 222.24), infrequent consonants with vowel diacritics (mean = 3.40, SD = 3.06), frequent consonant clusters with vowel diacritics

(mean = 49.10, SD = 46.76), infrequent consonant clusters with vowel diacritics (mean = 1.00, SD = 0.00).

2. *Visual complexity.* Visual complexity of all 411 akshara was evaluated by presenting participants semi-random combinations of four akshara (no combination included the same akshara twice); each akshara was presented in at least 23 different combinations. One thousand English-speaking university students who were not familiar with akshara orthographies were presented one ten-item sheet each and asked to rank each set of four akshara from the least visually complex (1) to the most visually complex (4). Mean rank was considered as the visual complexity score for the akshara. The same set of akshara was also analyzed using GraphCom software that estimated visual complexity on four dimensions (perimetric complexity, number of disconnected components, number of connected points, and number of simple features; see Chang, 2015, and Chang, Chen & Perfetti, 2017, for details). The correlation between the two sets of estimates was .73 (Li-Yun Chang, personal communication).
3. *Linearity.* An akshara was considered violating linearity when one or more phoneme markers were attached to the top and/or the bottom of the base consonant, appearing not fully inline in the text. Only /CV/ and /CCV/ akshara had the possibility of including linearity violations. This score was categorical.
4. *Number of linearity breaks.* We also counted the number of off-line phoneme markers (min = 0, max = 2) in each akshara.
5. *Akshara type.* Four different types of akshara (consonants with inherent vowel (Ca), consonants with vowel diacritics (CV), primary vowels (V), and consonant clusters

with vowel diacritics (CCV)) were included in the test. The effect of akshara type was assessed with three dummy coded variables comparing the first three categories to the last.

6. *Number of diacritic markers.* Number of diacritic markers attached to the base consonant was counted. Only diacritic markers that mark an additional phoneme were used (i.e., Ca and V akshara always had 0 and the maximum number of diacritic markers for CCV akshara was 3).
7. *Grapheme-phoneme sequence matching.* Grapheme-phoneme sequences were judged as matching when the position of each phoneme marker in the akshara was consistent with its position in the sound sequence of the spoken syllable. This variable was scored as 0 (perfect matching) or 1 (at least one mismatch) and overlaps with the linearity violations, but is not exactly the same as some sequence mismatched vowel markers can be inline (see example 2 above).
8. *Number of grapheme-phoneme sequence mismatches.* We also calculated the total number of phoneme markers in each akshara that were not in a position consistent with their spoken syllable. The maximum score was 3. Similar to above, this overlaps but is not equal to number of linearity violations.

The 80 akshara were presented on eight cards in rows of 10 akshara at a time. The first card included high-frequency Ca akshara, the second high-frequency V akshara, and the third high-frequency CV akshara. If the child made more than five errors in two of the three cards, the testing was discontinued; in all other cases, all the remaining cards were presented in the following order: card 4 (low-frequency Ca akshara), card 5 (low-frequency V akshara), card 6 (low-frequency CV akshara), card 7 (high-frequency CCV akshara), and card 8 (low-frequency

CCV akshara). Cronbach's alpha reliability for akshara reading accuracy ranged from .82 to .96 across the grades.

Rapid Automatized Naming (RAN)

RAN was assessed with Digit, Akshara, and Object Naming tasks. Digit and Object Naming tasks were taken from RAN/RAS test battery (Wolf & Denckla, 2005) and required children to say as fast as possible the names of five digits (2, 7, 4, 9, 6) or objects (book, chair, dog, hand, star – all highly familiar bisyllabic words in Sinhala) arranged semi-randomly in five rows of 10. Wolf and Denckla (2005) reported test-retest reliability across ages for Object and Digit Naming to be .84, and .92, respectively. The stimuli for Akshara Naming were five high-frequent (frequencies ranged from 2151 to 5293) visually simple akshara ව/wa/, ස/sa/, ර/ra/, ද/da/, and ක/ka/ that are taught early in Grade 1. Prior to beginning the timed naming, children were asked to name the stimuli in a practice trial to ensure familiarity. Children's score in RAN was the time taken to name all items. Time taken for Akshara Naming correlated .73 with Digit Naming and .65 with Object Naming.

Phonological Memory

Phonological memory was assessed with two syllable repetition tasks that manipulated the phonological familiarity of the items. The first task consisted of 18 strings of syllables made of high-frequency akshara; the number of syllables in the strings increased from 2 to 14, and the presentation was discontinued after three consecutive errors. The second task was otherwise similar but now the syllable strings were made of low-frequency akshara and varied in length from two to nine syllables. One syllable string at a time was read aloud to a child and the child was asked to listen carefully and repeat the string as clearly and correctly as possible. A

participant's score was the total number of correctly repeated syllable strings for both tasks. Cronbach's alpha reliability ranged from .54 to .98 across grades (the lower numbers were for the higher grades).

Phonological Awareness

Phonological awareness was assessed with two deletion tasks – Phoneme Deletion (60 items) and Syllable Deletion (60 items) – that had the same test format. The phoneme deletion task required the participant to repeat words (30) and nonwords (30) after removing the designated sound (underlined in the examples) from the beginning (10) '*kura*', middle (10) '*botheju*'or the end (10) '*kasi*'of the item. Cronbach's alpha reliability ranged from .80 to .98. Syllable deletion task required the children to repeat the item without saying the designated syllable. Cronbach's alpha reliability ranged from .90 to .98. Total score was the number of correctly pronounced items after removing the designated sound/syllable. If the child responded incorrectly to four consecutive items, the task was discontinued.

Home Literacy Practice

A questionnaire with 17 questions, adapted from the Home Language and Literacy Environment Questionnaire (Nag, 2004), was used to collect information about participants' home literacy practices. Parents provided the answers on a seven-point Likert-scale to questions that covered areas such as amount of print materials at home (1 for less than five and 7 for more than hundred), availability and frequency of adult support for reading (1 for less than 5 times a month and 7 for once a day), frequency and amount of children's home reading (1 for less than 10 minutes a day and 7 for more than one hour a day), as well as the total number of hours spent on literacy activities at home each week.

Socio-economic status (SES)

SES was assessed with parents' (1) educational qualifications (separately for fathers and mothers) that ranged from completion of compulsory education to completion of university degree, and (2) occupation that was classified into six levels ranging from no occupation (score was 0) to central government employees (score was 5) as indicated in the Classification of Employees by Professions produced by the Sri Lanka Ministry of Finance (2015).

Procedure

All participants were examined during the last term of the school year in September-December. Each child was tested individually in a quiet room in their school by trained graduate students who were native Sinhala speakers and received extensive training on test administration. Testing was completed within 40-60 minutes divided over 1 to 2 sessions depending on how long a child wanted to work. The tests were administered in a fixed order. The home practices and SES questionnaire was sent to the parents of the participants.

Results

Akshara Characteristics

Table II-1 shows the correlations between the item-level characteristics assessed.

Table II-1

Correlations between the Item-Level Characteristics

	1	2	3	4	5	6	7	8
1) Akshara frequency	1							
2) Visual complexity	-0.35*	1						
3) Linearity	-0.17*	0.46*	1					
4) Number of linearity breaks	-0.17*	0.50*	0.93*	1				
5) Type of Akshara	-0.32*	0.65*	0.70*	0.69*	1			
6) Number of diacritic markers	-0.23*	0.59*	0.73*	0.76*	0.82*	1		
7) Grapheme-phoneme sequence matching	-0.18*	0.46*	0.92*	0.86*	0.72*	0.80*	1	
8) Number of grapheme-phoneme sequence mismatches	-0.18*	0.55*	0.85*	0.92*	0.69*	0.87*	0.89*	1
9) Akshara recognition	0.20*	-0.22*	0.03*	0.02*	-0.10*	-0.05*	0.04*	0.01

Note. * $p < .001$ (two-tailed)

Most akshara characteristics correlated significantly with akshara recognition, albeit many of the correlations were small in magnitude. Most notably, akshara recognition was associated with frequency and visual complexity. Very high correlations between many akshara characteristics indicate that they are not independent; instead, type of akshara, visual linearity indices, number of diacritic markers, and grapheme-phoneme sequence matching are all closely associated.

Next, we calculated a generalized linear mixed-effects model with akshara recognition as the dependent variable and the other variables from Table II-1 as predictors. In the model, we used a hierarchical structure in which the items were nested within the participants. The measures from Table II-1 were used as fixed-effects, while the participants were used as the random effect component in the model. The models were estimated using the lme4 package (Bates, Maechler, Bolker, & Walker, 2015) in R (R Core Team, 2016). All variables of interest were iteratively entered into the model one-by-one based on the strength of their correlation with akshara recognition (see Table II-1). That is, we first used akshara frequency as the only predictor and concluded that it was a statistically significant predictor of akshara recognition. Next, we entered visual complexity into the model as the second predictor. We continued this iterative process by including new predictors as we kept the significant ones in the model. Type of akshara was assessed with three dummy coded contrasts where the last category (CCV) was the reference category. As can be seen in Table II-2, visual complexity, akshara frequency, type of akshara, grapheme-phoneme sequence matching, and the number of linearity breaks all affected akshara recognition.

We then conducted a second set of analyses to investigate whether the predictors summarized in Table II-2 would still be significant after the effect of Grade is accounted for in the model. The results of this analysis indicated that all of the predictors were still statistically significant. Thus, we conclude that akshara frequency, akshara type, visual complexity, grapheme-phoneme sequence matching, and the number of breaks from linearity of visual presentation (linearity breaks) all are significant predictors of how accurately an akshara is recognized.

Table II-2

Results of the Generalized Linear Mixed-Effects Model

Variables	*b*	*SE*	*z*
Intercept	0.293	0.100	2.93*
Akshara frequency	1.199	0.025	47.30**
Visual complexity	-0.199	0.032	-6.14**
Type of Akshara (1)	-1.565	0.084	-18.71**
Type of Akshara (2)	0.649	0.093	6.97**
Type of Akshara (3)	-0.703	0.091	-7.70**
Grapheme-phoneme sequence matching	0.397	0.098	4.04**
Number of linearity breaks	0.625	0.075	8.38**

Note. * $p < .05$; ** $p < .001$. Type of Akshara: 1 = Ca, 2 = V; 3 = CV. Comparison category for Type of Akshara analyses was CCV.

Child-Level Predictors of Akshara Recognition

Descriptive statistics for the child-level tasks are presented in Table II-3 separately for each grade. In general, akshara recognition approached ceiling in Grades 5 and 6, which is not surprising given that all the akshara in the test were taken from the children's textbooks. The other means indicate that syllable awareness improved quickly but phoneme awareness remained relatively low until Grade 5. RAN times are reduced across the grades but phonological memory performances are comparable from Grade 2 onwards. The time spent reading at home initially increases but then steadily declines; however, we should note the very large variability in this measure.

Table II-4 shows the correlations between the variables. An initial examination of the distributional properties of the variables revealed that akshara recognition and most of the child-level variables were not normally distributed. Log-transformation was performed to improve the distribution and transformed data was used in all correlational analyses. Table II-4 indicates that

akshara recognition correlated strongly with grade but also with all phonological processing tasks. Correlations between akshara recognition and mother's education, father's occupation, and time spent reading at home were smaller but significant.

Next, we used multiple regression analysis to assess the effects of socioeconomic variables, home reading time, and phonological processing on akshara recognition (see Table II-5). Model 1 included grade and gender as control variables and all the SES variables and home reading time as independent variables. It indicated that only home reading time was a significant predictor of akshara recognition. In model 2, SES and home reading time were replaced by the phonological processing measures and it showed that syllable awareness, phoneme awareness and phonological memory predicted unique variance in akshara recognition. Finally, model 3 combined the significant predictors from earlier models and showed that after controlling for grade and gender, home reading time, syllable awareness, phoneme awareness, and phonological memory all predicted unique variance in akshara recognition. This model explained about 78% of the variance.

Table II-3

Descriptive Statistics for Child-Level Characteristics

	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		Grade 6	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Akshara recognition	35.60	10.67	56.42	10.26	63.28	7.98	69.02	7.48	74.10	4.50	72.86	4.23
Syllable awareness	28.04	14.66	54.64	8.17	53.88	9.15	59.26	2.89	59.82	1.27	59.96	0.20
Phoneme awareness	7.66	4.21	19.06	7.39	22.60	6.81	29.52	12.30	46.58	16.83	41.66	16.58
RAN – Numbers	56.54	22.21	42.84	10.44	32.35	5.80	37.20	9.94	24.85	5.08	24.30	5.19
RAN – Akshara	43.15	13.78	36.87	10.07	28.54	6.72	33.35	10.32	23.23	4.97	23.19	5.87
RAN – Objects	64.01	14.93	55.95	11.21	47.73	9.21	51.77	14.31	40.54	7.82	37.75	5.84
Phonological memory	24.18	11.73	32.38	2.95	31.86	4.08	34.20	2.04	34.78	1.21	34.66	1.24
Home reading time (min.)	232.49	245.80	336.50	326.60	378.05	262.30	304.00	252.50	181.08	228.90	140.24	180.60
Mother's education	1.70	.79	1.90	.68	1.48	.68	1.50	.61	1.40	.59	1.52	.60
Mother's occupation	.72	1.51	.60	.99	.46	1.16	.54	1.37	.71	1.58	.50	1.15
Father's education	1.58	.88	1.54	.76	1.28	.61	1.34	.72	1.38	.66	1.25	.63
Father's occupation	2.90	.95	2.42	.81	2.58	.64	2.18	.85	2.62	.70	2.45	.78

Note. Education: 0 = Up to Ordinary Level Examination, 1 = Passed Ordinary Level Examination, 2 = Passed Advanced Level Examination, 3 = Above Advanced Level Examination (e.g., degrees, postgraduate diploma); Occupation: 0 = No occupation, 1 = Agriculture, 2 = Industry and Commerce, 3 = Services, 4 = Teachers, 5 = Central Government Officers

Table II-4

Correlations Between the Child-Level Variables

Task	1	2	3	4	5	6	7	8	9	10	11	12
1.Akshara knowledge	1											
2. Syllable awareness	.72**	1										
3. Phoneme awareness	.72**	.64**	1									
4. RAN-numbers	-.66**	-.46**	-.60**	1								
5. RAN-Akshara	-.48**	-.28**	-.46**	.73**	1							
6. RAN-objects	-.54**	-.33**	-.46**	.80**	.65**	1						
7. Phonological memory	.54**	.27**	.32**	-.37**	-.21**	-.28**	1					
8. Home reading time	.20**	.10	.02	-.06	.01	-.08	.12*	1				
9. Mother's education	-.12*	-.12**	-.12	.18**	.16**	.10	.01	.04	1			
10. Mother's occupation	-.04	-.07	.06	.06	.04	.02	.04	.04	.42**	1		
11. Father's education	-.06	-.06	-.08	.12*	.17**	.10	.07	.33**	.49**	.33**	1	
12. Father's occupation	-.15**	-.16**	-.15	.06	.03	.05	-.04	-.06	.07	.05	.22**	1
13. Grade	.73**	.56**	.73**	-.73**	-.50**	-.64**	.33**	-.05	-.17**	-.03	-.14*	-.13*
14. Gender	.06	-.02	-.00	-.00	-.09	-.06	.02	.07	.02	.02	.01	-.07

Note. *$p < 0.05$, **$p < 0.01$

Table II-5

Regression Analysis Result with Akshara Recognition as the Dependent Variable

	Model 1	Model 2	Model 3
Variables	*β*	*β*	*β*
Control			
Grade	.744**	.260**	.367**
Gender	.081*	.048	.055
SES & home reading time			
Mother's education	-.003		
Mother's occupation	-.046		
Father's education	.050		
Father's occupation	-.043		
Home reading time	.231**		.139**
Phonological processing			
Syllable awareness		.362**	.333**
Phoneme awareness		.129**	.145**
RAN-numbers		-.052	
RAN-akshara		-.074	
RAN-objects		.034	
Phonological memory		.273**	.269**
R^2	*.597*	*.775*	*.777*

Note. *p< 0.05, **p< 0.01

Combined Model for Akshara Recognition

In the final generalized linear mixed-effects model shown in Table II-6, we combined the significant item- and child-level predictors in the same model to estimate the probability of item correctness.

Table II-6

Results of the Generalized Linear Mixed-Effects Model with Item and Child Level Predictors and Akshara Recognition as the Dependent Variable

Variables	*b*	*S.E.*	*z*
Intercept	-10.214	0.830	-12.30**
Akshara frequency	1.168	0.025	46.36**
Visual complexity	-0.135	0.029	-4.63**
Type of Akshara	1.529	0.056	27.30**
Grapheme-phoneme sequence matching	0.862	0.090	9.54*
Number of linearity breaks	0.676	0.072	9.36**
Grade	0.294	0.046	6.34**
Gender	0.351	0.116	3.03*
Phonological memory	1.525	0.362	4.21**
Phoneme awareness	-0.032	0.023	-1.37
Syllable awareness	2.063	0.362	5.70**
Home reading time	0.847	0.176	4.80**

Note. *$p < 0.05$, **$p < 0.01$

Table II-6 indicates that all of the included predictors except phoneme awareness were statistically significant predictors of correctly naming an akshara, after removing the effect of grade and gender from the model.

Discussion

The purpose of this study was to examine symbol-level (akshara type, akshara frequency, visual complexity, number of diacritic markers, linearity and grapheme-phoneme sequence matching) and child-level (phonological awareness, RAN, phonological memory, SES and home reading time) predictors of akshara recognition in Sinhala elementary school children. Our first research question was what features of akshara predict the difficulty of mastering them. We found that visual complexity, akshara type, akshara frequency, grapheme-phoneme sequence matching and the number of linearity breaks in the akshara all accounted for unique variance in akshara recognition. These results replicate the connection between visual complexity, akshara frequency and akshara recognition reported by Nag and colleagues (2014) in Kannada, despite substantial differences in how visual complexity and akshara frequency was established in the two studies. In contrast to Nag et al.'s results with number of phoneme markers, the number of diacritic markers in the akshara was not predictive of akshara recognition in this study. Likely explanations for this difference are that our coding scheme was different and our predictive model already included multiple additional variables that captured a lot of the same variance as number of diacritic markers (see Table 1 for correlations between number of diacritic markers and akshara type, grapheme-phoneme sequence matching, and linearity) but that were not examined in the Nag et al.'s study.

In line with previous findings (Nag et al., 2014), akshara type was a unique predictor of akshara recognition. Multiple previous studies have indicated that words including akshara with

conjunct consonants (CCV akshara) are difficult for children to read (e.g., Nag, 2014; Wijaythilake & Parrila, 2014) and that CCV akshara are slow to be mastered (Nag, 2007; Nag et al., 2010; Tiwari et al., 2011). One possible explanation for this is that akshara with consonant clusters are less frequent, but our results do not support this interpretation: the correlation between akshara type and frequency was moderate and akshara type was a highly significant predictor even after frequency was controlled. We suspect that consonant clusters were difficult for our participants at least partly for instructional reasons: CCV akshara was taught as wholes only in Grade 4, and the akshara formation and ligaturing rules needed to break complex CCV akshara into their constituent phoneme markers are taught only in Grade 5. While children encounter a number of CCV akshara before Grade 4, in absence of understanding akshara formation and ligaturing rules that would allow reliable graphic parsing of the consonant clusters, CCV akshara are both visually and phonologically difficult to learn as wholes.

To our knowledge, this is the first study examining if orthography-phonology mismatches and nonlinearity in placements of diacritic markers affect akshara recognition and, as hypothesized, both were independent, albeit not strong, predictors of how easily an akshara was recognized. Earlier, Kandhadai and Sproat (2010) found that grapheme-phoneme sequence mismatches in Hindi reduced the accuracy of oral phoneme segmentation in literate adults. Though their study was not about akshara recognition, their results indicate that when orthographic symbols are presented in different order than the phonemes they capture, there is an additional processing cost for establishing the relationship between the two. Similarly, when several diacritic markers are offline, their proper phonological sequencing may be compromised and, at the minimum, there is an increased processing load for children leading to more errors. These results are broadly consistent with the findings from other visually complex writing

systems (Arabic and Hebrew: Abdelhadi, Ibrahim, & Eviatar, 2011; Chinese: McBride-Chang, Zhou, et al., 2011) demonstrating that when the surface-level orthographic information misguides children in understanding the underlying phonological information, the cognitive demands for breaking the code are higher. Given that most other akshara orthographies include high numbers of orthography-phonology mismatches and nonlinearly placed diacritic markers, the role of these factors in reading acquisition clearly warrants more research.

Our second research question was what child-level characteristics predict children's akshara recognition. Phoneme awareness, syllable awareness, phonological memory, and home reading time independently predicted akshara recognition. Our finding that phoneme and syllable awareness are predictors of akshara learning is consistent with evidence from other alphasyllabaries (Nag, 2007; Nag, et al., 2014) showing a reciprocal relationship between akshara mastery and the developmental patterns of phonological sensitivity. In the beginning of language instruction, vowels and consonants with an inherent vowel are introduced first and children do not have or do not need to have a clear understanding about the visuo-spatial distinction for the consonant-vowel combination. They process these akshara simply as an orthographic syllable. When the CV and CCV akshara are introduced with the combinatory principles, only then children need to pay particular attention to the phonological constituents of an orthographic syllable resulting in increased sensitivity to the phonemic information in the akshara. It is plausible that this increased sensitivity to the sub-syllabic information boost children's awareness of akshara and their ligaturing rules. It is also plausible that increased awareness of akshara as a combination of phonemic markers with a clear understanding about the ligaturing rules increases phoneme awareness as first suggested by Nag (2007). Future studies need to explore the direction of the relationship further.

Our results clearly show that learning a large akshara set is a prolonged process that continues throughout the elementary school and beyond. One possible implication of this is that for the models of reading acquisition to provide an explanation of how word recognition automaticity develops in akshara orthographies, they will need to include an additional developmental process of developing automaticity with a large set of orthographic symbols that represent the spoken language at multiple levels of mappings. Such a developmental process undoubtedly requires much more substantial cognitive resources than symbol-level learning in alphabetic orthographies, and may at least in part explain why there frequently seems to be a gap between word level reading skills and reading comprehension skills in studies on akshara orthographies (e.g., ASER, 2014; Nag & Snowling, 2011a, 2011b).

In terms of practice, we clearly need educational experiments on teaching the phonetic components and diacritics sooner. There is preliminary evidence from Bengali indicating that moving this instruction to earlier grades benefits reading and writing acquisition (Nag, 2014; Sircar & Nag, 2013). As we expected in this sample of children, akshara recognition was highly associated with akshara type, visual complexity, and nonlinear features in akshara. The reading and writing instruction our participants received follows a fixed sequence, introducing different types of akshara at different grade levels, and the instruction on how the more complex akshara are formed out of different components is available only at the end of the primary school. At this point, children already have learned hundreds of akshara as undifferentiated wholes, hardly the optimal learning condition for developing transferable skills. We suspect that early instruction on analyzing akshara into their constituent phonological and orthographic components would lead to quicker learning and likely reduce the role of visual confusability, nonlinearity, syllable awareness and phonological memory as predictors of akshara recognition. This is clearly a topic

that requires further study given the rising literacy demands across all akshara orthographies. More specifically to our study, we need well-controlled educational experiments in Sinhala to guide educational policy and literacy instruction.

In conclusion, our study indicates that the learning demands akshara orthographies impose on the learners are both similar and different from those learners of alphabetic or morphographic orthographies face (see also Nag, 2017). While learning to read in Sinhala (as well as other akshara orthographies) builds on many of the same cognitive–linguistic processes needed to learn an alphabetic orthography, the learning process itself is likely very different due to the extensive and complex symbol set. Learning the extensive symbol set of the Sinhala orthography is a demanding process by itself and segmenting visually and phonologically complex orthographic symbols into their separate phonemic parts is a major learning task in akshara orthographies. This is currently a very poorly understood process that no theory of reading development provides an account for.

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STUDY 2: EFFECTS OF PHONEME-LEVEL INSTRUCTION ON THE WORD READING SKILLS IN SINHALA

A number of longitudinal and intervention studies have shown that phonological skills provide a critical foundation for learning to read in alphabetic orthographies and that the relationship between phonological skills and reading is bidirectional (e.g., Caravolas, Lervåg, Defior, Seidlova Malkova, & Hulme, 2013; Hulme, Bowyer-Crane, Carroll, Duff, & Snowling, 2012; Hulme, Caravolas, Malkova, & Brigstocke, 2005; Perfetti, Beck, Bell, & Hughes, 1987; Wagner, Torgesen, & Rashotte, 1994). More specifically, as children learn letters and graphemes, they learn to identify the corresponding phonemes that then leads to enhanced phonemic awareness (e.g., Wagner et al., 1994), while the early phonological awareness, including phonemic awareness, makes the task of learning letter names and sounds easier (e.g., Burgess & Lonigan, 1998; Hulme, Hatcher, Nation, Brown, Adams & Stuart, 2002; Lerner & Lonigan, 2016). Given that graphemes in alphabetic orthographies represent phonemes and early reading instruction frequently focuses on this relationship, the link between learning letters (and graphemes) and improved phoneme awareness is expected. However, the relationship between phonology and orthography is different in Indic alphasyllabaries where the basic orthographic units, akshara, map to phonology both at the level of syllables and at the level of phonemes (e.g., Bright, 1996; Daniels, 1996; Nag, 2017). Further, the early reading instruction commonly emphasizes the syllable level mapping by teaching akshara as whole units, whereas the instruction on diacritics that mark individual phonemes only follows at later grades (Nag, 2007, 2011; Nag, Treiman & Snowling, 2010). In the current paper, we present a two-cohort one-year longitudinal study examining how exposure to complex akshara and instruction on diacritics

affects phoneme awareness and its relationship with akshara knowledge and word reading accuracy in children learning to read Sinhala.

Sinhala belongs to the Indo-Aryan branch of Indo-European languages and it is written with a unique akshara script belonging to the Brahmic scripts. Sinhala phonology includes about 40 consonant segments and 18 vowel sounds, of which 27 consonants and 14 vowels (seven vowel qualities each with two lengths) are common (Gair & Paolillo, 1997). The basic orthographic unit, akshara, can represent a vowel in its full akshara-initial form (/V/), an alphabetic consonant (/C/), a consonant or consonant cluster with the inherent vowel /a/ (/Ca/, /CCa/, /CCCa/), and a consonant or consonant cluster with a vowel other than the inherent vowel (/CV/, /CCV/). Both vowels and consonants have their primary forms while all the vowels and most consonants have also secondary post-initial forms, or diacritics. When a consonant with a vowel other than the inherent /a/ is written (/CV/, /CCV/, /CCCV/), the /a/ is dropped from the pronunciation of the syllable and the secondary sign (diacritic) of the new vowel is attached to the consonant core. If the akshara includes a consonant cluster, the first consonant can also be ligatured to the second, and it can include a "killer" diacritic, called hal lakuna, indicating that the inherent vowel is not pronounced for the first consonant. Therefore, the surface organization of an akshara is typically a symbol block with a core consonant and one of more phonemic markers attached to it (Nag, 2017). The vowel diacritic markers may be attached to the left, right, top or bottom of the consonant core, creating nonlinearities between the orthographic and spoken syllable that may complicate the extraction of phonetic information from the orthographic syllable.

The initial reading instruction presents akshara as whole graphemes pronounced as syllables. In Sri Lankan schools, reading and writing instruction follows a fixed sequence and

children are introduced to increasingly more complex akshara as wholes for the first four years. Grade 1 students are taught akshara in the following order: CV akshara with an inherent vowel, primary vowels (V), CV akshara with a vowel other than the inherent vowel and the primary consonants (C). Grade 1 Sinhala Language Arts books cover all of these four akshara categories. Students are expected to master consonants with eight vowel diacritics under the CV akshara category– diacritics for ා /a:/, ි /i/, ී /i:/, ු /u/, ූ /u:/, ෙ/æ/, ේ /æ:/, ෛ /e/, two forms of hal lakuna and 2 consonant diacritics (half of ය /ya/- ්‍ය and ර /ra/ ්‍ර) by the end of Grade 1; however, they do not receive instruction in how to identify the specific diacritics inside a complex akshara. In Grades 2 and 3, the major focus of the reading and writing instruction is to continue practicing the akshara categories learned in Grade 1 and correctly read the śuddha akshara set[5]. Teachers use akshara charts to introduce new akshara and excessive copywriting and rote memorization is the common practice in the classroom in order for students to memorize the shape and the name (which is also the sound) of akshara. In gGade 3, students' attention is also drawn to the reading and writing differences between ස /sa/, ෂ /Ša/ and ශ /Śa/. ෂ and ශ sound the same in modern usage but the meaning of a word can change depending on the akshara used. In Grade 4, consonant clusters and the miśra akshara set are introduced formally for the first time and the new akshara are still taught as whole units (syllables). Particularly, students' knowledge of akshara is sufficient to read Literary Sinhala until the introduction of miśra akshara although the contrasts they capture are no longer present in Spoken Sinhala. While the teachers cover the full register of miśra akshara in reading instruction and student are exposed to many CCV akshara,

[5] The śuddha akshara set is a subset of the miśra akshara set that contains all the akshara necessary to write classical Literary Sinhala. The current Spoken Sinhala can be represented fully by the śuddha akshara, but Literary Sinhala retains reference to special Sanskrit and Pali sounds captured by the miśra akshara. This is mostly needed for representing the Middle Indic phonemes, such as aspirates, that have disappeared from Spoken Sinhala over time (Gair & Paolillo, 1997; Paolillo, 1997).

only a small proportion of CCV akshara is explicitly taught in the classroom (similar to Bengali, Nag & Sircar, 2008, and Gujarati, Patel, 2004). In Grade 5, students are for the first time taught how to decompose CV and CCV akshara into their phonemic components and their ligaturing rules, thus opening the door to a more combinatorial understanding of Sinhala orthography. Students are first taught how to deconstruct single CV akshara into their phonemic components and next, akshara by akshara deconstruction for strings of akshara in words. From Grade 6 onwards, the practice of using clusters and ligaturing rules continues. This fixed sequence of instruction is naturally perturbed by the real word reading materials and vocabulary children are exposed to. Children's books and story books have a mixture of all akshara types and children's vocabulary contains a sizable number of words with complex akshara. For example, the CCV akshara /kka/ and /mma/ are common in early Sinhala text books in multi-akshara words like /akka/ (sister) and /amma/ (mother) and children typically learn these akshara alongside the vowel akshara and consonant akshara with inherent vowels due to frequent exposure.

Given that in most akshara orthographies children have to memorize hundreds of akshara (over 400 in Sinhala by Grade 6) while learning to decompose (and recompose) them, it is not surprising that akshara knowledge has emerged as the strongest predictor of reading accuracy and the most common area of deficit in poor readers (e.g., Nag & Snowling, 2012). Further, syllable awareness has consistently been associated with akshara knowledge and with reading performance across the primary school years (Nag-Arulmani, 2003; Nag, 2007; Nag & Snowling, 2011; Nakamura, Joshi & Ji, in press; Nakamura, Koda & Joshi, 2014; Prakash, Rekha, Nigam & Karanth, 1993), whereas phoneme awareness may be slow to emerge (Nag, 2007). Once it does emerge, it is concurrently associated with akshara knowledge and reading skills (Nag, 2007; Nag & Snowling, 2012), although it may not predict unique variance in

akshara knowledge (Nag, 2007) or word reading accuracy (Nakamura et al., in press, 2014) after syllable awareness is controlled. Nag and Snowling (2012) suggested that the nature of the writing system promotes syllable level representations making phoneme level processing slower to emerge. When children's knowledge of CV and CCV/CCCV types of akshara increases, their attention is drawn to diacritics and a stronger correlation (around .5 in their study) between reading and phonemic skills is apparent. Nag (2007) provided some support for this argument by showing that knowledge of complex akshara in time 1 predicted phoneme awareness a year later, but the opposite was not true.

It is, however, possible that the correlation between phoneme awareness and word reading and akshara knowledge results from direct instruction in diacritics rather than exposure to complex akshara alone. First, several studies have suggested that phoneme awareness improves as a consequence of instruction in English (e.g., Mishra & Stainthorp, 2007; Padakannaya, 2000; Prakash et al., 1993). In Sri Lankan schools, English instruction starts at Grade 2 and our cross-sectional data (Authors, in preparation) indicates a Grade 2 boost in phonemic awareness (from a mean of 7 to a mean of 19; see task description below) that does not seem to continue to Grade 3 (mean = 22). In the current study, we focus on learning the diacritics markers and phonemes in the native language. By the end of Grade 4, children learning Sinhala have been introduced to complex CCV akshara with multiple diacritic markers, but the explicit instruction on those markers and the phonemes they represent takes place only in Grade 5. Below we will first examine how phoneme awareness develops in Grade 4 to 6. Second, we examine cross-lagged associations between phoneme awareness and word reading and between phoneme awareness and akshara knowledge in Grade 4 when complex akshara are introduced and in Grade 5 when explicit phoneme-level instruction is introduced. On the basis of previous studies,

we expected slow development of phoneme awareness. However, if greater exposure to complex akshara is enough to boost phoneme awareness, then phoneme awareness should be greatly enhanced in Grade 4. In turn, if explicit instruction in diacritics is required to improve phoneme awareness, then the boost should be evident only in Grade 5. Further, we expected phoneme awareness to be only moderately correlated with akshara knowledge and word reading up to Grade 4, but more so in Grade 5 after the instruction on phoneme markers.

To our knowledge, this is the first study that examines the effect of phoneme level instruction on the relationships between phoneme awareness, akshara knowledge, and word reading in an Indic orthography. Further, we were not able to locate studies that examined whether the relationship between reading and phoneme awareness is bidirectional in alphasyllabaries. Understanding the relationship between akshara instruction and phoneme awareness has potentially significant practical importance in guiding reading interventions and general reading instruction in the school system as no such studies exist so far.

Method

Participants

One-hundred and fifty Sinhala-speaking children from two well-functioning government schools in Kandy and Kegalle districts in Sri Lanka participated in this study. These students were taken from the same student pool as in Study 1. Fifty students with no documented sensory or behavioural disorders from each of the Grades 3 to 5 were selected and assessed towards the end of the school year and again a year later. One or two children in each grade withdrew from the study. Students' first language and the medium of instruction was Sinhala. Both schools were suburban schools serving families from middle to upper-middle socioeconomic backgrounds. All teachers had tertiary education and were Government certified. Students received English and

Tamil instruction for several periods during the school week from Grade 2 onwards in line with the language education policy in Sri Lanka. English instruction in Grade 2 is limited to oral English practice. English reading and writing instruction starts in Grade 3.

Materials

Phoneme Awareness

Phoneme deletion task required the participant to repeat the words (30) and nonwords (30) after removing the designated sound from the beginning (10), middle (10), or end (10) of the word or nonword. Cronbach's alpha reliability ranged from .94 to .98. Total score was the number of correctly pronounced words/nonwords after removing the designated sound.

Word Reading Accuracy

The participants were asked to read aloud 110 words taken from Grade 1 to 6 language arts books and arranged in terms of increasing difficulty. The syllable length of words increased from 2 syllables to 9 syllables and the test included words with and without consonant clusters. A participant's reading accuracy score was the total number of correctly read words. Cronbach's alpha reliability for the current sample ranged from .85 to .97.

Akshara Recognition

Participants were asked to name aloud (the name and the sound of akshara are the same) 80 akshara taken from Grade 1 to 6 language arts books. Ten most and least frequently appeared akshara from four different akshara categories (Ca, CV, V and CCV) were included in the test. The akshara were presented on paper and the score was the total number of correctly named akshara. Cronbach's alpha reliability ranged from .82 to .96 across the grades, the lower number

reflecting a small ceiling effect for the higher grades (who had been exposed to all the akshara presented).

Procedure

All participants completed the assessments during the last term of the school year between September and December. Each child was tested individually in a quiet room in their school by a trained, native Sinhala-speaking graduate student who received extensive training on test administration. Testing was completed within 45 minutes in one session. The tests were administered in fixed order (word reading accuracy, phoneme awareness, akshara knowledge).

Results

Statistical Analyses

To examine the cross-lagged associations between phoneme awareness, akshara knowledge, and word reading accuracy, we performed path analysis using Mplus (Version 7; Muthén & Muthén, 1998–2015). Two separate models were constructed for each combination among the measures for the Grade 4 group (assessed at the end of Grade 3 and again at the end of Grade 4) and the Grade 5 group (assessed at the end of Grade 4 and again at the end of Grade 5; see Figures III-1 and III-2). Grade 6 group was not included in these analyses due to ceiling effects in akshara knowledge and word reading accuracy. Because the models were saturated, no fit indices could be estimated. The parameters of the models were estimated using full-information maximum likelihood estimation (FIML; Muthén & Muthén, 1998–2015), which enables all the observations in the data set to be used in estimating the parameters of the models. To avoid statistical biases resulting from deviations from normality in some measures (see below), we used maximum likelihood estimation with robust standard errors (MLR; Muthén &

Muthén, 1998–2015).

Next, in order to examine whether the cross-lagged associations among measures differ between the groups, we performed multigroup analyses. A set of models was tested by fixing each of the cross-lagged path coefficients to be equal across the groups, one at a time, and then comparing the constrained model with the freely estimated model. If the fit of the model did not change significantly after the restrictions, the constrained associations were assumed equal between the groups (Muthén & Muthén, 1998–2015).

Descriptive Analysis

Descriptive statistics for the two groups are shown in Table III-1. Prior to analyses, we examined the data for normality and outliers. In the Grade 4 group, word reading accuracy in Time 2 was negatively skewed. In the Grade 5 group, phoneme awareness in Time 2 and word reading accuracy in Time 1 and Time 2 were negatively skewed. For these measures, reflection plus log transformation was used to improve the distributions (Tabachnick & Fidell, 2012). Because the scores were reflected, we multiplied the reflected scores by -1 to correct for direction. One or two univariate outliers (more than 3 *SD* above/below the mean of each group) were moved to the tail of the distribution to avoid overemphasizing their impact on the results: one outlier in Time 2 phoneme awareness in the Grade 4 group and in Time 1 akshara knowledge and Time 2 word reading accuracy in the Grade 5 group; and two outliers in Time 1 phoneme awareness in the Grade 4 group.

Cross-sectional data shows a slow but steady increase in all the measures from one grade to the next with the exception of phoneme awareness. Phoneme awareness shows slow growth from Grade 3 to Grade 4, but then a large increase from Grade 4 (29.52) to Grade 5 (46.56).

Table III-1

Descriptive Statistics of the Measures in Each Sample

	Grade 4			Grade 5		
Measures	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Time 1						
Phoneme awareness	22.60	6.81	14–49	29.52	12.30	15–58
Akshara knowledge	63.44	7.51	45–77	69.08	7.29	47–77
Word reading accuracy	76.90	15.62	44–104	91.70	15.72	52–110
Time 2						
Phoneme awareness	26.90	9.03	12–57	46.56	10.92	20–60
Akshara knowledge	67.19	6.83	49–77	71.10	6.57	52–80
Word reading accuracy	92.92	13.71	58–108	100.82	9.82	71–110

Note. For the Grade 4 sample, Time 1 measures were administered at the end of Grade 3 and Time 2 measures at the end of Grade 4. For the Grade 5 sample, the respective times were the end of Grade 4 and the end of Grade 5.

We also conducted a mixed model repeated-measures ANOVA with bootstrapping technique in order to estimate effect sizes for growth with confidence intervals. The results showed slow (but significant) growth for most participants in Grade 4, and a significantly faster growth in Grade 5 (see Figure III-1). Growth in Grade 6 was not reliably different from zero.

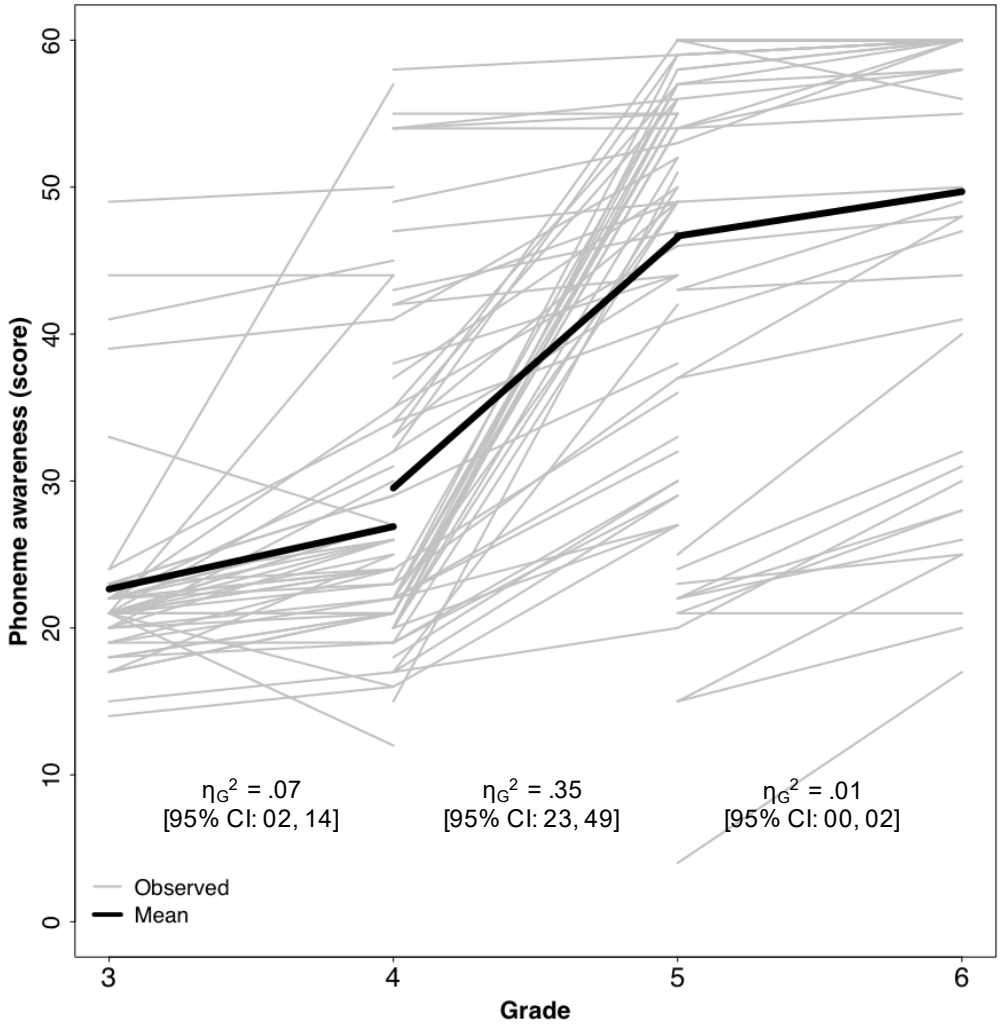

Figure III-1. Growth in phoneme awareness in each subsample

Correlations among the Variables

The zero-order correlations among the measures for each group are shown in Table III-2. Correlations at the same time point ranged from .20 to .62 in the Grade 4 group, and from .02 to .59 in the Grade 5 group. Phoneme awareness did not correlate significantly with akshara knowledge (r = .26) and correlated only moderately with word reading accuracy (r = .35) at the end of Grade 3; however, at the end of Grade 4 phoneme awareness was not correlated

significantly with akshara knowledge or word reading in either group (Time 1 above the diagonal, Time 2 below the diagonal). When the same children reached Grade 5 and received instruction in diacritics, phoneme awareness correlated significantly with akshara knowledge (r = .48) and word reading accuracy (r = .55; Time 2 above the diagonal). Correlations between akshara knowledge and word reading were strong at all points (ranging from .57 to .72).

Table III-2

Correlations among the Measures in Each Sample

		1.	2.	3.	4.	5.	6.
1.	Phoneme awareness_T1		.05	.02	.33*	.10	-.09
2.	Akshara knowledge_T1	.26		.59**	.42**	.93**	.65**
3.	Word reading accuracy_T1	.35*	.62**		.51**	.58**	.72**
4.	Phoneme awareness_T2	.70**	.30	.33*		.48**	.55**
5.	Akshara knowledge_T2	.24	.85**	.62**	.20		.72**
6.	Word reading accuracy_T2	.24	.57**	.67**	.24	.57**	

Note. Correlations below the diagonal are from the Grade 4 group, whereas correlations above the diagonal are from the Grade 5 group. T1 = Time 1; T2 = Time 2.
*p < .05. **p < .01.

Cross-Lagged Relationships

The cross-lagged model for phoneme awareness and word reading accuracy (Figure III-2) showed that (a) Time 1 word reading accuracy predicted Time 2 phoneme awareness in the Grade 5 group (β = .51) but not in the Grade 4 group (β = .10), and (b) Time 1 phoneme awareness did not predict Time 2 word reading accuracy in either group.

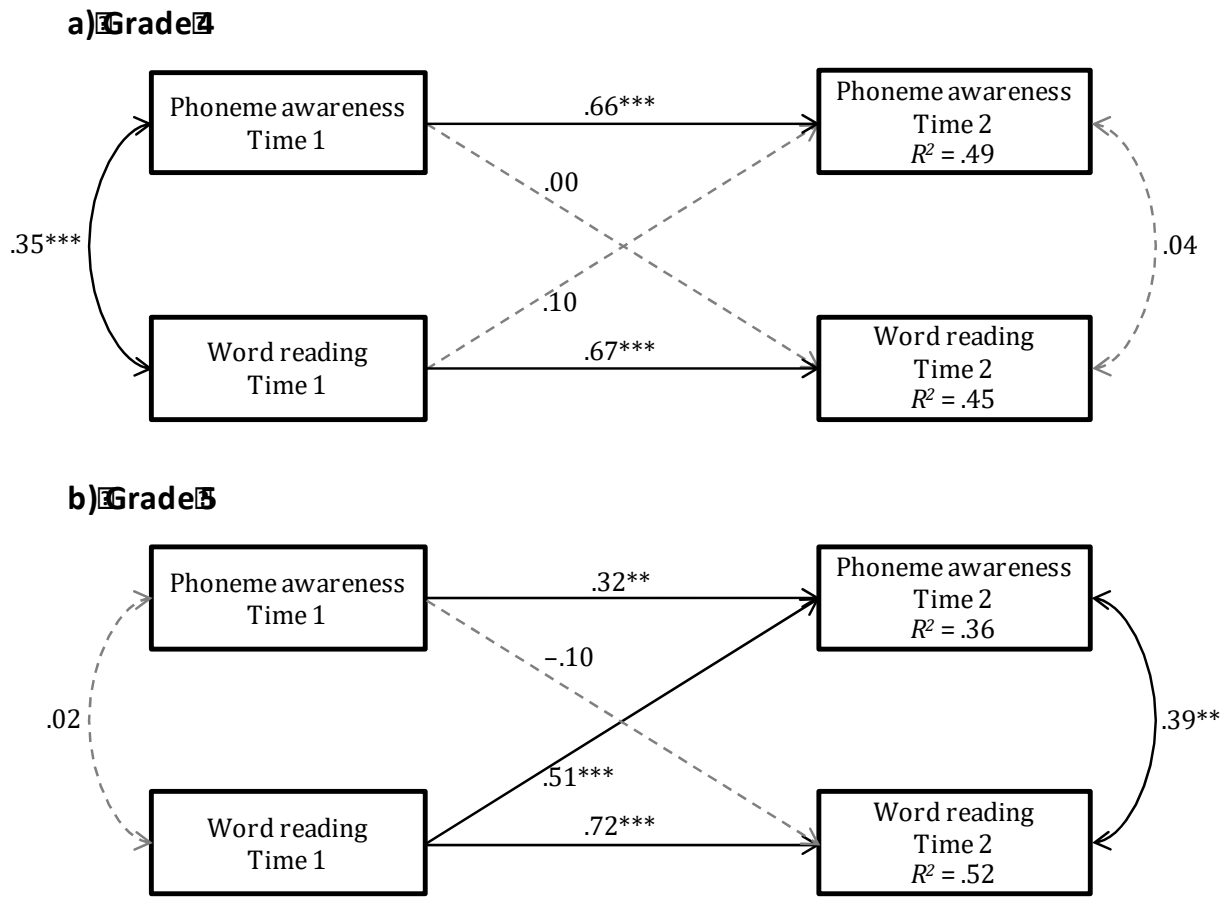

Figure III-2. Cross-lagged associations between phoneme awareness and word reading accuracy in the Grade 4 group (a) and the Grade 5 group (b). Standardized coefficients are shown. Solid lines represent significant coefficients and dashed lines represent nonsignificant coefficients. *$p < .05$. **$p < .01$. ***$p < .001$.

The results of a series of multigroup analyses showed that one parameter in the models was statistically significantly different between the two groups: The path coefficient from Time 1 word reading accuracy to Time 2 phoneme awareness for the Grade 5 group was larger than that for the Grade 4 group ($\Delta\chi^2 = 10.26$, $\Delta df = 1$, $p < .001$).

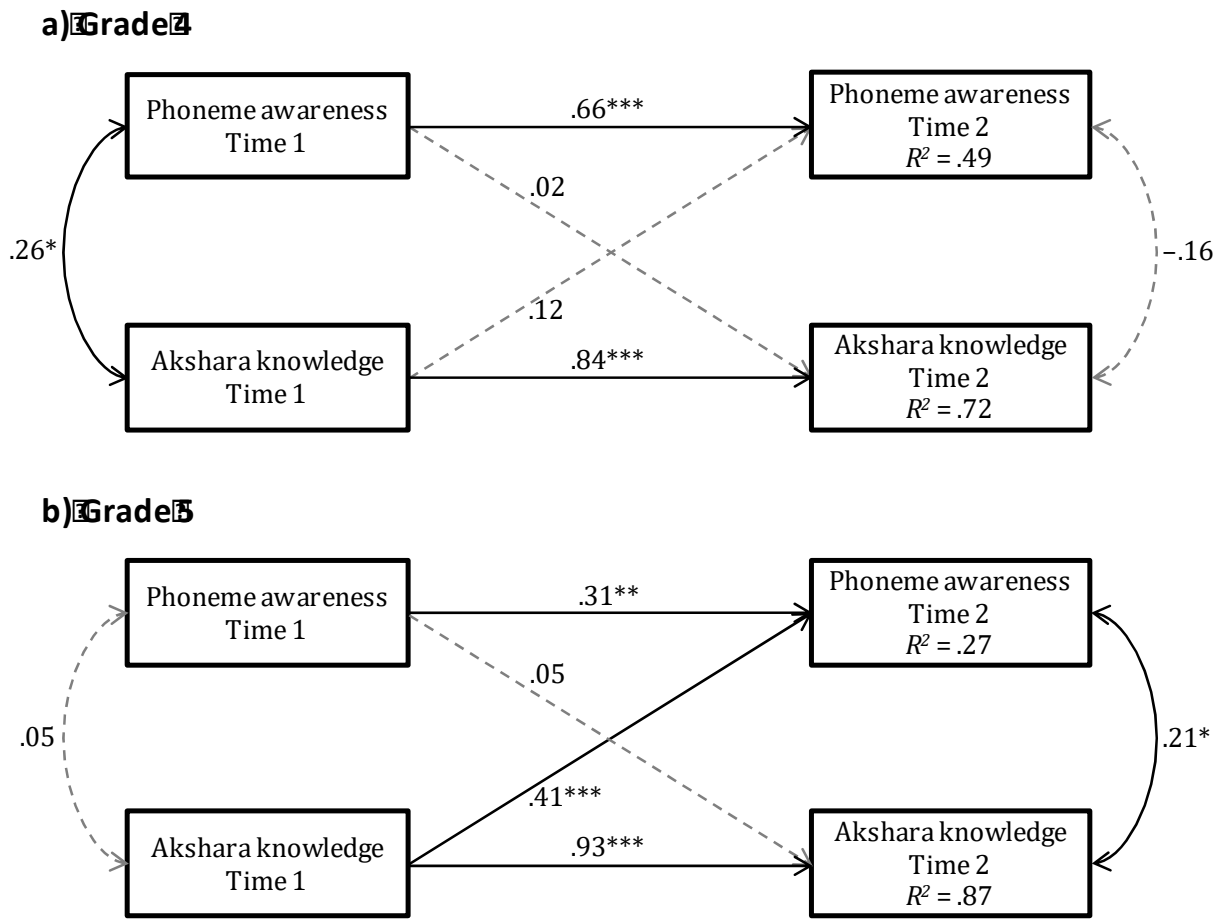

Figure III-3. Cross-lagged associations between phoneme awareness and akshara knowledge in the Grade 4 group (a) and the Grade 5 group (b). Standardized coefficients are shown. Solid lines represent significant coefficients and dashed lines represent nonsignificant coefficients. *$p < .05$. **$p < .01$. ***$p < .001$.

The model for akshara knowledge and phoneme awareness (Figure III-3) shows an identical pattern to the word reading and phoneme awareness model with no significant relationships from Grade 3 to 4 and akshara knowledge predicting phoneme awareness from Grade 4 to 5. However, multigroup analysis showed that the path coefficients from Time 1 akshara knowledge to Time 2 phoneme awareness were not statistically different between the two groups ($\Delta\chi^2 = 2.42$, $\Delta df = 1$, $p = .12$).

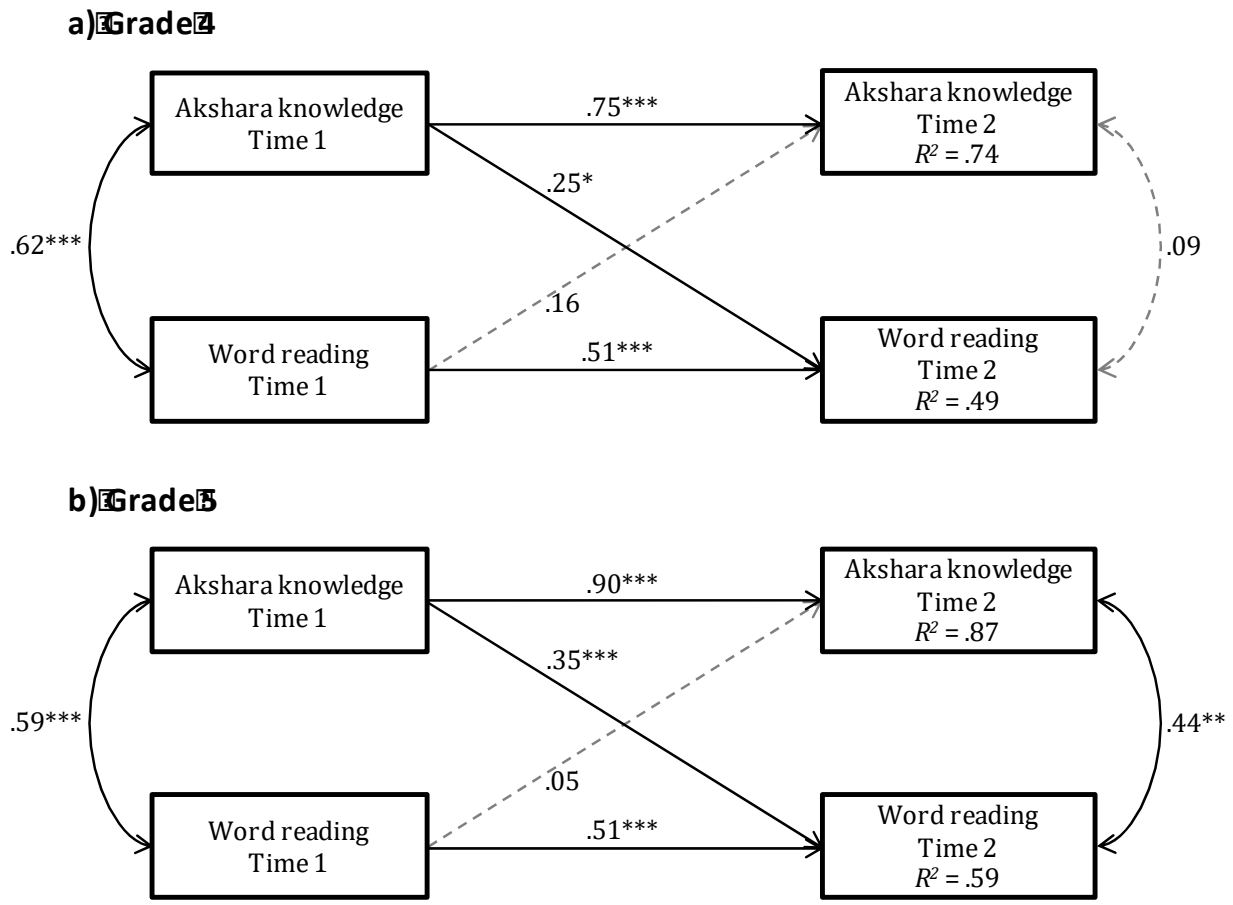

Figure III-4. Cross-lagged associations between akshara knowledge and word reading in the Grade 4 group (a) and the Grade 5 group (b). Standardized coefficients are shown. Solid lines represent significant coefficients and dashed lines represent nonsignificant coefficients. *p < .05. **p < .01. ***p < .001.

Finally, Figure III-4 shows the cross-lagged model for akshara knowledge and word reading. As expected on the basis of previous studies, akshara knowledge was a significant predictor of word reading growth on both grades.

Exposure to Complex Akshara

To further examine the effects of introduction of complex akshara on the association between akshara knowledge and phoneme awareness, we repeated the multigroup cross-lagged analysis with the akshara knowledge score for the 20 CCV akshara alone. A mixed model

repeated-measures ANOVA confirmed a significantly faster growth in CCV akshara knowledge in Grade 4 (see Figure III-5).

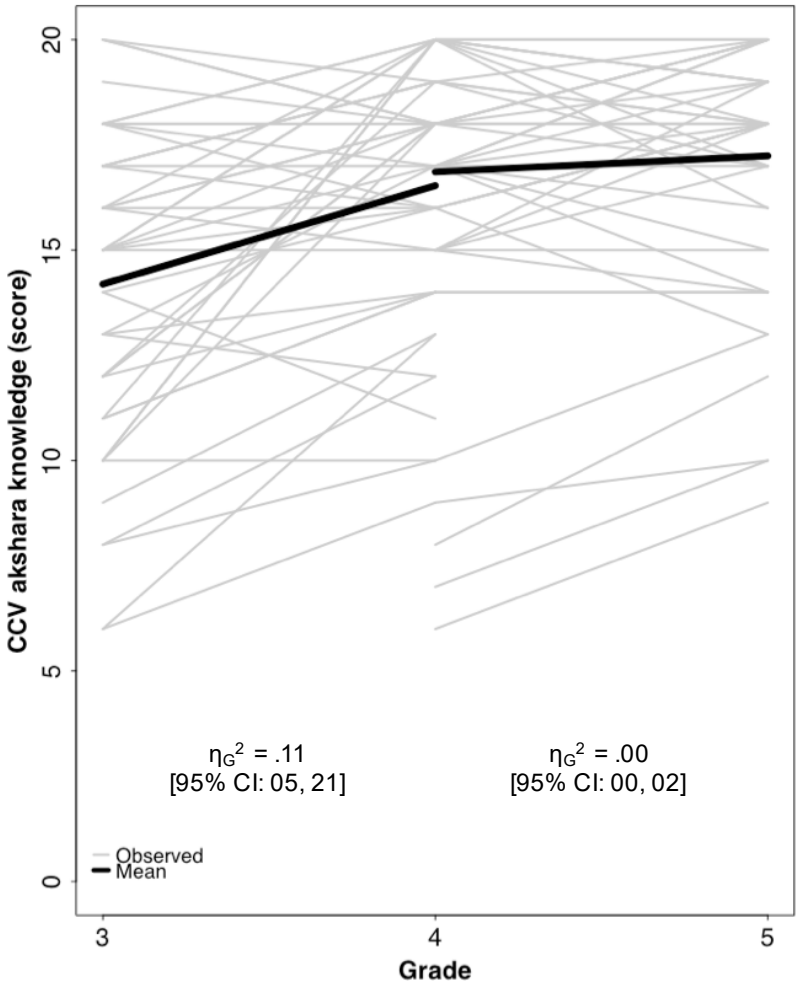

Figure III-5. Growth in CCV akshara knowledge in Grades 4 and 5.

The cross-lagged model for phoneme awareness and CCV akshara knowledge (Figure III-6) shows the same pattern as the model with the total akshara knowledge score, except for the effect of Time 1 CCV akshara knowledge to Time 2 phoneme awareness in the Grade 4 group is now statistically significant. However, multigroup analysis showed that the effect of Time 1

CCV akshara knowledge to Time 2 phoneme awareness for the Grade 5 group was larger than that for the Grade 4 group ($\Delta\chi^2 = 5.10$, $\Delta df = 1$, $p < .05$).

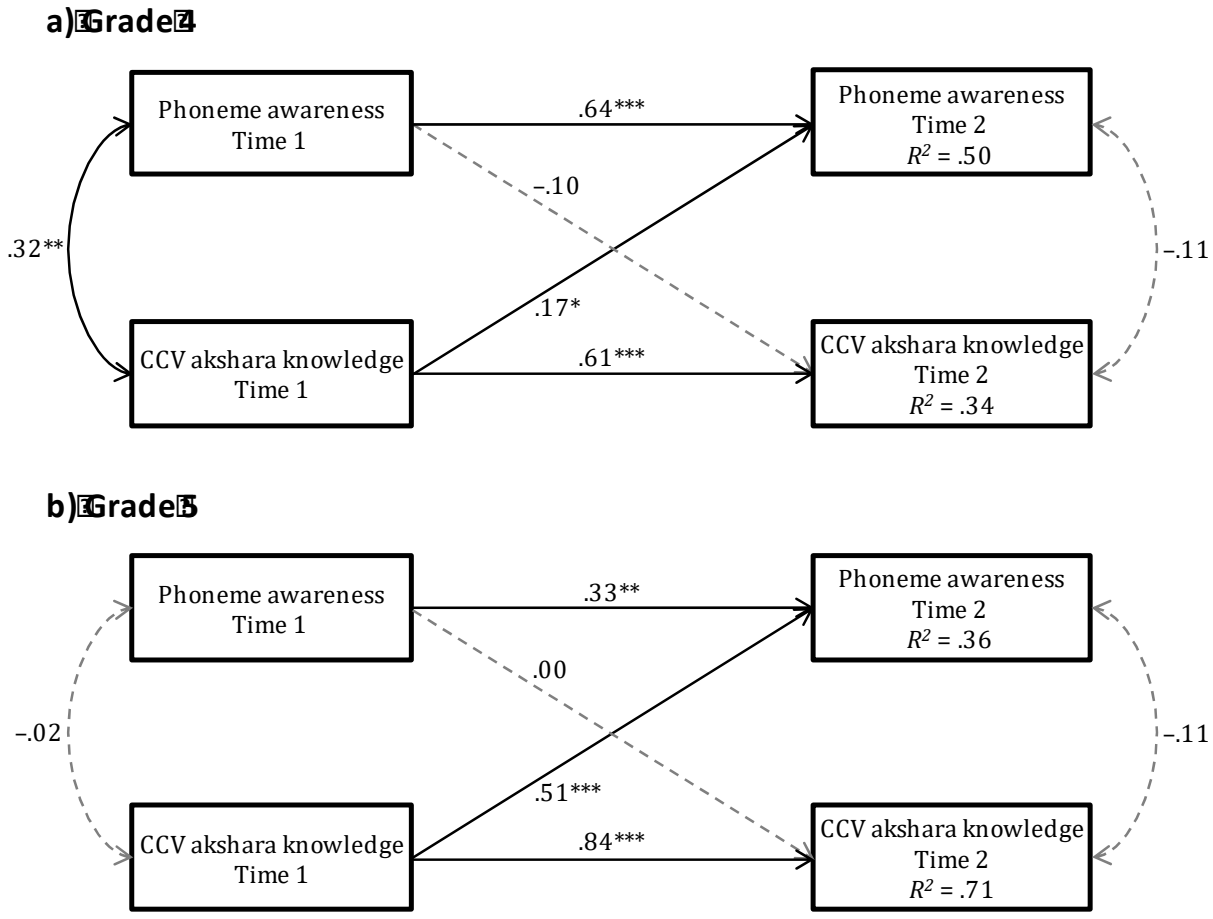

Figure III-6. Cross-lagged associations between phoneme awareness and CCV akshara knowledge in the Grade 4 group (a) and the Grade 5 group (b) Standardized coefficients are shown. Solid lines represent significant coefficients and dashed lines represent nonsignificant coefficients.
*$p < .05$. **$p < .01$. ***$p < .001$.

Discussion

The purpose of this study was to examine the effects of introduction of complex akshara and instruction on the diacritic markers representing phonemes on the development of phoneme awareness and its association with akshara knowledge and word reading accuracy. First, our findings are in line with existing studies in alphasyllabaries in that phoneme awareness is slow to emerge (e.g., Nag, 2007; Nag & Snowling, 2011, 2012; Nakamura et al., in press; Prakash et al., 1993;). In our study, phoneme awareness showed strong growth only in Grade 5. This is the same time when children receive instruction in the diacritics marking phonemes in Sinhala. Second, we expected phoneme awareness to correlate only moderately with akshara knowledge and word reading accuracy in Grades 3 and 4, but more strongly in Grade 5 after the instruction in diacritics. In essence, this pattern was observed (see Table 2) and replicated for Grade 4 in both cohorts. Finally, we expected that akshara knowledge (either with or without explicit instruction in diacritics) would predict phoneme awareness that would then predict growth in word reading. This pattern was not observed in full as both akshara knowledge and word reading predicted phoneme awareness rather than vice versa, and this was only true in Grade 5.

In Sri Lanka, akshara are taught as whole units (syllables) from Grade 1 to Grade 4 and students are expected to memorize the akshara set. Though they are not explicitly taught about the phonemic constituents in akshara, some development of phoneme awareness can be expected as a result of implicit learning of the phoneme-level regularities in the script combined with instruction in English (albeit minimal). With the formal introduction of consonant clusters in Grade 4, students are asked to pay close attention to the internal details of akshara and be aware of secondary vowel and consonant markers and the ways of stacking them onto the core consonant following ligaturing rules. In line with Nag (2007), our results suggest that this

increased exposure to more complex akshara with multiple diacritics in Grade 4 helped phoneme awareness to develop. To further support understanding of diacritics, students in Grade 5 are taught how to decompose an akshara into its different phonemic constituents and how to build an akshara by adding separate phonemic constituents together. Not surprisingly, we see a large increase in phoneme awareness in Grade 5. This instruction was also required for the strong relationship between phoneme awareness and akshara knowledge or word reading accuracy to emerge. Perhaps somewhat surprisingly, this relationship was unidirectional from akshara knowledge and word reading to phoneme awareness. Future studies will need to establish whether the improved phoneme awareness at some point predicts growth in word reading, but our results suggest that for Sinhala learners, phoneme awareness is a by-product of instruction rather than a driver of reading development. We should note that these results are in line with the only other study by Nag (2007) that examined longitudinal relationships between word reading and phoneme awareness, and extend those findings to akshara knowledge. More longitudinal studies in akshara orthographies are clearly needed to establish if our results replicate in other orthographies.

Finally, and in line with previous studies, our results show that akshara knowledge predicts growth in word reading even at the later stages of word reading development. This is not surprising given that akshara is the basic decoding unit early in reading, but we could expect this relationship to diminish when students learn to decompose akshara into their phonemic constituents. Again, future longitudinal studies are required to establish whether this relationship continues beyond elementary school years. Further, our study adds fresh insights into the framework for akshara knowledge proposed by Nag (2011, 2017). Our results suggest that (1) both global and analytical akshara knowledge promote word reading, (2) some forms of

analytical akshara knowledge require explicit instruction in akshara decomposition, and (3) only analytical akshara knowledge promotes phoneme awareness.

In conclusion, our study shows that the development of phoneme awareness in Sinhala is directly related to phoneme-level instruction and there was a strong causal relationship between phoneme awareness and word reading when the students' attention was drawn from the whole akshara to the internal phonemic details of akshara. This change was not persistent when the phoneme-level instruction was replaced again by the whole akshara teaching in Grade 6 (see Figure 1). Word reading accuracy predicted phoneme awareness once students received phoneme-level reading instruction. Taken together, these findings suggest that phoneme awareness is particularly sensitive to the methods of reading instruction and raise the question whether students learning to read Sinhala would benefit from receiving direct phoneme–level instruction in their language sooner. To speculate, we would predict that earlier attention to phonemic markers would boost not only phoneme awareness but also more analytic approach to akshara learning, which would then improve word recognition. Earlier consolidation of word recognition skills might then further impact reading comprehension, a frequently noted area of concern in children learning to read in akshara orthographies.

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STUDY 3: COGNITIVE PREDICTORS OF WORD READING IN SINHALA

One in every four primary school-age children in the world, that is 168 million children as estimated by the UNICEF (2015), lives in South Asia and learns to read an Indic alphasyllabary. The existing reading studies in alphasyllabaries suggest that word reading development of young readers follows at least a somewhat different developmental pathway compared to the reading development of readers of alphabetic orthographies due to the unique structural and functional features of akshara, the orthographic symbols in alphasyllabaries (Nag, 2007; Nag & Snowling, 2012; Nakamura, Koda & Joshi, 2014). For example, the majority of vowels in Indic alphasyllabaries are not marked as full-sized symbols but are either inherent (and therefore left unmarked) or appear as diacritics attached to the full-sized base consonant; in contrast, the majority of consonants are full-sized akshara (Share & Daniels, 2016). Further, akshara simultaneously represent sounds both at the levels of syllables and phonemes, with the initial instruction focusing on learning the akshara as a whole (Nag, 2007, 2017). Finally, learning of the large akshara set (see below) is yet to be completed by the end of the primary school (Nag, 2007; Nag, 2014; Nag & Snowling, 2011, 2012; Tiwari, Nair, & Krishnan, 2011). Currently, we know very little about the factors that influence early word reading development in alphasyllabaries and the purpose of this study was to examine the predictors of word reading development in Sinhala-speaking Grade 1 to 6 children in Sri Lanka.

Predictors of Reading in Alphasyllabaries

There are only a handful of studies that have examined association between word reading skills, akshara knowledge, and the cognitive correlates of word reading established in alphabetic orthographies. In the largest of these studies, Nag and Snowling (2012) assessed Grade 4 to 6 Kannada reading children's word reading accuracy with a composite measure of individual word

and nonword reading tests and reading words-in-context in passages. Their result indicated that akshara knowledge, syllable awareness, phoneme awareness and rapid naming (RAN) were all associated with word reading accuracy, with akshara knowledge, phoneme awareness and RAN being the strongest associates of reading fluency. Nag and Snowling noted further that poor readers had deficits in one or more of these domains and more severe reading problems were associated with multiple deficits; the single most common area of deficit was akshara knowledge.

A few other studies have also shown slow akshara learning to be the defining characteristic of poor readers (e.g., Gupta, 2004; Nag, 2007; Tiwari, Nair, & Krishnan, 2011; Vasanta, 2004) and phonological awareness, in turn, may be associated with the pace of the acquisition of akshara knowledge (Nag, 2007). Syllable awareness has had a strong consistent correlation with reading scores across primary grades in most studies (e.g., Nag, 2007; Nag & Snowling, 2012). Phoneme awareness seems to emerge slowly in earlier stages of reading development (Nag, 2007; Nag & Snowling, 2011; Prakash, Rekha, Nigam, & Karanth, 1993) and may be associated with instruction in English (Nag, 2007; Nag & Snowling, 2011; Nag-Arulmani, 2003; Prakash et al., 1993). However, Nag (2007) and Nag and Snowling (2012) have reported a moderate correlation between knowledge of complex akshara and phoneme awareness at later stages of reading development (correlations were .48–.68 in Nag & Snowling [2012] and .51–.60 in Nag [2007]). Nag and Snowling (2012) explained that the nature of the writing system promotes syllable level representations making phoneme level processing slow to emerge. When children paid growing attention to phonemic markers as a result of their increasing knowledge of the CV and CCV/CCCV types of akshara symbols with their ligaturing rules, a stronger relationship between reading and phonemic awareness was apparent.

Even fewer studies have examined how phonological memory and rapid naming speed (RAN) are associated with word reading development in akshara orthographies. Wijayathilake and Parrila (2014) reported that RAN, phoneme awareness and phonological memory correlated with word reading accuracy in Grade 3 in Sinhala, though word length (assessed by the number of akshara in words) and word complexity (assessed by the presence of consonant clusters in words) did not show significant interactions with either phoneme awareness or phonological memory. Ramaa et al. (1993) showed that 8–10-year-old Kannada dyslexic and non-dyslexic struggling readers had difficulties in the digit span task compared to good readers. However, in this study, phonological memory was assessed with a measure that allows for long-term memory support (e.g., Hulme et al., 1997) as opposed to a purer phonological memory measure.

The few studies that have examined the relationship between RAN and reading have indicated that RAN is uniquely correlated with word reading in primary school-aged Kannada readers (Nag & Snowling, 2011, 2012). Nag et al. (2014) reported further that age, vocabulary and RAN were associated with akshara recognition concurrently, and age, vocabulary, RAN and phoneme awareness predicted akshara knowledge 8-months later after controlling for time 1 akshara knowledge. In Wijaythilake and Parrila (2014), RAN was more strongly associated with reading accuracy for shorter words and words with only simple akshara for struggling readers than for good readers, pointing to the possibility that RAN-reading relationship in alphasyllabaries is possibly affected by the slowly developing automaticity of akshara processing as well.

In sum, akshara knowledge, syllable awareness, phoneme awareness, RAN and phonological memory have emerged as unique correlates of word reading in alphasyllabaries.

How their association with reading development changes across the primary school grades is largely unknown.

Sinhala Phonology and Orthography

Sinhala, one of the two official languages in Sri Lanka spoken by about 74% of the population (Central Bank of Sri Lanka, 2016), belongs to the Indo-Aryan branch of Indo-European languages and it is written with a unique akshara orthography belonging to the Brahmic writing system. Sinhala orthography is largely consistent in that each akshara stands for the same sound(s) across all words; spelling, however, is complicated by two factors: one-to-many correspondence from sounds to symbols, and significant differences between the spoken and literate forms of the language. Literate Sinhala includes symbols that no longer have phonemic equivalents in spoken Sinhala, and traditional texts include akshara that are no longer commonly used in modern Sinhala. Sinhala phonology includes about 40 consonant and 18 vowel sounds, of which 27 consonants and 14 vowels (seven vowel qualities each with two lengths) are common today (Gair & Paolillo, 1997). In the new Grade 1 Sinhala Reading textbook introduced by the Sri Lankan government (Educational Publications Department, 2016), only 12 vowels and 26 consonants are considered common.

Similar to other Indic alphasyllabaries, each vowel in Sinhala has an independent primary symbol, used mostly when the vowel is in the initial position of a word, and a secondary diacritic sign (vowel marker). Each consonant also has a distinct symbol that is pronounced with an inherent vowel /a/. When a consonant is written with a vowel other than /a/, the secondary vowel marker is attached to the consonant symbol and the inherent /a/ is dropped from the pronunciation. When consonant clusters are formed, vowels and the second consonants are ligatured to the first consonant using their secondary diacritic forms. The diacritic for the second

consonant of the cluster is always attached to the bottom of the first consonant and some vowel diacritics of the cluster are attached to the top of the first consonant giving it a non-linear arrangement of markers.

Individual diacritics have a designated location in the akshara that is predictable and rule-governed. The predictability of the location of diacritics eases the memory load for the Sinhala readers once they master the ligaturing rules. According to Chandralal (2010), contemporary literate Sinhala can be written with about 54 independent symbols (16 primary vowels and 38 primary consonants) combined with 18 diacritics, and 38 symbols (12 primary vowels and 26 primary consonants) are sufficient to represent colloquial Sinhala. Of the 18 diacritics, 17 denote vowels (including two diphthongs and the syllabic r) and one (with two different forms), called *hal lakuna* or *hal kirīma*, is used for suppressing the pronunciation of the inherent vowel to make a pure consonant form. Sinhala writing system includes over 600 akshara; our analyses of the Grade 1 to 6 Sinhala reading textbooks identified 411 individual akshara that children were taught by the end of Grade 6. In the same language arts books, words with V, Ca and CV structure were the most common while consonant clusters appeared less frequently.

Literacy Instruction in Sinhala

The literacy instruction in Sinhala in Sri Lanka follows a fixed sequence determined by the official curriculum. Consonants with the inherent vowel and primary vowels are introduced first in the beginning of Grade 1. CV akshara with ligaturing rules for vowels are started to be taught at the end of Grade 1 and continue for the next grades followed by instruction on frequently used CCV akshara. In Grade 4, consonant clusters are formally introduced for the first time. High frequency CV and CCV akshara may be learned earlier because of repeated exposure. In Grade 5, students further practice using clusters and are exclusively taught how to decompose

CV and CCV symbols into their phoneme components (phoneme-level instruction of akshara formation), thus opening the door to a more combinatorial understanding of Sinhala orthography. Students additionally receive English instruction for several periods during the school week from Grade 2 in line with the language education policy of Sri Lanka. English instruction in Grade 2 is limited to oral English practice. English reading and writing instruction starts in Grade 3.

The fixed sequence of instruction is naturally perturbed by the real world reading materials and vocabulary children are exposed to. Children's books and story books have a mixture of all akshara types and children's vocabulary contains a sizable number of words with complex akshara. For example, in Sinhala, the CCV akshara /kka/ and /mma/ are common in early text books in multi-akshara words like /akka/ 'sister' and /amma/ 'mother' and children typically learn these akshara alongside the vowel akshara and the consonant akshara with inherent vowels due to frequent exposure. Children who read frequently should therefore gain exposure to a more extensive akshara set, and we would expect this alone to improve their reading skills. We were not able to locate other studies examining home literacy practices in Sinhala and its effect on reading needs to be established in future studies.

Current Study

In the current study, we examine the effects of akshara knowledge, phonological awareness, phonological memory and RAN on word reading development in a sample of Sinhala speaking Grades 1 to 6 children. We hypothesize that akshara knowledge is strongly associated with word reading accuracy and fluency across the primary school years given the crucial role it plays in learning to read in alphasyllabaries (Nag, 2007; Nag & Snowling, 2011, 2012). In contrast, we expect that the association of phonological skills with word reading varies across different levels of reading development with syllable awareness being important early and

phoneme awareness later when children have received instruction in English and in complex akshara. The association of phonological memory with reading should be evident throughout the grades due to the length of the words, whereas RAN is likely less important early when automaticity with akshara is still developing.

To our knowledge, this is the first study that examines the cognitive correlates of word reading in Sinhala. Most of the previous studies in alphasyllabaries have assessed children only at the beginning or at the end of their primary school years, or pooled data across multiple grades. We include children from Grades 1 to 6 in order to examine whether the expected changes in relationships can be observed as reading skills develop. We hope that the current study will enhance our understanding of the factors involved in word reading development and, together with studies in other akshara orthographies, will inform reading instruction and future reading experiments.

Method

Participants

Three hundred Sinhala-speaking children from Study 1 (148 male, 152 female) in Grades 1 to 6 (between ages 6 years 4 months and 11 years 4 months) from two well-functioning government schools in Kandy and Kegalle districts in Sri Lanka participated in this study. Both schools were suburban schools serving families from middle to upper-middle socioeconomic backgrounds. All teachers had tertiary education and were Government certified. Fifty students with no documented sensory or behavioural difficulties from each of the first six grades were selected and assessed. Students' first language and the medium of instruction was Sinhala. Students additionally received English and Tamil instruction for several periods during the school week from Grade 2 in line with the language education policy of Sri Lanka.

Materials

Reading Ability

Participants' reading ability was assessed with five tasks that measured akshara recognition, word reading accuracy, word reading fluency, nonword reading accuracy and nonword reading fluency.

Akshara Recognition

Participants were asked to name aloud 80 akshara taken from Grades 1 to 6 language arts books. The akshara were presented on paper and the score was the total number of correctly named akshara. Cronbach's alpha reliability ranged from .82 to .96 across the grades, the lower number reflecting a small ceiling effect for the higher grades (who had been exposed to all the akshara presented).

Word/nonword Reading

The participants were asked to read aloud 110 words/nonwords that were arranged in terms of increasing difficulty. The syllable length of words increased from two syllables to nine syllables and included words/nonwords with and without consonant clusters. The akshara in the real words were arranged in a different order to make nonwords. A five-word practice list was given to children prior to the actual test to ensure all children understood the instructions.

For the reading fluency tests, the child was asked to read the words/nonwords aloud as fast and accurately as possible for one minute and a child's total score for the fluency test was the total number of words/nonwords read correctly within the minute. Reading accuracy was measured using the same test that measured reading fluency. Children were asked to correct errors they made in the fluency test and then continue reading words/nonwords until they made 10 consecutive errors. A participant's reading accuracy score was the total number of correctly

read words/nonwords. Cronbach's alpha reliability in our sample ranged from .85 to .97 for the word reading accuracy test and .94 to .97 for the nonword reading accuracy test.

Phonological awareness

Phonological awareness was assessed with two deletion tasks – Phoneme Deletion (60 items) and Syllable Deletion (60 items) – that had the same test format. The phoneme deletion task required the participant to repeat words (30) and nonwords (30) after removing the designated sound from the beginning (10), middle (10), or end (10) of the item. Cronbach's alpha reliability ranged from .80 to .98. Syllable deletion task required the children to repeat the item without saying the designated syllable. Cronbach's alpha reliability ranged from .90 to .98. Total score was the number of correctly pronounced items. If the child responded incorrectly to four consecutive items, the task was discontinued.

Rapid Automatized Naming (RAN)

RAN was assessed with Digit and Akshara Naming tasks. The Digit Naming task was taken from RAN/RAS test battery (Wolf & Denckla, 2005) and required children to say as fast as possible the names of five digits (2, 7, 4, 9, 6 – all highly familiar bisyllabic words in Sinhala) arranged semi-randomly in five rows of 10. Wolf and Denckla (2005) reported test-retest reliability across ages for Digit Naming to be .92. Akshara Naming consisted of five highly frequent (frequencies ranged from 2151 to 5293) visually simple akshara ව/wa/, ස/sa/, ර/ra/, ද/da/ and ක/ka/ that are taught early in Grade 1. Prior to beginning the timed naming, children were asked to name the stimuli in a practice trial to ensure familiarity. Children's score in RAN was the time taken to name all items. Akshara Naming correlated .73 with Digit Naming.

Phonological memory

Phonological memory was assessed with two syllable repetition tasks that manipulated the phonological familiarity of the items. The first task consisted of 18 strings of syllables made of high-frequency akshara; the number of syllables in the strings increased from 2 to 14, and the presentation was discontinued after three consecutive errors. The second task consisted of 19 strings of syllables made of low-frequency akshara and varied in length from two to nine syllables. One syllable string at a time was read aloud to a child and the child was asked to listen carefully and repeat the string as clearly and correctly as possible. A participant's score was the total number of correctly repeated syllable strings for each task. Cronbach's alpha reliability ranged from .58 to .93 for the test with high frequency akshara and, from .55 to .98. for the test with low frequency akshara for Grades 1 to 4. The reliability coefficients for the test with low frequency akshara in Grades 5 and 6 could not be computed because of the ceiling effect.

Procedure

All participants were examined during the last term of the school year in September-December. Each child was tested individually in a quiet room in their school by trained graduate students who were native Sinhala speakers and received extensive training on test administration. Testing was completed within 40–60 minutes divided over one to two sessions depending on how long a child wanted to work. The tests were administered in a fixed order.

Results

Descriptive Analysis

Descriptive statistics for each grade are shown in Table IV-1 and the results of one-way ANOVA with grade as a factor are shown in Table IV-2 together with effect sizes from pairwise comparisons.

Table IV-1

Descriptive Statistics of the Measures

	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		Grade 6	
Measures	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Akshara knowledge (max: 80)	35.60	10.67	56.42	10.26	63.44	7.51	69.08	7.29	74.12	4.44	72.86	4.23
Syllable awareness (max: 60)	28.04	14.66	55.04	6.83	54.18	8.14	59.58	0.95	59.98	0.14	59.96	0.20
Phoneme awareness (max: 60)	7.66	4.21	18.34	4.52	22.42	6.17	29.52	12.30	46.58	16.83	41.66	16.58
Phonological memory (max: 37)	24.18	11.73	32.38	2.95	31.98	3.68	34.24	1.92	34.82	1.10	34.66	1.24
RAN-digits	55.73	18.95	42.69	9.97	32.35	5.80	37.20	9.94	24.51	3.76	24.30	5.19
RAN-akshara	43.63	12.66	36.87	10.07	28.54	6.73	33.19	9.80	23.02	4.23	23.04	5.37
Word reading accuracy (max: 110)	17.46	11.16	63.12	21.84	76.90	15.62	91.70	15.72	104.92	5.07	104.46	7.51
Word reading fluency (max: 80)	12.68	6.03	24.68	4.93	32.50	6.45	35.32	11.19	47.62	9.57	53.00	12.17
Nonword reading accuracy (max: 110)	21.52	12.43	68.22	20.15	81.30	19.96	99.64	13.39	104.72	6.85	102.06	9.22
Nonword reading fluency (max: 80)	13.56	4.97	21.00	4.19	26.36	5.30	28.90	7.93	35.42	6.89	37.80	6.99

Table IV-2

Results of One-Way Analysis of Variance and Effect Sizes for the Pairwise Grade Comparisons.

	Main effect of grade		Pairwise comparison (Hedges's g)				
	$F(5, 294)$	η_G^2	G1 vs. G2	G2 vs. G3	G3 vs. G4	G4 vs. G5	G5 vs. G6
Akshara knowledge	171.16	.74 [.67, .79]	1.97 [1.49, 2.45]	0.77 [0.37, 1.18]	0.76 [0.35, 1.16]	0.83 [0.42, 1.24]	−0.29 [−0.68, 0.11]
Syllable awareness	140.28	.70 [.60, .78]	2.34 [1.83, 2.85]	−0.11 [−0.51, 0.28]	0.92 [0.51, 1.34]	0.58 [0.18, 0.98]	, 0.12 [−0.51, 0.28]
Phoneme awareness	81.82	.58 [.49, .65]	2.43 [1.91, 2.94]	0.75 [0.34, 1.15]	0.72 [0.32, 1.13]	1.15 [0.72, 1.57]	−0.29 [−0.69, 0.10]
Phonological memory	29.36	.33 [.26, .42]	0.95 [0.54, 1.36]	−0.12 [−0.51, 0.27]	0.76 [0.36, 1.17]	0.37 [, 0.03, 0.76]	−0.14 [−0.53, 0.26]
RAN-digits	68.12	.54 [.47, .58]	−0.85 [−1.26, −0.44]	−1.26 [−1.69, −0.83]	0.59 [0.19, 0.99]	−1.68 [−2.13, −1.22]	−0.05 [−0.44, 0.35]
RAN-akshara	44.13	.43 [.35, .49]	−0.59 [−0.99, −0.19]	−0.97 [−1.38, −0.55]	0.55 [0.15, 0.95]	−1.34 [−1.77, −0.90]	0.00 [−0.39, 0.40]
Word reading accuracy	280.21	.83 [.80, .85]	2.61 [2.08, 3.15]	0.72 [0.32, 1.12]	0.94 [0.52, 1.35]	1.12 [0.70, 1.54]	−0.07 [−0.46, 0.32]
Word reading fluency	140.16	.70 [.65, .74]	2.16 [1.67, 2.66]	1.35 [0.92, 1.79]	0.31 [−0.09, 0.70]	1.17 [0.75, 1.60]	0.49 [0.09, 0.89]
Nonword reading accuracy	238.14	.80 [.76, .83]	2.77 [2.22, 3.32]	0.65 [0.24, 1.05]	1.07 [0.65, 1.49]	0.47 [0.08, 0.87]	−0.32 [−0.72, 0.07]
Nonword reading fluency	106.64	.64 [.58, .68]	1.61 [1.16, 2.06]	1.11 [0.69, 1.53]	0.37 [−0.02, 0.77]	0.87 [0.46, 1.28]	0.34 [−0.05, 0.74]

Note. G1 = Grade 1; G2 = Grade 2; G3 = Grade 3; G4 = Grade 4; G5 = Grade 5; G6 = Grade 6. Numerals in brackets are 95% confidence intervals.

All the skills except RAN-akshara showed a large improvement from Grade 1 to Grade 2 (*g*s = 0.95–2.77). Syllable awareness and phonological memory reached ceiling early and their performance were comparable after Grade 2 onwards. A large improvement in akshara knowledge, phoneme awareness and word reading skills were also observed between Grades 4 and 5 where children received explicit phoneme instruction. Akshara knowledge and

word/nonword reading accuracy reached ceiling in Grade 5, which is perhaps not surprising given that all the akshara used in the test were taken from the children's textbooks.

Table IV-3

Correlations among the Measures

	1	2	3	4	5	6	7	8	9	10
Grade 1 and 2										
1. Akshara knowledge		.36*	.33*	.47**	–.25	–.25	.74**	.51**	.78**	.24
2. Syllable awareness	.47**		.28	.21	.19	.16	.21	.06	.11	–.21
3. Phoneme awareness	.17	.39**		.46**	–.14	–.22	.37*	.13	.36*	.16
4. Phonological memory	.53**	.12	.11		–.10	–.10	.52**	.29*	.57**	.15
5. RAN–digits	–.26	–.07	–.01	–.27		.72**	–.40**	–.47**	–.49**	–.44**
6. RAN–akshara	–.19	.13	–.07	–.15	.71**		–.21	–.37*	–.41**	–.36*
7. Word reading accuracy	.80**	.41**	.23	.49**	–.38*	–.33*		.46**	.88**	.31*
8. Word reading fluency	.73**	.37*	.20	.57**	–.47**	–.43**	.90**		.59**	.62**
9. Nonword reading accuracy	.82**	.44**	.25	.52**	–.35*	–.33*	.91**	.84**		.37*
10. Nonword reading fluency	.61**	.31*	.26	.61**	–.48**	–.50**	.74**	.87**	.76**	
Grade 3 and 4										
1. Akshara knowledge		.36*	.05	.27	–.38*	–.49**	.77**	.55**	.82**	.57**
2. Syllable awareness	.49**		–.03	.39*	–.16	–.15	.41**	.26	.31*	.30*
3. Phoneme awareness	.26	.21		–.01	–.19	–.12	.03	–.06	.10	.00
4. Phonological memory	.34*	.13	.15		.01	.01	.39*	.05	.21	.04
5. RAN–digits	–.17	.11	–.19	–.18		.77**	–.44**	–.49**	–.38*	–.51**
6. RAN–akshara	–.18	.13	–.22	–.14	.60**		–.59**	–.60**	–.51**	–.50**
7. Word reading accuracy	.62**	.39*	.36*	.28	–.35*	–.21		.71**	.68**	.69**
8. Word reading fluency	.52**	.09	.17	.25	–.20	–.19	.46**		.54**	.75**
9. Nonword reading accuracy	.65**	.34*	.30*	.38*	–.30*	–.20	.74**	.40**		.52**
10. Nonword reading fluency	.45**	.01	.13	.28	–.29*	–.33*	.31*	.56**	.43**	
Grade 5 and 6										
1. Akshara knowledge		.12	.26	.13	–.39**	–.36*	.43**	.31*	.48**	.20
2. Syllable awareness	–.03		.23	.11	.12	.08	.07	–.14	.12	–.14
3. Phoneme awareness	.26	.27		–.04	–.18	–.15	.38*	.28	.45**	.28
4. Phonological memory	.17	–.02	.14		–.06	–.04	.08	–.04	.03	–.09
5. RAN–digits	–.10	.28	–.01	–.09		.84**	–.41**	–.46**	–.11	–.35*
6. RAN–akshara	–.22	.21	–.18	.11	.70**		–.43**	–.41**	–.09	–.36*
7. Word reading accuracy	.65**	.20	.21	.01	–.04	–.18		.62**	.42**	.29*
8. Word reading fluency	.39*	.18	.22	–.18	–.22	–.33*	.36*		.34*	.59**
9. Nonword reading accuracy	.51**	.18	.36*	.21	–.03	–.23	.59**	.37*		.43**
10. Nonword reading fluency	.50**	.09	.23	.02	–.32*	–.48**	.36*	.68**	.53**	

Note. Correlations below the diagonal are from Grade 1, 3, and 5, respectively, whereas correlations above the diagonal are from Grade 2, 4, and 6, respectively.
*$p < .05$; **$p < .01$.

The zero-order correlations among the measures are shown in Table IV-3. Akshara knowledge showed the highest correlations with word/nonword reading skills across grades. Syllable awareness and phonological memory were weakly to moderately correlated with some reading skills in Grades 1 to 4. Phoneme awareness was weakly correlated with reading accuracy, but not fluency, after Grade 2 onwards. RAN-digits and RAN-akshara were weakly to moderately correlated with reading skills across grades, particularly with reading fluency.

Multiple Regression Analyses

To examine the relative importance of akshara knowledge, syllable awareness, phoneme awareness, phonological memory and RAN in predicting children's reading skills, we performed multiple regression analyses. Separate regression models with reading accuracy and reading fluency as dependent variables were constructed in each grade. In the analyses, we calculated composite scores for reading accuracy/fluency by averaging *z*-scores for word and nonword reading accuracy/fluency and used them as dependent variables. We also calculated a composite score for alphanumeric RAN (RAN-AN) by averaging *z*-scores for RAN-digits and RAN-akshara and used it as an independent variable. For Grades 5 and 6, we constructed only the regression models for reading fluency because both word and nonword reading accuracy showed a ceiling effect in those grades. The cognitive correlates (i.e., akshara knowledge, syllable awareness, phoneme awareness, phonological memory and RAN-AN) were entered to the regression equation simultaneously. We did not include syllable awareness and phonological memory in the models for Grades 5 and 6 because they had no variability due to the ceiling effect. The results are presented in Table IV-4.

Table IV-4

Results of Multiple Regression Analysis for Predicting Reading Accuracy and Fluency.

	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		Grade 6	
Predictors	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
DV: Reading accuracy												
Akshara knowledge	.67***	[.46, .87]	.61***	[.42, .81]	.48***	[.24, .72]	.66***	[.51, .81]				
Syllable awareness	.07	[–.12, .26]	–.09	[–.27, .09]	.11	[–.12, .34]	.05	[–.09, .19]				
Phoneme awareness	.08	[–.08, .25]	.04	[–.14, .22]	.13	[–.07, .34]	.00	[–.12, .13]				
Phonological memory	.09	[–.09, .27]	.24*	[.05, .43]	.10	[–.10, .31]	.11	[–.03, .24]				
RAN-AN	–.21*	[–.38, –.04]	–.21*	[–.39, –.02]	–.19	[–.42, .05]	–.21**	[–.36, –.06]				
Total R^2	.71		.69		.49		.78					
DV: Reading fluency												
Akshara knowledge	.37**	[.14, .59]	.31*	[.03, .59]	.53***	[.27, .80]	.37**	[.13, .61]	.37**	[.14, .60]	.06	[–.19, .31]
Syllable awareness[a]	.11	[–.09, .31]	–.14	[–.39, .12]	–.21	[–.46, .04]	.11	[–.11, .34]				
Phoneme awareness	.08	[–.09, .26]	–.01	[–.27, .25]	.01	[–.21, .23]	–.11	[–.31, .09]	.10	[–.13, .32]	.20	[–.03, .44]
Phonological memory[a]	.30**	[.10, .49]	.07	[–.19, .34]	.09	[–.13, .31]	–.09	[–.31, .13]				
RAN-AN	–.38***	[–.57, –.20]	–.35*	[–.62, –.09]	–.15	[–.40, .11]	–.41**	[–.65, –.17]	–.32*	[–.56, –.07]	–.37**	[–.62, –.11]
Total R^2	.67		.28		.33		.46		.30		.23	

Note. [a] Syllable awareness and phonological memory were not entered in the models for Grades 5 and 6 because of the ceiling effect. CI = confidence intervals.
*p < .05; **p < .01; ***p < .001.

The total explained variances in each grade ranged from .49 to .78 and from .23 to .67 for reading accuracy and reading fluency, respectively. Among the cognitive skills, akshara knowledge had the strongest unique association with both reading accuracy and fluency across grades, except for Grade 6 where akshara knowledge was at ceiling. RAN-AN was uniquely associated with reading accuracy and fluency across grades, with the exception of Grade 3. Additionally, phonological memory had a unique association with reading fluency in Grade 1 and with reading accuracy in Grade 2.

Next, to examine the effect of explicit phoneme instruction on the association between cognitive and word reading skills, we divided the sample into two groups: those who had not received phoneme instruction (i.e., Grades 2 to 4; n = 150) and those who had received phoneme instruction (i.e., Grades 5 and 6; n = 100). We did not include Grade 1 into the first group because the performances of Grade 1 children were markedly different from those of Grades 2 to 4 children on most measures (see Tables IV-1 and IV-2). As in the previous analyses, separate regression models were constructed for reading accuracy and reading fluency in each group. Grade was entered in the first step of the regression models as a covariate, and the cognitive skills were entered in the second step simultaneously. The results are presented in Table IV-5. After controlling for grade, the cognitive skills accounted for 42% of the variance in reading accuracy in the Grade 2–4 group, and 27% and 26% of the variance in reading fluency in the Grade 2–4 group and the Grade 5–6 group, respectively. Similar to the first set of analyses, akshara knowledge and RAN-AN were uniquely associated with reading accuracy and fluency in both groups. In addition, phonological memory was uniquely associated with reading accuracy in the Grade 2–4 group. In contrast, neither syllable awareness nor phoneme awareness were uniquely associated with word reading skills in either group.

Table IV-5

Results of Multiple Regression Analysis for Predicting Reading Accuracy and Fluency in the Combined Sample.

		Grade 2–4 (n = 150)			Grade 5–6 (n = 100)		
Step	Predictors	ΔR^2	β	95% CI	ΔR^2	β	95% CI
DV: Reading accuracy							
1.	Grade	.34***	.17**	[.07, .26]			
2.	Akshara knowledge	.42***	.58***	[.46, .68]			
	Syllable awareness		.02	[–.07, .11]			
	Phoneme awareness		.04	[–.05, .13]			
	Phonological memory		.16***	[.07, .24]			
	RAN-AN		–.15**	[–.25, –.06]			
	Total R^2	.76					
DV: Reading fluency							
1.	Grade	.25***	.26***	[.13, .40]	.04	.26**	[.10, .41]
2.	Akshara knowledge	.27***	.37***	[.22, .53]	.26***	.21*	[.05, .38]
	Syllable awareness[a]		–.07	[–.19, .06]			
	Phoneme awareness		–.07	[–.19, .05]		.15	[–.01, .31]
	Phonological memory[a]		.02	[–.10, .14]			
	RAN-AN		–.33***	[–.46, –.20]		–.32***	[–.49, –.15]
	Total R^2	.52			.30		

Note. [a] Syllable awareness and phonological memory were not entered in the models for Grades 5 and 6 because of the ceiling effect. CI = confidence intervals.
*p < .05; **p < .01; ***p < .001.

Finally, we examined the extent syllable awareness, phoneme awareness, phonological memory, and RAN-AN have indirect effects on word reading via akshara knowledge. Grade was entered as a control variable, and both direct and indirect effects (via akshara knowledge) were estimated for all the predictor variables. The results of these analyses are shown in Table IV-6.

Table IV-6

Direct, Indirect, and Total Associations of the Cognitive Correlates with Reading Accuracy and Fluency.

	Grade 2–4				Grade 5–6	
	Accuracy		Fluency		Fluency	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Total effect						
Syllable awareness[a]	.21	[.09, .36]	.06	[–.06, .19]		
Phoneme awareness	.05	[–.03, .14]	–.07	[–.22, .08]	.22	[.03, .39]
Phonological memory[a]	.31	[.18, .43]	.12	[.00, .24]		
RAN-AN	–.34	[–.47, –.21]	–.46	[–.58, –.33]	–.40	[–.53, –.23]
Direct effect						
Syllable awareness[a]	.02	[–.06, .12]	–.07	[–.17, .04]		
Phoneme awareness	.05	[–.02, .12]	–.08	[–.21, .07]	.17	[–.02, .36]
Phonological memory[a]	.16	[.09, .25]	.02	[–.09, .14]		
RAN-AN	–.15	[–.25, –.06]	–.33	[–.45, –.21]	–.33	[–.47, –.18]
Indirect effect						
Syllable awareness[a]	.19	[.10, .29]	.13	[.07, .22]		
Phoneme awareness	.01	[–.05, .08]	.01	[–.03, .05]	.05	[.00, .16]
Phonological memory[a]	.14	[.06, .23]	.10	[.04, .17]		
RAN-AN	–.19	[–.30, –.10]	–.13	[–.22, –.06]	–.06	[–.16, –.01]

Note. [a] Syllable awareness and phonological memory were not entered in the model for Grades 5 and 6 because of the ceiling effect. CI = confidence intervals; when they don't include zero, the estimate is considered significant.

Table IV-6 shows that akshara knowledge, phonological memory, and RAN-AN were directly associated with reading accuracy in the Grade 2–4 group. Syllable awareness, phonological memory, and RAN-AN also had a significant indirect association via akshara knowledge. The same pattern was also observed in the model for reading fluency, except that the direct association between phonological memory and reading fluency was not significant. In the Grade 5–6 group, akshara knowledge and RAN-AN were directly associated with reading fluency, and RAN-AN also had a significant indirect association via akshara knowledge. Phoneme awareness was uniquely associated with akshara knowledge, but its indirect association with reading fluency was not statistically significant.

Discussion

We examined the cognitive correlates of word reading development in Sinhala primary school children in Sri Lanka. Our first research question was whether akshara knowledge is uniquely associated with word reading accuracy and fluency across primary school years. As we expected, akshara knowledge had the strongest unique association with both reading accuracy and fluency across grades, with the exception of Grade 6 where akshara knowledge had reached ceiling. Our results are in line with the previous studies (Nag, 2007; Nag & Snowling, 2011, 2012) concluding that akshara knowledge was the most robust predictor of reading in Kannada and difficulties with symbol knowledge impacted reading accuracy, reading fluency, and reading comprehension. Compared to the letter learning process in alphabetic languages that reaches ceiling quickly (Adams, 1990; Seymour, 2005), alphasyllabic readers take a long time to master the symbol set due to large symbol registry and the visual and phonological complexity of akshara themselves (Nag et al., 2010; Nag et al., 2014; Tiwari et al., 2011). That is, in all grade levels, children will encounter not only new words but also new symbols in those words that they may or may not be able to decipher on the basis of their existing symbol knowledge, and the deciphering process itself is not the focus of instruction before Grade 5.

Our second hypothesis was that phonological skills will be associated with reading differently for different stages of reading development. In contrast to Nag and Snowling (2012), syllable awareness and phoneme awareness did not have a strong impact on reading accuracy or fluency across grades. Further, our analysis of the influence of explicit phoneme instruction on the relative importance of the cognitive skills in word reading skills showed that neither syllable awareness nor phoneme awareness was uniquely associated with reading skills; instead, their association, when significant, was mediated by akshara knowledge.

In line with previous research (Nag & Snowling, 2011, 2012; Wijayathilake & Parrila, 2014), RAN predicted word reading accuracy and fluency in all stages of reading development (with the exception of Grade 3), showing its universality as a predictor of reading across writing systems (Georgiou, Aro, Liao, & Parrila, 2016; Georgiou, Parrila, Cui, & Papadopoulos, 2013; Lervåg & Hulme, 2009; Liao, Georgiou, Parrila, 2008). However, some studies in nonalphabetic languages (e.g., Chinese) have found that RAN does not predict reading accuracy in early years (Chow et al., 2005; Liao et al., 2015; McBridge-Chang & Ho, 2005) and a Sinhala reading study with Grade 3 children (Wijayathilake & Parrila, 2014) reported that RAN was a more significant predictor of reading accuracy on shorter words, words with only simple akshara, and for struggling readers when compared to the good readers. Therefore, it is still not clear whether RAN captures exactly the same underlying phonological processes in alphasyllabaries that it captures in alphabetic languages due to the differences in phonological access and visual feature discrimination in akshara (Nag, 2017). Further RAN studies in alphasyllabaries have promise in helping to understand RAN-reading relationship in general (Wijayathilake & Parrila, 2014).

Phonological memory was uniquely associated with reading accuracy in Sinhala for the beginning and intermediate readers, and it was also associated with reading fluency for the beginning readers. To date, there is a paucity of research that has examined the developmental dynamics between phonological memory and word reading in alphasyllabaries and a previous study in Sinhala (Wijayathilake & Parrila, 2014) indicated that phonological memory was robustly associated with word reading in Grade 3 Sinhala readers. The possible reason could be that the beginning and intermediate readers lack the advantage of sub-syllabic level reading instruction to support their decoding of complex akshara; an instructional advantage readily available only for the advanced readers in Sinhala. As a result, beginning and intermediate

readers have to rely more on phonological memory in order to capture the phonological complexity of some of the akshara and compensate for the possible need to manipulate the orthographic order of phoneme markers to match the spoken order of phonemes.

Further, we examined, albeit indirectly, the effect of explicit phoneme instruction on the relative importance of different cognitive skills in predicting reading skills. Our results show that, again, akshara knowledge and alphanumeric RAN were associated with reading accuracy and fluency in both groups, one of whom had not received and the other had received phoneme level instruction, and phonological memory was associated with reading accuracy in the former group. Neither syllable awareness nor phoneme awareness were uniquely associated with reading skills in either group after akshara knowledge was controlled. Given the significant correlations between phoneme awareness and reading accuracy in Grades 5 and 6, however, it is possible that phoneme instruction influences the strength of the relationship between phoneme awareness and reading, possibly by changing the akshara deciphering strategy from holistic to more analytic. This is another topic that clearly requires further study in akshara orthographies.

In terms of practice, our results indicate that learning to read words accurately and fluently in alphasyllabaries is a prolonged process, and akshara knowledge is the key to this learning process until the end of the primary school. Given that the symbol learning and word reading development proceed simultaneously, it is likely that teaching the formation of complex akshara out of different phonemic components and diacritics sooner than Grade 5 would be beneficial by giving children skills to sound out most of the new akshara they encounter. As Nag (2017) suggested, learning to read in akshara orthographies builds on many of the same cognitive–linguistic processes needed to learn an alphabetic orthography, but additional

processing cost related to the visual and phonological complexities of akshara themselves makes akshara learning different and difficult compared to letter learning in alphabetic orthographies.

In conclusion, more scientific studies are needed in all aspects of literacy acquisition and development in akshara orthographies focusing on akshara knowledge, word recognition, phonological and other cognitive skills, reading comprehension, vocabulary and visual processing skills (Nag, 2007; Nag & Snowling, 2011, 2012; Nakamura, Koda, & Joshi, 2014). Given the crucial role of akshara knowledge as the major predictor of reading accuracy and fluency, the dearth of experimental akshara learning studies is particularly troubling. The current instructional methods are based more on tradition than on scientific evidence, and we believe that the impact of early instruction on analyzing akshara into their constituent phonological and orthographic components needs to be examined. We argue that learning to read in Sinhala (and other alphasyllabaries) is a different process from learning to read in alphabetic orthographies, and currently a very poorly understood process that available models and theories of reading in alphabetic languages are unable to explain. This study suggests that, apart from the fact that learning the symbol set in an extensive Sinhala orthography is a demanding process by itself, it is likely that the cognitive skills employed during different stages of reading are at least partly different from those needed to learn contained alphabetic orthographies.

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GENERAL DISCUSSION

Despite its seeming simplicity for most of the children, reading is a late-acquired human ability that we must achieve with effort in comparison to speaking (Snowling & Hulme, 2005). Given its crucial role in becoming a successful citizen in the modern society, it is important to understand the nature of the reading acquisition process and the factors that push some children forward and others towards a possible downword spiral as struggling readers. An impressive array of reading literature over the last few decades has come from alphabetic orthographies (with a sizable amount of studies from morphosyllabic scripts such as Chinese as well [Hanley, 2005; Perfetti & Liu, 2005]) examining the role of different cognitive, linguistic and environmental factors in learning to read (Share, 2008). For example, orthographic knowledge and phonological awareness have been shown to be crucial for reading mastery in English (Duff & Hulme, 2012; Seymour, 2005; Taylor, Plunkett, & Nation, 2010; Vandervelden & Siegel, 1997). However, our understanding of the universal and orthography-specific aspects of reading development is still incomplete due to the large gap of the reading literature on alphasyllabaries (Nag, 2007; Tiwari, Nair, & Krishnan, 2011) and many other non-European orthographies. Compared to the voluminous reading studies in European alphabetic orthographies, reading studies in alphasyllabaries are still rare and our knowledge of the language and orthography specific factors that affect reading development in alphasyllabaries is in its infancy. The purpose of this dissertation was to contribute to this knowledge by examining the role of linguistic, cognitive and environmental variables in word reading development in Sinhala-speaking elementary school children in Sri Lanka.

The Role of Symbol-Level and Child-Level Characteristics of Akshara on Akshara Recognition

The role of orthography in the mastery of orthographic knowledge in alphasyllabaries is still largely unknown. The basic structure of akshara is unique in that it seems to elicit representation of sounds it captures simultaneously at the level of both the syllable and the phonemes.This dual-level representation drives the orthography in a functionally different way as well from that of 'letters' (Nag, 2007, 2017). For example, the most common vowel in Sinhala (and in Hindi [Share & Daniels, 2016]), the inherent schwa, has no sign at all (Chandralal, 2010). In contrast to all alphabetic systems (with the exception of Korean) where vowels and consonants are similar in size and linearly arranged, noninitial vowels in Brahmi-derived alphasyllabaries are subordinated (both in size and spatial location) to the main array of consonants—appearing above, below or beside them (Share & Daniels, 2016) and thus creating a nonlinear, visually complex, symbol arrangement (Nag, 2007). The existing few studies have shown that akshara–specific features, such as akshara type, frequency, visual complexity, and phonological complexity, slow down akshara recognition and make akshara learning an extended process (Nag, Quinlan, Snowling & Hulme, 2014). Thus, the purpose of Study I was to examine the symbol-level (akshara type, akshara frequency, visual complexity, number of diacritic markers, grapheme-phoneme sequence matching, and orthographic linearity) and child-level (phonological awareness, phonological memory, RAN, home reading time and socioeconomic status) predictors of akshara recognition in Sinhala-speaking elementary school children in Sri Lanka.

The first question was to examine which features of akshara explain unique variance in how well akshara are recognized. The results showed that akshara type, akshara frequency, visual complexity, grapheme-phoneme sequence matching, and the number of orthographic

linearity breaks in akshara were independent symbol-level predictors of how accurately an akshara is recognized. The number of diacritic markers in the akshara was not predictive of akshara recognition, possibly because of the other variables that captured a lot of the same variance as number of diacritic markers in the predictive model. Our second research question was what child-level characteristics predict children's akshara recognition. Syllable awareness, phoneme awareness, phonological memory, and home reading time were unique child-level predictors of akshara recognition.

The results suggest that the akshara learning process in alphasyllabaries is qualitatively different from letter learning in alphabetic languages for two reasons. First, learning the large symbol set with their rules of ligaturing makes akshara learning a prolonged and qualitatively different process that continues throughout the primary school years and beyond (Nag, 2007; Nag & Snowling, 2012). Second, learning akshara itself is a complex and demanding process due to the symbol-specific characteristics. Both of these dimensions are absent from the process of learning to read in alphabetic orthographies and missing from existing reading acquisition theories. Moreover, the relationship between akshara knowledge and phonological awareness highlights the need for future studies to explore the direction of the relationship further because two contradicting explanations were plausible for this relationship. One possibility was that increased akshara knowledge with a clear understanding of the ligaturing rules increases phoneme awareness. The other possibility was that increased sensitivity to the sub-syllabic information increased children's akshara knowledge.

Effects of Phoneme-Level Instruction on the Word Reading Skills in Sinhala

Orthography to phonology mapping in alphabetic languages are at the level of graphemes and phonemes and a large number of reading studies show that phonological skills provide a

critical foundation for learning to read (e.g., Hulme, Snowling, Caravolas, Carroll, 2005; Mann & Wimmer, 2002; Muter, Hulme, Snowling & Stevenson, 2004) and that the relationship between phonological skills and reading is bidirectional (e.g., Caravolas, Lervåg, Defior, Seidlova Malkova, & Hulme, 2013; Hulme, Bowyer-Crane, Carroll, Duff, & Snowling, 2012; Wagner, Torgesen, & Rashotte, 1994). The importance of phonological skills in reading extends to nonalphabetic scripts such as Chinese (Chan & Siegel, 2001; Hu & Catts, 1998; Shu, Peng & Mc-Bride-Chang, 2008; Georgiou, Su, & Shu, 2016). However, akshara in alphasyllabaries map to phonology both at the level of syllables and at the level of phonemes (e.g., Bright, 1996; Daniels, 1996; Nag, 2017) but the role of phonological skills in learning to read in alphasyllabaries is still far from clear (Nag & Snowling, 2011). A few studies have shown that phoneme awareness is slower to emerge compared to alphabetic orthographies and less critical for learning to read (e.g., Nag, 2007; Prakash et al., 1993). Thus, the purpose of Study II was to examine how exposure to complex akshara and instruction on diacritic markers affects phoneme awareness and its relationship with akshara knowledge and word reading accuracy in children learning to read Sinhala.

As expected in the first hypothesis, phoneme awareness was slow to emerge and this was in line with the existing studies (e.g., Nag, 2007; Nag & Snowling, 2011, 2012; Nakamura et al., in press; Prakash, et al., 1993). The results suggest that formal introduction of consonant clusters in Grade 4 helps phoneme awareness to develop and that the provision of explicit instruction in akshara decomposition in Grade 5 leads to strong growth in phoneme awareness. The possible explanation is that the introduction of complex akshara in Grade 4 demanded students' attention to sub-syllabic details while explicit teaching of phoneme markers in Grade 5 strengthens their representation in the lexicon and increases phonemic awareness.

With respect to the second research question, the results showed that phoneme awareness correlated only moderately with akshara knowledge and word reading accuracy in Grades 3 and 4, but more strongly in Grade 5 after the instruction in akshara decomposition. With regard to the third research question that explored the direction of the relationship between akshara knowledge, phoneme awareness and word reading, there was a unidirectional relationship in that both akshara knowledge and word reading predicted phoneme awareness in Grade 5 after children had received phoneme-level instruction. In line with the previous studies (Nag, 2007; Nag & Snowling, 2011, 2012), akshara knowledge predicted growth in word reading even at the later stages of word reading development. This was expected given the large symbol set and the symbol-level features of akshara that led the mastery of akshara set to be extended well beyond the elementary school years.

Taken together, the results of this study suggest that phoneme awareness in Sinhala is particularly sensitive to the nature of the reading instruction and, in all likelihood, a result of instruction. To confirm this subordinate role of phoneme awareness in reading in Sinhala, the strong relationship between phoneme awareness, akshara knowledge and word reading faded when the focus of instruction shifted again from phonemes to syllables in Grade 6. Future studies are needed to examine the longitudinal relationships between word reading and phoneme awareness in alphasyllabaries and the possible benefits of instruction on akshara decomposition in earlier grades.

Cognitive Predictors of Word Reading Skills in Sinhala

Compared to the phoneme-based alphabetic scripts, akshara represent sounds both at the levels of phonemes and the syllables. Akshara is taught as a whole unit (syllable) for the first four years of the reading instruction before children's attention is drawn to the sub-syllabic

details of akshara. The orthographic inventory exceeds 600 akshara (roughly 200 to 700 depending on the akshara orthography) and the time taken to master this large akshara set with their visual and phonological complexities continues beyond the primary school years. Due to these unique features of akshara and word reading development, the purpose of Study III was to examine the cognitive correlates of word reading development in Sinhala-speaking Grade 1 to 6 children in Sri Lanka. I expected that reading-related variables in Sinhala would not only have similarities but also noteworthy differences from those of the alphabetic orthographies.

The results showed that akshara knowledge was robustly associated with both word reading accuracy and fluency across grades. This finding is in line with what has been reported before for other alphasyllabaries (Nag, 200; Nag & Snowling, 2012). RAN was uniquely associated with word reading skills in all grades except Grade 4. Phonological memory was uniquely associated with reading accuracy until the intermediate stage of reading development and with reading fluency only for the beginning readers. Notably, neither syllable awareness nor phoneme awareness were uniquely associated with reading skills across grades when akshara knowledge was controlled.

The results suggest that the relative importance of cognitive skills employed during different stages of reading development in Sinhala are somewhat different from those needed to learn alphabetic orthographies. In contrast to the critical importance of phoneme awareness in learning to read in alphabetic orthographies, phoneme awareness was not driving reading development in Sinhala. At the same time, these findings suggest that learning to read words accurately and fluently in alphasyllabaries is a prolonged process, in which two parallel processes, symbol learning and word decoding, continue well beyond primary school. Akshara knowledge is the most important contributor to the process of learning to read words.

Implications of the Studies

The findings of the three studies in this dissertation have implications for building models and theories explaining reading acquisition and development in alphasyllabaries. According to Seymour et al. (2003), the ease or the difficulty of reading acquisition across orthographies depends on transparency of spelling-sound relations and the complexity of syllable structure. Sinhala, together with other alphasyllabaries (Chandralal, 2010, Nag, 2007; Padakannaya & Mohanty, 2004), is transparent and has a relatively simple syllable structure. In that sense, learning to read Sinhala should be fairly easy for children. However, the findings of this dissertation show that the opposite is true and, contrary to what Seymour et al. (2003), Ziegler and Goswami (2005), and Katz and Frost (1992) would lead to expect, learning to read in Sinhala is a prolonged process that extends to middle school. Orthographic transparency does not guarantee ease of symbol learning in alphasyllabaries (Nag & Snowling, 2011), including Sinhala, likely because of the large symbol inventory.

Moreover, the findings of this dissertation provide guidance for building models of literacy acquisition by showing that the learning demands akshara orthographies impose on the learners are both similar and different from those learners of alphabetic or morphographic orthographies face. Large symbol inventory and symbol-specific characteristics, such as visual and phonological complexity of the symbols, are two currently-known major factors that impact the ease or difficulty of akshara recognition. Neither of these factors are relevant for learning European alphabetic scripts and therefore not present in existing models developed to explain reading acquisition in alphabetic orthographies. Though having two forms – both the primary and the secondary – for vowels and some consonants seem overwhelming, the choice between the two forms is rule-governed. Learning the regularities and the irregularities of akshara

formation is time-consuming and evidently sensitive to instruction (Study II). Furthermore, the heavily dependable role of phoneme awareness in learning to read alphabetic orthographies is not evident in Sinhala. Phoneme awareness developed as a by-product of phoneme-level instruction focused on akshara decomposition at the later stages of reading development, and not as a critical foundational skill for akshara learning. Instead, akshara knowledge is strongly associated with reading proficiency in Sinhala, and other alphasyllabaries as well, that continues to have a dominant role at the end of the elementary grades, again something not seen in alphabetic orthographies. Finally, the results of the studies in this dissertation suggest that the current Anglocentric focus of reading science (Share, 2008) is largely insufficient in explaining the nature of the reading acquisition and development in nonalphabetic writing systems and the existing reading models and theories need to be revisited and modified in the light of the research findings in alphasyllabaries in order to capture a more complete picture of what affects reading and to understand the language-universal and script-specific characteristics of reading.

In terms of practice, the pivotal role of akshara knowledge in learning to read and the large influence of symbol-level characteristics in akshara recognition should be taken into account in reading instruction. Provision of explicit phoneme-level instruction in akshara formation for the beginning readers could be beneficial and would need to be contrasted in future studies with the current practice of waiting until children reach Grade 5. Using a more analytic approach to akshara learning might lessen students'confusion around primary and secondary forms of akshara and help them to learn the regularities and irregularities of akshara formation much quicker. Early instruction on analyzing akshara into their constituent phonological and orthographic components may also alleviate the challenges imposed by the visual and phonological complexities of the symbols. In identification and assessment of reading

difficulties, an array of factors related to linguistic, cognitive and environmental domains need to be considered because of the relative importance of orthographic, phonological and environmental factors differ in different stages of reading development and is moderated by the nature of instruction and the characteristics of the language.

Conclusion

Comparing the precursors and the outcomes of symbol learning and word decoding in Sinhala with what has been reported in English, the results of the studies in the dissertation suggest that children master these two writing systems differently. Akshara learning and learning to decode words in Sinhala are prolonged processes that continue side by side to the end of the primary school years and likely beyond. Learning the large set of visually and phonologically complex akshara incurs a processing cost that likely impacts other aspects of literacy learning. Akshara knowledge is the most important predictor of learning to read in Sinhala and other Indic alphasyllabaries. Future research is required to examine the influence of symbol- and child-level factors on akshara recognition in more depth given the resource demanding nature of akshara learning.

To end this dissertation, I would like to call for more scientific research. Though the number of research studies conducted in akshara orthographies is steadily rising, the current reading instruction methods in Sinhala, and evidently in many other alphasyllabaries as well, are more informed by tradition than by research evidence. In the absence of well-controlled large scale educational experiments, it is impossible to close the gap between ‘what we think is right’ and evidence-based literacy instruction. We urgently need well-controlled large scale educational experiments in all aspects of literacy acquisition and development in Sinhala in order to build evidence-based policy and practice for future generations of students.

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