The Role of Phonological Processing and Oral Language in the Acquisition of Reading Skills in Devanagari

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Abstract We examined the relative contributions of phonological processing and oral language on word and non-word reading abilities in Devanagari in 230 children from grades 1 to grade 5. Phonological skills were assessed using tasks of rhyming and syllable replacement while oral language was assessed using semantic and verbal fluency. Phonological awareness made independent contributions to word reading across all grades. In addition, across grades 1 and 2, akshara recognition significantly explained word reading while in grades 3–5, oral language fluency was uniquely associated with word reading performance. Our study provides new insights on reading acquisition in Devanagari and adds to a growing body of literature on reading in akshara orthographies.

Keywords Akshara · Devanagari · Fluency · India · Oral · Orthography · Phonological

Introduction

In recent years, there has been an upsurge of studies that investigate word recognition in akshara-based orthographies prevalent across South and Southeast Asia (Nag & Perfetti, 2014; Share & Daniels, 2016). Findings from these studies have suggested that the processing of akshara-based orthographies, which have origins in Brahmi, are neither syllabic nor phonemic but unique in many ways (Share & Daniels, 2016). A vast variety of Indic languages use the akshara based writing system and past research focused on reading in such systems has primarily explored how the structure of the writing system influences reading in akshara based

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languages. However, relatively little research has focused on the role of oral language, in learning to read in akshara based orthographies. It is well known that the successful acquisition of reading in any language is jointly explained by spoken language and its writing system (Perfetti, 2003). Here we examine how the relative contributions of features of oral language and writing systems modulate word recognition in Devanagari, an akshara-based orthography.

The writing system that a language uses affects acquisition of literacy because each system is based on a different set of symbolic relations and requires different cognitive skills (Coulmas, 1989). Devanagari is an akshara based orthography, reported to be accessed by a population of over 200 million Devanagari readers (Census 2011). Devanagari is used to write several languages in North India including Hindi, Sanskrit, Marathi, Nepali, Bihari, and Konkani. The basic symbolic unit in Devanagari is an akshara (Bright, 2000) which can be a vowel, or a consonant with either an inherent vowel or a diacritic representing the vowel, or a combination of two or three consonants with a vowel (Karanth, 2006). Basic consonant aksharas represent CV syllables with an inherent /ʌ/ or schwa. Word-initial vowels are written using basic vowel aksharas, while others are typically represented by diacritics written to the right, left, top or bottom of the preceding consonant. Geminates and conjunct consonants are represented by ligaturing a secondary form of one consonant onto the basic akshara of the other. For example, the basic aksharas द –/d̪ʌ/ and न – /nʌ/ combine with vowel diacritics ू and ी (/u:/ and /i:/ respectively) to produce दून (/d̪u:n/, meaning *valley*) and नदी (/nʌd̪i:/, *river*), while the word-initial /u:/ is written using the akshara ऊ in ऊन (/u:n/, *wool*). The secondary form ◌् representing न is ligatured onto द in नन्द (/nʌnd̪/, *joy*), and the secondary form ◌ी (standing for र, /rʌ/) is ligatured onto श (/ʃʌ/) in दर्शन (/d̪ʌrʃʌn/, *view*) (Rao & Singh, 2015). The most prominent feature of Devanagari is its visuospatially complex layout, arising from the nonlinear arrangement of vowels as well as consonant ligatures (see examples above). Similar to other Indic writing systems, successful phonological retrieval in Devanagari requires accurate deciphering of visuospatial details.

Psycholinguistic studies investigating the nature of phonological processing in Devanagari have been scarce, and the sole study on segmentation in Devanagari by native Hindi speakers has suggested a partly phonemic and partly syllabic level of segmentation (Vaid & Gupta, 2002). Children who begin to read in Devanagari are exposed to aksharas as whole units and do not receive explicit instruction in phonemic segmentation but still learn to read successfully. Assessment of the orthography of a writing system typically is done through tasks of phonological processing and letter identification while spoken language is assessed using measures of picture naming and fluency. In the present study, we used measures of rhyming and syllable replacement to assess phonological processing and semantic and verbal fluency, to ascertain how features of oral language and phonological processing influence word recognition in Devanagari in children between 5 and 10 years of age.

The role of phonological awareness in learning to read alphabetic languages is now well established, and it is known that phonological awareness proceeds from large units to smaller units —namely from awareness of syllables to phonemes (Carroll, Snowling, Hulme, & Stevenson, 2003; Treiman & Breaux, 1982). However, in order to develop robust phonological skills, early readers of alphabetic languages need to acquire letter knowledge and phoneme awareness (Byrne, 1998; Share, 1995). Only then will they be able to efficiently map the units of print to those of sound. Since phonemic information is embedded and often not explicitly taught in the classroom, an alternative view has suggested that phoneme awareness is a consequence rather than a precursor of learning to read (Castles & Coltheart, 2004; Goswami & Bryant, 1990; Morais, Carey, Alegria, & Bertelson, 1979).

However, the precise role of phonological awareness in reading akshara-writing systems continues to emerge and is a subject of active interest and research. The structure of the akshara orthographies is such that they primarily encode sounds at the syllable level. The sub-syllabic information is encoded in matras or diacritics and does not have a uniform representation. The matras are 'vowel phonemic markers' and in spatial representation may be located below or after, above or below the consonant. Further, when represented as diacritics, the 'matras' do not clearly resemble their original representations, and this adds to the symbolic inventory that needs to be learned during the process of reading acquisition. Studies that have investigated these complex ortho-phonological properties of aksharas have shown that both syllable and phoneme awareness are predictive of word decoding (Joshi, 2014; Nag, 2007; Reddy & Koda, 2013; Sircar & Nag, 2013; Tiwari, Nair, & Krishnan, 2011), but that syllabic awareness is acquired more rapidly as compared to sub-syllabic information (Nag, 2007; Vasanta, 2004). Interestingly, studies with monolingual Oriya (another akshara orthography) speakers have indicated that only syllable awareness was predictive of word reading (Mishra & Stainthorp, 2007). However Reddy and Koda (2013), who found that both syllabic and phoneme awareness predicted Kannada decoding, also reported that phoneme-level awareness did not contribute unique variance to decoding when introduced after syllable-level awareness in a step-wise regression model of Kannada reading. These studies seem to suggest that while syllabic and phonemic awareness influence word decoding in Devanagari, the role of syllabic awareness is more important, especially during early reading acquisition. These studies also suggest that the precise nature of the syllabic and phonemic relationship in akshara decoding may vary across Indic languages. Thus the two primary challenges while learning to read akshara orthographies are (1) the large inventory of symbols/syllabographs that are required to be learned (Nag, 2007) estimate this to be as high as 400 in Kannada and (2) the complex visuo-spatial representation of the script. At the same time, a distinct advantage in akshara orthographies include the consistency of akshara-sound mapping and the fact that the basic sound unit is a syllable that is easily identifiable. The acquisition of a large symbol set in addition to the complex visuo-spatial nature of the writing system prolongs the process of word reading (Nag, 2007) and prompts one to speculate that relative contributions of phonological and orthographic processes might be age- and instruction-dependent.

Finally, it is universally acknowledged that the successful acquisition of reading in any language is jointly explained by spoken language and its writing system (Perfetti, 2003). Thus, a third factor that will also impact reading skill and later reading comprehension is vocabulary or oral language skill (Ouellette, 2006; Ouellette & Beers, 2010; Perfetti & Hart, 2002; Scarbourgh, 2001; Sénéchal, Ouelette, &

Rodney, 2006). Past studies on decoding in akshara orthographies have been unable to establish a clear pattern for oral language in reading acquisition. According to the Simple View of Reading (SVR), the ability to decode words into constituent sounds and language comprehension are two necessary skills to achieve reading comprehension (Gough & Tunmer, 1986; Hoover & Gough, 1990). Past research has shown that each of these competencies makes independent contributions to reading comprehension (Kendeou, van den Broek, White, & Lynch, 2009). While in the early grades the relative contribution of decoding skills is higher, language comprehension skills become increasingly important after decoding is proficient (Byrne, Freebody, & Gates, 1992; Florit & Cain, 2011; Hoover & Gough, 1990; Tilstra, McMaster, van den Broek, Kendeou, & Rapp, 2009). We therefore propose that an investigation of word recognition in an akshara system in young children should include an assessment of the relative roles of vocabulary and phonological processing. In light of the consistency of akshara-sound consistency, coupled with the visuo-spatial complexity of the akshara orthography, we hypothesized that for beginning readers, akshara recognition should take precedence over phonological processing and oral fluency in explaining word recognition. However, as children achieve akshara recognition skills, we speculated that oral vocabulary skills and phonological processes would independently contribute to word recognition.

Methods

Participants

Devanagari is used as a writing system for multiple Indian languages (e.g., Hindi, Marathi, Konkani, Bihari and Nepali), and data for this study were collected from young learners of both Hindi and Marathi. The forms of Devnagari used by Hindi and Marathi are identical in every way except for the addition of one akshara /ळ/ used in the Marathi language. The data presented in this study were part of a larger scale survey of literacy skills conducted in primary and middle schools in the cities and neighboring districts of the National Capital Region (New Delhi and its surrounding areas) and the city of Allahabad located in the state of Uttar Pradesh in the northern part of India. The Marathi data were collected from Mumbai and Pune in the western part of India. Hindi is the dominant language in areas in and around New Delhi while Marathi is the dominant language of Maharashtra to which both Mumbai and Pune belong. Consent for the study was obtained from parents of the children as per the norms prescribed by the Human Ethics Committee of the National Brain Research Centre.

Data were collected from 28 schools. In order to reflect the profile of the socioeconomic status (SES) in these regions, the survey sample comprised children from a mix of schools: 20.2% from upper SES, 70% from middle and 9.8% from lower SES. Schools in the Delhi region were under a common curriculum, namely, the Central Board for Secondary Education (Department of Elementary Education and Literacy & Department of Secondary and Higher Education, 2005) while schools in

Table 1 Demographic information by language

	Hindi	Marathi
Number of schools	18	9
Number of participants	130	100
Gender information	64 F, 66 M	55 F, 45 M
Grade 1–2	39	36
Grade 3–5	91	64

the Mumbai and Pune regions were under another common curriculum, namely, the State Board Curriculum (Department of Elementary Education and Literacy & Department of Secondary and Higher Education, 2005) However, to a large extent, schools followed a similar reading program. In these schools, formal literacy instruction for Hindi and Marathi began in grade 1, between the ages of 5 and 6 years. As per the education policy, many of the schools were also required to introduce English in grade 1. Data were collected from children across grades 1–5 (Grades 1–2 n = 75, M_{age} = 7.1, SD = 0.8; Grades 3–5 n = 155, M_{age} = 9.6, SD = 1.1). A detailed description of the sample is provided in Table 1. The analysis presented here describes the children who displayed no reading difficulties and formed a chronological group from each grade. An exhaustive battery of tests was administered for every child participating in the survey and is described in the next section.

Assessments

General Cognitive Ability

This was assessed using Raven's Coloured Progressive Matrices. General ability is reported in percentile scores based on Indian norms (Raven, 2004).

The battery of behavioral tests may be broadly divided into three groups, namely, reading (akshara, word list 1, word list 2, and non-word), phonological processing (rhyme and syllable replacement), vocabulary (verbal fluency and semantic fluency) and picture naming. While the phonological processing, vocabulary, and picture naming tests were common across all the children, the reading tasks were varied. Grades 1 and 2 read completed akshara reading and word list 1, while grades 3 to 5 completed word list 2 and non-word reading.

Literacy Skills

Akshara Knowledge

Children read 10 aksharas comprising no specific phoneme markers. The list of aksharas in Hindi and Marathi was identical, and included 3 vowels and 7 consonants. Cronbach's alpha was .68.

Word Reading 1(Grade 1–2)

Each child was asked to read a list of 25 words arranged in increasing order of difficulty. The list contained 3 syllabographs monosyllabic words, 13 bisyllabic words, 6 trisyllabic words, and 4 polysyllabic words. Correct reading of an item was given an accuracy score of 1. Cronbach's alpha was 0.90.

Word Reading 2 (Grade 3–5)

Each child was asked to read aloud a list of 50 words and all words were arranged in order of increasing difficulty. Cronbach's alpha was 0.90.

Non Word Reading (Grade 3–5)

Each child was asked to read aloud a list of 30 words. All items had been constructed by replacing one or more akshara and/or the consonant or vowel component or a real word in the respective language. The non word list was arranged in order of increasing difficulty of decoding. Cronbach's alpha was 0.82.

Phonological Awareness Tasks

Rhyming

A total of 12 sets of triplet of words were presented in each language (e.g., Hindi: नाम(nam)-काम(kam)-नील(nil)); Marathi: गोल(gol)-मोल(mol)-तोड़(tod)). Participants were required to listen 3 set of words carefully, and then say the two words that end with the same sound. Cronbach's alpha was 0.81.

Syllable Replacement

In the syllable replacement task, participants were instructed to replace the syllable at the beginning or end of a given word in Hindi or Marathi. The task consisted of 10 items in each language. Cronbach's alpha was 0.77.

Picture Naming

This test was common across the grade 1–5. The objective of the picture naming task was to assess the speed of retrieval and production of the phonology (sound) of whole words. The Picture Naming Tasks in both Hindi and Marathi made use of line drawings of five common objects (shoe, flower, house, chair, and key) where the participant had to identify and name the objects shown on the card, using only the task language.

Fluency

This test was common across grades 1–2 and grades 3–5. The Fluency Test had two sub-tests, namely, Verbal Fluency Test and Semantic Fluency Test.

Participants were given 1 min to produce as many unique words as possible within a semantic category (animals and vegetables) or starting with a given akshara (verbal fluency). Fluency tasks have emerged as important tools to assess both lexical access ability as well as executive control ability. These tests are designed to assess both verbal (sound-based) and semantic (meaning-based) long term memory. These tests also provide the information on the vocabulary of the participants. The sound and category fluency task differ in subtle but important ways in task demands. While the category fluency task may be compared to a shopping list, that can exploit existing links between related concepts (e.g., between the category label and the category members and among associated category members) the sound (verbal) fluency task, requires words with a same initial sound to be retrieved. Thus participants must consciously inhibit semantically or associatively related words and must instead employ novel retrieval strategies (e.g., Luo et al., 2010; Katzev et al., 2013).

Procedure

Each child was assessed individually for approximately 90 min (the testing battery included tests of oral language, picture naming, reading, phonological processing, dictation, and reading comprehension (some of which are not reported here) by a clinical psychologist and four research assistants who were native speakers of Hindi and/or Marathi and were trained to administer the tests.

Results

Only children who completed all 9 tasks were included in the analysis. All children from grades 3–5 were at ceiling level for the akshara identification task, and this task has not been included in the analysis for grades 3–5. Table 1 describes data by language and grade.

Based on the tests administered, data children from grades 1–2 (mean age = 7.1, SD = 0.8)) were combined into group 1 and those from grades 3–5 (mean age = 9.6,

Table 2 Descriptives of picture naming, phonological processing, and reading measures

	Grade 1–2, N = 75		Grade 3–5, N = 155		t-test
Measure	*Mean*	*SD*	*Mean*	*SD*	*P value*
CPM	106.7	11.1	109.2	9.8	NA
Picture naming (time in seconds)	61.4	17.4	52.0	10.2	<0.001
Semantic fluency	14.6	4.7	18.7	5.3	<0.001
Verbal fluency	9.8	4.0	14.1	5.2	<0.001
Rhyme (12)	10.1	1.9	11.1	1.3	<0.001
Syllable replacement (10)	8.4	1.6	9.3	1.2	<0.001
Letter Reading (10)	9.3	1.1	NA	NA	NA
Word Reading (25) (50)	21.4	4.4	44.0	6.5	NA
Non word Reading (30)	NA	NA	24.9	4.8	NA

Note. NA-Not applicable.

SD = 1.1) were combined to form group 2. We describe in Table 2 means and standard deviations of groups 1 and 2, respectively, on all tasks. The data reported here are for only those participants who showed reading accuracies above 60 percent in their grade. The picture naming scores are reported in terms of time taken to complete the task in seconds.

Bivariate Correlation Analysis

In order to ascertain sub-skills which might theoretically play a causal role in determining reading performance in word and non-word reading, we first examined correlations between various behavioral skills and reading performance. Bivariate correlations across all measures were performed and revealed several significant trends shown in Tables 3, 4, and Fig. 1. Fluency skills of semantic and verbal fluency were all highly correlated. Phonological skills of syllable replacement and rhyming also showed a strong significant correlation. Correlations between measures of fluency and phonological processing suggested that while fluency and phonological processing both explained word reading, phonological processing might be a stronger correlate as compared to fluency.

In terms of phonological skills, rhyming and syllable replacement both explained Hindi word reading and non-word reading almost equally. To understand this phenomenon better, hierarchical regression analyses were computed.

The correlational analyses clearly established that akshara reading, phonological processing, and fluency were moderately associated with reading and decoding outcomes in Devanagari. In order to test the relative contributions of each sub-skill, we conducted stepwise regression analyses. Since the bivariate correlational analyses showed strong correlations among semantic and verbal fluency and syllable awareness and rhyming, composite measures for fluency and phonological awareness (PA) were obtained. Fluency was an average measure of semantic and verbal fluency

Table 3 Correlations among measures for group 1 (Grade 1–2, mean age M 7.1, SD = 0.8)

	Picture naming	Semantic fluency	Verbal fluency	Rhyme	Syllable replacement	Letter reading	Word reading
Picture naming	1						
Semantic fluency	−.26*	1					
Verbal fluency	−.13	.38**	1				
Rhyme	.01	.09	.25*	1			
Syllable replacement	.02	.08	.32**	.32**	1		
Letter reading	−.19	.23*	.30**	.05	.37**	1	
Word reading	−.27*	.42**	.35**	.23*	.29*	.67**	1

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

Table 4 Correlation measures for group 2 (Grade 3–5, mean age = 9.6, SD = 1.1)

	Picture naming	Semantic fluency	Verbal fluency	Rhyme	Syllable replacement	Word reading	Non word reading
Picture naming	1						
Semantic fluency	−.26**	1					
Verbal fluency	−.19*	.31**	1				
Rhyme	−.11	.24**	.10	1			
Syllable replacement	.10	.16*	.14	.23**	1		
Word reading	−.11	.17*	.25**	.26**	.30**	1	
Non word reading	−.12	.16*	.18*	.29**	.25**	.82**	1

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

scores and PA was an average measure of rhyme and syllable replacement scores. Composite measures were used for fluency and phonological awareness (PA) as unique correlates for word reading.

In all stepwise regression analyses, non-verbal intelligence was entered as a covariate at the first step. Table 5 describes the hierarchical regression models for grades 1–2. It was found that irrespective of the order of entry, letter reading, fluency and phonological awareness (PA) were significant correlates of word reading.

Table 6 describes the hierarchical regression models for grades 3–5. Irrespective of the order of entry, both phonological awareness (PA) and fluency were significant predictors of Devanagari decoding. The same effects were seen with non-word reading too as reflected in Table 7. It may therefore be proposed that learners' awareness of the syllabic akshara is significantly related to the decoding ability in Devanagari.

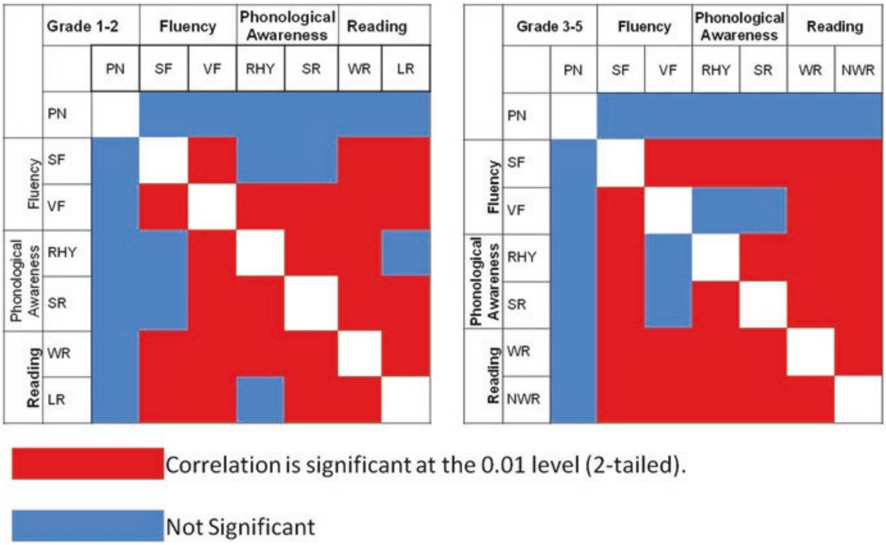

Fig. 1 Correlations for Grades 1–2 and Grades 3–5
Note. PN Picture Naming, *SF* Semantic Fluency, *VF* Verbal Fluency, *LR* Letter Reading, *WR* Word Reading, *NWR* Non Word Reading

Table 5 Stepwise regression models predicting word reading for grade 1–2

	ΔR^2	ΔF	p
Model 1			
CPM	.00	.31	.58
Letter reading	.45	59.71	.00
Fluency	.07	10.88	.00
Phonological awareness	.02	2.42	.12
Model 2			
CPM	.00	.31	.58
Letter reading	.45	59.71	.00
Phonological awareness	.03	4.32	.04
Fluency	.06	8.73	.00
Model 3			
CPM	.00	.31	.58
Fluency	.22	20.29	.00
Phonological awareness	.04	3.97	.05
Letter reading	.28	42.88	.00
Model 4			
CPM	.00	.31	.58
Phonological awareness	.10	7.92	.01
Fluency	.16	15.57	.00
Letter reading	.28	42.88	.00

Table 6 Stepwise regression models predicting word reading for grade 3–5

	ΔR^2	ΔF	P
Model 1			
CPM	.01	.95	.33
Fluency	.06	10.29	.00
Phonological awareness	.09	15.84	.00
Model 2			
CPM	.01	.95	.33
Phonological awareness	.12	21.23	.00
Fluency	.03	5.30	.02

Table 7 Hierarchical regression analysis predicting non word reading for grade 3–5

	ΔR^2	ΔF	P
Model 1			
CPM	.01	1.14	.29
Fluency	.04	6.96	.01
PA	.09	15.57	.00
Model 2			
CPM	.01	1.14	.29
PA	.12	19.95	.00
Fluency	.02	2.99	.09

It is noteworthy to mention that fluency also contributed significantly to word recognition in grades 3–5.

Discussion

This study investigated the predictors for reading among 5- to 11-year-old children, divided into two groups based on grade levels, learning to read in Devanagari, an akshara-based writing system. Hindi and Marathi both use the Devanagari script, which is a consistent orthography yet at the same time requires an extensive set of visuo-spatially complex symbols and syllabographs to be mastered. However given the visuo-spatial complexity of the symbols which form a large set, learning to read in Devanagari is quite challenging. Our first finding was that picture naming, phonological skills, and fluency showed distinct age effects. Since identical tasks were used across groups, we were able to estimate age effects and not surprisingly we found significantly increased performance for rhyming and syllable replacements across groups 1 and 2. Similarly, vocabulary was significantly larger in children belonging to group 2 as compared to group 1.

The primary objective of this study was to delineate the roles of phonological processes, and oral fluency in explaining reading performance in Devanagari. The most consistent finding of our study was the finding that oral fluency or vocabulary emerged as the most consistent independent correlate for word reading in Devanagari. Bivariate correlational analyses followed by hierarchical regression analysis indicated that oral fluency emerged as an important independent predictor for word reading skills across groups 1 and 2. However for group 1, as seen in Table 5, the variance in word reading was primarily determined by akshara knowledge but in group 2, it was determined by phonological processing. Given the transparent nature of the akshara-sound mapping, the finding that phonological awareness was a strong predictor for reading was not surprising. The finding that PA explained both word and non-word reading almost equally confirms its role in decoding in consistent orthographies.

With regard to fluency, a noteworthy finding was its role in explaining the variance in word reading but little change in the prediction of non-word reading performance. The role of oral language fluency in reading fluency has been well established (NICHD, 2005). The results of a longitudinal study wherein children were followed from age 3 through third grade, suggested that oral language broadly plays both a direct and an indirect role in word recognition and during the transition to school and serves as an excellent foundation for early reading skill (NICHD, 2005).

In summary, our results corroborate findings from other recent akshara reading studies particularly from Kannada which indicate an important role for phonological information encoded at the syllabic level in akshara systems (Nag & Snowling, 2012, Nakamura, Koda, & Joshi, 2013). However our second finding of a role for oral language is noteworthy though not surprising. In recent years a large body of work has revived an interest in the role of oral language in reading acquisition. A recent review by Nag et al. (2014) commissioned to address issues pertaining to foundation learning and literacy, from early childhood to Grade 8 (approximately 3–13 years) concluded that children with poor oral language were at a high risk for reading and education failure that included both numerical and scientific thinking. Critical to recognizing words is the ability to connect graphemic units to phonological segments. However, decoding the pronunciation of a word may not yield lexical understanding, and, therefore, vocabulary knowledge is also an important skill in learning to read.

Finally we evaluate our findings in the terms of psycholinguistic grain size theory proposed by Ziegler and Goswami (2005). One of the primary advantages of the akshara based writing system has been the availability of orthographic units or writing symbols at the level of the akshara. The syllable provides a concrete/tangible platform for the early reader who can readily map a spoken syllable to an orthographic unit. This process is facilitated further by the transparency of the mapping. The sound-symbol mapping in Devanagari is consistent to a large extent. This is beneficial during early learning because if akshara identification is systematic and thorough, children begin to appreciate early on the fun and joy of learning to read. However as pointed out by other studies (Nag, 2007; Nag, Treiman, & Snowling, 2010), it is the mastery of the low-frequency symbols that sets the pace of development in reading and spelling.

A limitation of this study was the absence of a specific task on phonemic awareness. Past research on akshara orthography has suggested that only syllabic awareness (Mishra & Stainthorp, 2007) is important in akshara decoding, while others have demonstrated that phonemic awareness correlates with reading and spelling scores (Nag, 2007); others have suggested that the role of phonemic awareness reduces with age. Unfortunately this study was unable to resolve this debate in the context of Devanagari.

A second limitation of this study was the absence of a task on orthographic processing. The acquisition of decoding skills is necessary not only for processing novel words in reading but also to generate orthographic strings in spelling. Thus in order to achieve skilled visual reading, children are also required to achieve visual processing and discrimination abilities. While children's orthographic knowledge and letter knowledge are causal factors in subsequent reading development in English (e.g., Badian, 1994; Lonigan et al., 2000), phonological processing abilities have emerged as the best predictors for reading in English. However, visual skills have emerged as stronger and more reliable predictors for reading in Chinese when compared to English (e.g., Huang and Hanley, 1994, 1995; Ho and Bryant, 1997; Siok and Fletcher, 2001; Mcbride-Chang and Ho, 2005; Luo et al., 2013). Given the visual complexity of the aksharas of Devnagari, it is crucial that that visual processing be examined in greater detail in Devnagari. We hope future research will attempt to include tasks on orthographic processing to provide a more holistic picture of reading in Devnagari. Finally, the data used in this study were cross-sectional and could therefore not provide causal links between reading and other related cognitive skills. Despite these limitations, this study adds to a growing body of literature on the akshara orthographies (Nag & Perfetti, 2014; Share & Daniels, 2016).

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