Psychology of Language and Communication 2018, Vol. 22, No. 1

DOI: 10.2478/plc-2018-0022

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READING ALPHASYLLABIC HINDI: CONTRIBUTIONS FROM PHONOLOGICAL AND ORTHOGRAPHIC DOMAINS

Phonological and orthographic processing are important cognitive skills required in reading. The present study attempts to investigate the role of phonological processing and orthographic knowledge, in reading alphasyllabic Hindi orthography. The sample constituted 65 children from Grade 4. The result of hierarchical multiple regression indicated that the variance in reading fluency was significantly explained by phonological processing and orthographic knowledge measured through the tasks of rapid automatized naming, syllable deletion and dictation. The variance in reading accuracy was significantly explained only by orthographic knowledge measured through a dictation task. Phonological short-term memory showed significant correlations with all the reading measures but was non-significant in explaining the unique variance in reading. The limitation of the study and suggestions for future research is discussed.

Key words:semantic Alphasyllabic, Phonological awareness; Rapid automatized naming, Spoonerism

Introduction

The importance of phonological processing in reading has been widely acknowledged in alphabetic languages (Goswami, 2011; Moll et al., 2014; Patel, Snowling, & de Jong, 2004; Ramus et al., 2003; Shanbal, Goswami, Chaitra, & Prathima, 2010; Shankweiler, 1999; Wagner, Torgesen, & Rashotte, 1994). Phonological processing is the ability to understand the structure of speech sounds and use this information while processing of oral and written language (Siddaiah & Padakannaya, 2015; Wagner & Torgesen, 1987). It has been explored for its perceived role in reading from three angles: awareness

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of different speech sounds, capacity to store sound-based information, and, quick retrieval of lexical information (de Jong & van der Leij, 1999; Hulme & Snowling, 2009; Wagner et al., 1987; Wagner & Torgesen, 1987). Initial research predominantly came from alphabetic languages with substantial orthographic variations regarding shallowness/depth and regularity. In shallow orthographies, single phoneme map onto single grapheme showing the direct and consistent relationship. On the other hand, in the deep orthographies, the visual representation of the higher level linguistic units remain invariant but their pronunciation is context dependent. An orthography which is deep can still be a regular if it provides a complete set of pronunciation rules including context-dependent changes (Scheerer, 1986). Some orthographies show unidirectional regularity as in the case of the German language; it is regular in grapheme to phoneme mapping but irregular in phoneme to grapheme mapping (Wimmer & Schurz, 2010). These variations among different alphabetic orthographies showed a modulating effect on the process of reading (Aro, 2004; Georgiou, Parrila, & Papadopoulos, 2008; McDougall, Brunswick, & Davies, 2010).

Orthographic variations have influenced the reading process in two ways; one, it affects the trajectory of reading development, and, second, it affects the involvement of the cognitive skills (Moll et al., 2014; Ziegler & Goswami, 2005; Ziegler, Pech-Georgel, Dufau, & Grainger, 2010). In one comprehensive study, that included 13 alphabetic languages with varying consistency, it was reported that in the consistent orthographies, most of the children showed a ceiling effect in reading accuracy at the end of grade I whereas children in the opaque languages still struggled with many of the complex aspects of the language (Seymour, Aro, & Erskine, 2003). In another study, the predictability of phonological awareness, phonological short-term memory and rapid naming were measured at different stages of reading (from Grade 1 to 4) in three different languages; Hungarian, Portuguese and Dutch (Vaessen et al., 2010). In this study, it was found that across orthographies, phonological awareness was the strongest predictor of reading for beginning readers, and RAN showed the better predictability in the later phase of reading when readers become experts. The rate of reading development differed in all the three languages, but it was only the phonological awareness that was modulated by the orthographic variation. Similarly, Landerl et al., (2013) looked at how dyslexics and typical readers differed in the cognitive skills involved in reading considering 6 different alphabetic languages. They observed the mediating role of the orthographic depth in their study and concluded that phoneme deletion and RAN were significant concurrent predictors of reading in all the languages and so as to identify the cases of dyslexia. But, this trend was more apparent in opaque than in transparent orthographies. Apart from these, the modest role of phonological short-term memory in predicting reading was also reported.

In yet another study done on an orthographically distinct Korean Hangul language, that shows the typological combination of alphabetic and syllabic orthographies, children from Grade 1 to 4 were tested on reading-related tasks and their cognitive skills. Phoneme awareness was seen to be the most important predictor of reading accuracy (words as well as for non-words) in Grade 1 and 2, but in Grade 3 and 4, it got replaced by receptive vocabulary (Park & Uno, 2015). On the other hand, fluency of reading was best predicted by naming speed and receptive vocabulary but not by phoneme awareness. The reduced importance of the phonological awareness in reading especially in grade 3 or 4 was attributed to consistent grapheme-phoneme mapping in Hangul.

The differential involvement of cognitive skills may also be the result of the reading strategy adopted by the readers of different orthographies. Katz and Frost, (1992) in their "Orthographic Depth Hypothesis" proposed that in shallow orthographies, the grapheme-phoneme invariance helps the readers to rely more on the phonology of the language, whereas readers in deep orthographies depend more on morphology or visual orthographic feature for word recognition. Computational models of reading also validated the dual-route approach of reading (Ziegler, Bertrand, et al., 2010). In one study conducted on the young Japanese children, who were learning either Kanji (kind of logographic phonemic) or Kana (a syllabic language); and it was noted that their reading trajectory was quite different. It was attributed to the different reading strategy adopted by the two groups of readers (Uno, Wydell, Haruhara, Kaneko, & Shinya, 2008). In transparent syllabic Kana, there was greater reliance on the phonological strategy whereas children reading Kanji adopted the visual orthographic strategy (Uno et al., 2008; Wydell & Butterworth, 1999).

The prevalence of reading disability is quite different in different orthographies. For example, in alphabetic orthographies, it ranges from 5-17.5% (Shaywitz, Morris, & Shaywitz, 2008; Shaywitz & Shaywitz, 2008). Primarily, the difference in prevalence is attributed to the definition criteria of dyslexia adopted in different studies. However, the orthographic depth may also affect the ease of reading that in turn affects the manifestation of dyslexia. In one of the studies, the standard defining criteria were used for selecting the dyslexic children from two different languages; the Italian and the English (using the standard behavioural definition of word recognition accuracy in relation to IQ). The prevalence rate of dyslexia was substantially lower in Italian children than American children reading English when the mild defining criterion of dyslexia was used. The prevalence rate rose almost double in American children in comparison to Italian children when stringent defining criteria of dyslexia was used (Lindgren, Renzi, & Richman, 1985) Even within a variant of Japanese language of Hiragana, Katakana (having syllabic properties) and Kanji (having logographic property), the prevalence rate was noted to be quite different i.e. 0.2%, 1.6% and 6.9%

respectively (Uno et al., 2008). The other reason for this difference could be that the orthographic consistency may affect the ease of reading that may, in turn, affects the manifestation of dyslexia.

Despite the differential involvement of cognitive skills, one of the consistencies in different findings is the importance given to phonemic level processing in reading (Caravolas et al., 2012; Carroll, 2004; Castles & Coltheart, 2004; Landerl et al., 2013). The significance of phonemic level awareness is also noted in the case of at-risk dyslexic readers, who benefitted significantly as a result of the training in phoneme awareness coupled with letter knowledge (Elbro & Petersen, 2004; Schneider, Roth, & Ennemoser, 2000). In the *dual route cascaded computational models of visual word recognition*, the presence of phonemic representation in both the routes (lexical and non-lexical) for word production is also significant (Coltheart, Raste, Perry, Langdon, & Ziegler, 2001). In this model the *Letter identification* acted as input for word recognition and *phonemic representation* was important for word pronunciation.

Apart from alphabetic languages, in some of the alphasyllabic languages also, phonemic processing skill is observed to be significantly correlated with reading (Nag & Perfetti, 2014). Alphasyllabic languages show the characteristic features of alphabetic as well as the syllabic orthographies (For details of other alphasyllabic languages, see Daniels & Bright, 1996). Graphemes (called akshara) represent phoneme as well as syllable unlike most of the alphabetic languages in which letters correspond to phonemes. Apart from this hybridity, most of these alphasyllabic languages have the orthographic complexity that affects fine-grained phonemic processing (Nag & Perfetti, 2014). In Kannada alphasyllabary, for example, it was found that phonemic processing (measured through phoneme substitution task) developed very slowly when children of Grade 1, 2 and 3 were compared at two different times (Nag, 2007). In 1st grade children, the average accuracy for phoneme substitution ranged between 5-8% and in Grade 3 it ranged between 51-58%. Despite the late development of phonemic level processing, it significantly contributed to reading accuracy of children from Grade 1 to 3. In yet another study on Kannada language, orthographic knowledge, phonemic awareness and RAN were observed as independent predictors of reading fluency whereas syllabic awareness predicted individual differences in reading accuracy (Nag & Snowling, 2012). In the same study, it was seen that good readers were always better at phonemic processing across grades. Nag and Snowling (2011) in their study also noted that phonemic manipulation was the only variable that could significantly differentiate between poor and normal Kannada readers when assessed on different phonological processing skills. In addition to phonemic awareness, akshara knowledge is seen to be significantly related to reading accuracy in many alphasyllabic languages such as in the

Bengali (Nag & Sircar, 2008) and with the overall reading skills in Kannada (Nag, 2007; Nag & Snowling, 2011a).

In some of these consistent alphasyllabic languages, an extensive list of graphemes is introduced to maintain the consistency, which can be seen in the case of Kannada, Bengali and, Hindi language (Nag, 2007, 2011). In such cases, the trajectory of reading becomes prolonged as readers have to memorise the extensive list of symbols (Nag & Perfetti, 2014). As a result, the identification of symbols, especially the complex ones, remain problematic even after finishing the period of primary schooling (Nag, 2007; Nag & Sircar, 2008; Sircar & Nag, 2014).

Hindi has a lot of similarity with Kannada writing system as both are alphasyllabic but there are differences at the level of phonology to orthography mapping and visuospatial arrangements of aksharas (Nag, 2007). At this stage, it is desired to discuss some of the linguistic aspects of the Hindi language.

Hindi is written in Devanagari script that carries the properties of syllabic as well as alphabetic orthography. This language is also debated for its orthographic categorization and as a result is attributed with the names like abugida, alphasyllabary (Bright, 1996a, 2000) and neosyllabary (Fervier, 1959 cited in Bright, 2000). Vowels and consonants both have independent symbols similar to the alphabetic orthography. Vowels are represented either as free allographs, that come in a word-initial position such as /अमर/ [əmər] or as bound allographs such as /मीरा/ [mi:rā], that come as diacritic markers attached with the preceding consonant (Rogers, 2004). All the consonants necessarily carry an unmarked schwa [ə] if they are not carrying any other bound vowel. The diacritic property of vowels combined with consonants makes it similar to abugida (Daniels, 1996). The only exception is the short vowel [ə] that does not denote itself in diacritic form but acts as a schwa. The consonants in Hindi are syllabic but they are different from pure syllabic orthographies because of the presence of a common visual marker for different syllabic sounds and also because consonant and vowel have individual identification markers. For example, the visual symbol /क/ [kə] is commonly present in different syllabic sounds such as क [kə], का [kā], कि [kI], की [ki:], कु [ku], के [ke], को [ko] and in each of these symbols consonants and vowels can be easily identified with their independent markers. The visual identification of different sounds becomes easier with the visible changes in the bound vowel allographs. This property is different from other syllabaries in which entire visual symbol changes due to change of syllabic sound (Bright, 2000).

Hindi is syllable-timed that is visible in variation in length of vowels such as [ə] is just half the length of [a:] and similarly [ki:] is just double the length of [kI]. The unit of timing chosen is the matra, which corresponds to what we now refer to as the "mora". A short vowel represents one matra, a long vowel two matras, consonants usually have half-matra and long consonants carry one matra (Rogers, 2004). Stress in Hindi does not play an important role as it does not affect the meaning of the words. The arrangement of Hindi aksharas is strictly phonetic as all the aksharas are classified by place and manner of articulation; starting from the velar sound production to palatal, then retroflex and dental and finally the bilabial sounds (Agnihotri, 2013; Koul, 2009). Usually, the formal instruction in schools starts with the introduction of the vowels and diphthongs sounds followed by consonants (Vaid & Gupta, 2002). Words in Hindi can be structured as V, C, CV, CCV, CCCV, CVV, CCVV, CVCCVC, and CCCVV units (see for detail Agnihotri, 2013). Here VV stands for long vowels or diphthong and not two vowels. Word's final syllable can be open as well as closed. Hindi has 10 vowels and 40 consonants but visually there are approximately 400 symbols to represent each possible sound contributing to its transparency (Agnihotri, 2013; Koul, 2009). The name of Akshara and their phonemic sound are identical which may facilitate their sound representation in memory as opposed to the English letters that are named differently than their phonemic sound. For example, Hindi akshara 'क' is named as /kə/ and its syllabic sound is also /kə/ but the English letter 'B' is named as /bi:/ whereas the phoneme it represents is /b/ (Carroll, 2004).

The visual representation of akshara is complex especially in the case of vowel diacritic markers that invariably take different shapes and breaks the linearity in all four directions, for example, का [ka:], कि [kI], की [ki:], कु [ku], कू [ku:], के [ke], कृ [kri] (Agnihotri, 2013). Unlike other transparent alphabetic orthographies where phonemes always map onto small grain size orthographic representations, in Hindi, there is a lack of consistency for this. There are consonant conjuncts like /क्ष/ [kshə], /त्र/ [trə], /ज्ञ/ [gnyə], and /श्र/ [shrə] that are coarser on granularity parameter as each of these represent three phonemes. On the contrary, in the case of other permitted consonant clusters, all individual phonemes are visually very clear and can be identified easily e.g. /लड्डू/ [ləddu], /इज़्ज़त/ [Izzət] etc. Similarly, in some cases, there is a mismatch between phonological and orthographic syllables, for example, in both the words गरम [gərəm] means warm, and गिरना [gIrna:] means to fall, the medial [r] visually shows the presence of schwa, but in speech, the schwa is dropped in the latter word. Similarly, the sound [r] takes invariable shapes when it is present in a consonant cluster. Sometimes, it attaches on the top of the following consonant which is similar to a diacritic marker such as in कर्त्तव्य [kərtəʊjə] means duty, while at some other places, it gets attached to the preceding consonant as slanting bar such as in क्रम [krəm] means *serial order*. Though this change of positioning is rule governed, orthographically it is confusing to the readers. It needs fine phonemic level processing and temporal sense to gauge that, in the former word; the consonant [r] र is not followed by schwa /ə/ but in the case of the latter word, the schwa /ə/ follows [r].

Some aspects of complexity in the Hindi language have been addressed in previous research, for example, the aspect of visuo-temporal disparity found in the case of the secondary vowel placement especially in the case of short vowel /I/ as in कितना [kItna:] and long vowel /i:/ in पीसना [pi:sna:] (Vaid & Gupta, 2002). In this kind of disparity, readers need additional processing time which further increases if the grapheme representing the secondary vowel crosses the syllabic boundary as in the case of स्थिति [sθItI]. In this word, the vowel [I] is attached temporally with the middle akshara थ [θ] and with the last akshara त [t]. But visually it confuses to be attached with the first consonant स [s] of the word. The author reported that the visuo-spatial complexity of the orthography causes confusion to the dyslexic readers and they committed more graphemic than the phonological errors (Gupta, 2004; Gupta & Jamal, 2006). The errors at the level of secondary vowel placements may also be an indication of the phonemic level processing difficulties. Readers need to auditorily process the individual phonemes of a syllable that is possible based on their timings. Hindi aksharas are syllabic-timed and each sound can be identified based on its temporal judgment. It is also observed that Hindi readers are required to use syllabic as well as phonemic processing strategy while reading (Gupta, 2004) that is supported even in the functional imaging study of adult readers while reading nonlinear Hindi words (Das, Bapi, Padakannaya, & Singh, 2011). The cortical activations of these readers were matching with the processing areas involved in syllabic as well as alphabetic orthographies.

On the basis of previous research findings of different languages and keeping in view the visual complexity and alphasyllabic aspect of Hindi language, we formulated the following research question:

What is the relative importance of the phonological processing (phonological awareness, phonological short-term memory and RAN) and orthographic knowledge in reading Hindi?

Method

Procedure

Our sample constituted 4th-grade children who were typical native Hindi speakers. Children in Grade 4 are expected to have a reasonable level of mastery in reading as the literature suggests that approximately 80% of the Akshara symbols are learnt by the grade 4 in Malayalam, Kannada and Hindi (Nag, 2007, 2011). Secondly, teaching starts with proper phonic based training in Grade 1 and 2 (Nag & Perfetti, 2014; Nag & Sircar, 2008). It is seen that a certain level of reading proficiency is achieved by the end of grade 3 with the exception of certain complex consonant clusters (Gupta, 2004; Gupta & Jamal, 2006). The children who participated in this study were selected from six different schools in the two northern states of India (Uttar Pradesh and Bihar). In these states, Hindi is the main language of communication. Formal learning of Hindi starts in Grade 1 in almost all the schools here in both the states with the introduction of 10 vowels followed with the syllabic consonants. Later in Grade 2, children are introduced to the concept of consonants with vowel ligatures (vowels in their secondary forms).

To be included in this study, the children had to meet the three criteria i) a score of 90 and above on the composite score of the MALIN's Intelligence Scale for Indian Children (Malins, 1969) ii) average or above average academic achievements mentioned in their academic report cards and 3) normal physical, mental, emotional and behavioural well-being as rated by teachers and parents. A total of 71 children participated in this study. Among them, 6 showed mild to severe problems in reading and writing. They read monosyllabic words with a lot of effort, naming each akshara of the word loudly and trying to join them to produce the words. In the identification of akshara with vowel ligatures task, their correct score was near zero. Therefore, we excluded their scores from the main analysis.

Finally, 65 children (26 girls and 39 boys, Mean age = 112 months, *SD* = 8.8) were included in the study. Participants were monolinguals native Hindi speakers from a middle socio-economic background. The participants were exposed to the English language formally in their schools as a second language but they were far from being fluent in it. Hindi was the language of instruction in all these schools.

Materials

For the construction of the tests, the three textbooks prescribed for children in Grade 3 by the State Board, the central boards; National Council of Educational Research and Training (NCERT) and for Sarva Shiksha Abhiyan (SSA) were used. Using these words, different tasks of *phonological processing skills* (syllable segmentation and spoonerism tasks, RAN, Forward digit span), *orthographic knowledge* (akshara identification, matra identification and dictation tasks) and *reading skills* (word and paragraph reading tasks) were constructed. 260 common words were selected from these three books to design word and paragraph reading tasks. For Dictation task, 16 words were randomly selected from a separately prepared list of 45 disyllabic words with consonant clusters either at initial, medial or final positions of the words. All the tests in this study were presented on A4 sized paper in the form of a grid to maintain equidistance presentation of aksharas with Mangle font size 20.

Akshara Identification (AKI). This test was constituted with 7 primary vowels and 24 consonants with inherent schwa vowel and 3 consonant conjuncts (includes three phonemes). Aksharas were taken from all possible categories of velar, palatal, retroflex, dental, labial, approximants, sibilants, glottal fricatives and retroflex flaps present in Hindi. Aksharas were randomly presented in 15 rows with 5 aksharas in each row, and no akshara was repeated in a row. One pair of phonetically close aksharas (same place of articulation) was kept in 10 rows, for example, [kə] क and [gə] ग and one pair of visually close aksharas were kept in rest of the five rows, for example, [mə] म and [bhə] भ. For each row, children encircled the target akshara that was aurally presented to them. Maximum and minimum score for this test was 15 and 0 respectively. Reliability (Cronbach's α) could not be calculated as there was a ceiling effect noted for this measure.

Matra Identification (MI). For this test, 36 consonant aksharas with vowel ligatures were considered, for example, the akshara [kI] कि has [k] and [I] sound. Aksharas were presented in 9 rows with 4 aksharas in each row. The vowel sound was aurally presented and children encircled the akshara with which the aurally presented vowel was attached in the form of secondary allograph. Maximum and minimum score for this test was 9 and 0 respectively. The reliability (Cronbach's α) was .54.

Dictation of Words with Consonant Clusters (Dic). This test was constituted with 16 disyllabic words with consonant clusters appearing at either in the initial, medial or the final positions, for example, ध्यान /dhja:n/, मच्छर /məchchər/, कुत्ता /kutta:/. These words were aurally presented to children and they wrote them on the plain sheet. Maximum and minimum score for this test was 16 and 0 respectively. The reliability (Cronbach's α) was .73.

Syllable Deletion Task. There were 27 disyllabic words each in the initial and final syllable deletion tasks. Each word was presented aurally to the subject. The participants had been asked to ignore the first and the last syllable respectively for initial {[mə] in [məchhəli] and pronounce [chhəli]} and for final {[ka:] in [chhilka] and pronounce [chhil]} syllable deletion tasks. Maximum and minimum score for this test was 54 and 0 respectively. The reliability (Cronbach's α) was .82.

Spoonerism Task. For this task, 10 pairs of disyllabic word were generated. Each word pair was presented to the participants aurally and participants were required to swap the initial syllable of both the words to make new words and orally present the new pair of words. For example, [kəchchi:] [sədək] to be pronounced as səchchi:] [kədək]. The transformed words were also real words. Maximum and minimum scores for this test were 10 and 0 respectively. Cronbach's alpha could not be calculated for this task because no participant could attempt this task successfully.

Rapid Naming Measure. A *RAN* task was designed with 5 consonant akshara that were taken from four different places of articulation; velar, palatal, approximants and labial. Akshara were presented on a piece of A4 sized paper arranged in 8 columns and 10 rows (total 80 akshara). They were repeated 16 times in such a way that any akshara never repeated consecutively in any row. The subjects were asked to name all the akshara aloud, moving from left to right horizontally, as fast as possible. The maximum score was 80 with the reliability (Cronbach's α) of .82.

Digit Span. Instead of constructing a separate digit span measure, scores of *forward Digit Span* of the MALIN's intelligence test was used for final analysis as a measure of the storage capacity under the phonological domain

Word Reading. Children read a list of 80 disyllabic and 20 trisyllabic words that were used as a measure of *word reading*. Maximum possible score for this test was 100. The reliability (Cronbach's α) was .86.

Paragraph Reading. A short text with 132 words was prepared as a measure of *paragraph reading*. The maximum possible score was 132.

Procedure

The task was administered individually and children performed all the tasks within the school premises in a room specially allotted for it. Informed consent was taken from parents prior to the administration of the tests. For some tasks, only the accuracy (number of correct responses) was measured (*AKI, MI, dictation, syllable deletion, spoonerism, digit span*), while for other tasks (*paragraph reading, word reading and RAN*), both speed (time in second) and accuracy (number of correct responses) were noted. There was no time limit kept for these tasks. Tasks were terminated only when children denied performing the test. Before the beginning of each task, children were instructed to finish the task as fast and accurately as they could.

For *dictation test*, a plain sheet was given to the participants with 1 to 16 numbers marked on it. The words were presented aurally and the participants were asked to write those down on the plain sheet against the number marked on it. Each word was repeated twice. *Word reading, paragraph reading* and *RAN* were given to the participants on A4 sized paper and they were asked to read them aloud as fast as possible moving from left to right horizontally. Each test started with a trial session followed by the main test of one set only. The number of correct responses was taken as a measure of accuracy and the time taken to read the correct words counted as a measure of fluency.

Results

Descriptive Analysis

The test of *spoonerism* used as a measure of phonological awareness was dropped from the main analysis as only two out of 65 participants could answer a few items. Descriptive statistics for age and all the cognitive measures used in the study are presented in Table 1. Average Akshara identification was quite high for akshara with inherent schwa but it was low when akshara had vowels attached to the secondary allographs (matra form).

Table 1. Mean and standard deviation of the variables used in the study

Variables	*M*	*SD*	Min-Max
Age (in months)	112.1	8.8	97-128
Forward Digit Span	5.5	1.1	3-8
IQ	112.4	9.7	86.2-136.6
Akshara Identification[a] (15)	13.8	0.9	12-15
Matra Identification[a] (9)	6.1	1.6	2-9
Syllable Deletion[a] (54)	48.5	4.3	36-54
RAN (Akshara)[a]	78.4	2.4	64-80
RAN (Akshara)[b]	55.9	8.0	38-75
Word Reading[a] (100)	92.9	7.1	70-100
Word Reading[b]	142.7	71.6	62-342
Paragraph Reading[a] (132)	129	3.2	117-132
Paragraph Reading[b]	90.1	32	38-180
Dictation[a] (16)	8.1	2.9	0-15

Note: $N = 65$. RAN= Rapid Automatized Naming; [a]Number of items read or written accurately; [b]Time taken in seconds

Correlation Analysis

Table 2 shows the result of the correlation analysis between different measures of orthographic knowledge, phonological processing and reading. Among the orthographic knowledge, only *dictation* accuracy showed significant correlations with reading accuracy (for both *word* and *paragraph*) but showed significant correlations only with word reading fluency and not with paragraph reading fluency. The dictation accuracy also showed significant correlations with phonological awareness and phonological short-term memory but not with RAN. Akshara identification showed significant correlation only with the word reading fluency. Matra identification showed no significant correlation with any of the reading measures. Within the phonological processing measures, the syllable deletion task showed significant correlations with RAN and with the accuracy measures of reading. RAN showed significant correlation with the fluency measures of reading and not with the accuracy in reading. The forward digit span (phonological short-term memory) showed significant correlations with word reading fluency and paragraph reading accuracy.

Regression Analysis

In order to ascertain the shared predictive variance of orthographic knowledge and phonological processing in reading, a series of hierarchical multiple regression analysis was conducted. Initially, the phonological processing measures (*RAN, forward digit span* and *syllable deletion*) were entered alone as a block into the regression equation to estimate their contribution to reading. In the next analysis, the orthographic knowledge measures (*dictation* and *matra identification*) were entered in the regression equation first as a block at step 1 followed by phonological processing measures as a block at step 2. Akshara Identification measure was not entered in the equation because of the ceiling effect. Word and paragraph reading accuracy and fluency were entered as dependent measures.

Table 2. Correlation between measures of orthographic knowledge, phonological processing, RAN and reading

		1	2	3	4	5	6	7	8	9
1	Forward Digit Span	_								
2	Akshara Identification Accuracy	.31*	_							
3	Matra Identification Accuracy	-.02	.06	_						
4	Dictation Accuracy	.26*	.34**	.33**	_					
5	Syllable Deletion Accuracy	.14	-.01	.09	.22	_				
6	Rapid Naming Fluency	-.21	-.13	-.11	-.34**	-.22	_			
7	Word Reading Accuracy	.11	.19	.15	.47**	.30*	-.24*	_		
8	Word Reading Fluency	.18	-.33**	-.14	-.51**	-.29*	.55**	-.69**	_	
9	Paragraph Reading Accuracy	.25*	.23	.11	.52**	.32**	-.29*	.83**	-.55**	_
10	Paragraph Reading Fluency	-.19	-.26*	-.12	-.48**	-.37**	.56**	-.59**	.83**	-.52**

Note: * $p < .05$, ** $p < .01$

In the next set of analyses, the orthographic measures (*dictation* and *matra identification*) were entered alone as a bock to estimate their contribution to reading. In the next analysis, the orthographic measures were entered as a block at step 2 after controlling for phonological processing (*RAN, forward digit span* and *syllable deletion were entered in the regression model as a bock at step 1*). Word and paragraph reading accuracy and fluency were entered as dependent variables. Table 3, 4, 5 and 6 shows the results of the regression analyses.

Table 3. Hierarchical regression results predicting word and paragraph reading accuracy from phonological processing after controlling for orthographic knowledge; *Beta* value, R^2 change and significance levels are shown

		Word reading accuracy				Paragraph reading accuracy			
Step	**Variables**	***B***	***SE B***	***Β***	**R^2 change**	***B***	***SE B***	***Β***	**R^2 change**
1	RAN (PhP)	-0.17	0.11	-.19		-0.08	0.04	-.21	
1	Forward digit span (PhP)	0.24	0.76	.04	.13	0.47	0.31	.18	.19
1	Syllable deletion (PhP)	0.42	0.21	.25		0.18	0.09	.24*	
1	Dictation (OrK)	0.93	0.29	.41**	.22	0.43	0.12	.46**	.28
1	Matra Identification (OrK)	-.08	0.51	-.02		-0.13	0.21	-.07	
2	RAN (PhP)	-0.7	0.10	-.09		-0.04	0.04	-.10	
2	Forward digit span (PhP)	-0.24	0.73	-.04	.05	0.24	0.30	.09	.06
2	Syllable deletion (PhP)	0.33	0.20	.19		0.14	0.08	.19	

Note: * $p < .05$, ** $p < .01$

Table 4. Hierarchical regression results predicting word and paragraph reading fluency from phonological processing after controlling for orthographic knowledge; *Beta* value, R^2 change and significance levels are shown

		Word reading fluency				Paragraph reading fluency			
Step	**Variables**	***B***	***SE B***	***Β***	**R^2 change**	***B***	***SE B***	***Β***	**R^2 change**
1	RAN (PhP)	4.11	0.94	.48**		1.74	0.41	.46***	
1	Forward digit span (PhP)	-4.44	6.72	-.07	.32	-1.99	2.95	-.07	.19
1	Syllable deletion (PhP)	-2.77	1.87	-.16		-1.88	0.82	-.25*	
1	Dictation (OrK)	-8.42	2.60	-.37**	.26	-3.26	1.17	-0.32**	.28
1	Matra Identification (OrK)	1.63	4.50	.04		1.06	2.02	0.06	
2	RAN (PhP)	3.29	0.91	.39**		1.43	0.41	0.38**	
2	Forward digit span (PhP)	0.03	6.45	.00	.16	-0.23	2.89	-0.00	.06
2	Syllable deletion (PhP)	-2.00	1.76	-.12		-1.60	0.79	-0.21*	

Note: * $p < .05$, ** $p < .01$

Table 5. Hierarchical regression results predicting word and paragraph reading accuracy from orthographical knowledge (OrK) after controlling for phonological processing; *Beta* value, R^2 change and significance levels are shown

		Word reading accuracy				Paragraph reading accuracy			
Step	**Variables**	***B***	***SE B***	***Β***	***R^2* change**	***B***	***SE B***	***Β***	***R^2* change**
1	Dictation (OrK)	1.06	0.27	.47***	.22	0.53	0.11	.55***	.28
1	Matra Identification (OrK)	-0.03	0.51	-.01		-0.13	0.21	-.07	
1	RAN (PhP)	-0.07	0.10	-.09	.13	-0.04	0.04	-.10	.19
1	Forward digit span (PhP)	-0.24	0.73	-.04		0.24	0.30	.09	
1	Syllable deletion (PhP)	0.33	0.20	.19		0.14	0.08	.19	
2	Dictation (OrK)	0.93	0.29	.41**	.14	0.43	0.12	.45**	.15
2	Matra Identification (OrK)	-0.08	0.51	-.02		-0.13	0.21	-.07	

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Table 6. Hierarchical regression results predicting word and paragraph reading fluency from orthographical knowledge (OrK) after controlling for phonological processing; *Beta* value, R^2 change and significance levels are shown

		Word reading fluency				Paragraph reading fluency			
Step	**Variables**	***B***	***SE B***	***Β***	***R^2* change**	***B***	***SE B***	***Β***	***R^2* change**
1	Dictation (OrK)	-11.91	2.63	-.52***	.26	-5.01	1.21	-.49***	.23
1	Matra Identification (OrK)	1.25	4.92	.03		0.87	2.26	.05	
1	RAN (PhP)	3.29	0.91	.39**	.32	1.43	0.41	.38**	.35
1	Forward digit span (PhP)	0.03	6.45	.00		-0.23	2.89	-.01	
1	Syllable deletion (PhP)	-1.99	1.76	-.12		-1.60	0.79	-.21*	
2	Dictation (OrK)	-8.42	2.60	-.37**	.11	-3.26	1.17	.32**	.08
2	Matra Identification (OrK)	1.63	4.50	.04		1.06	2.02	.06	

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

The result of the hierarchical regression indicated that orthographic knowledge (only the dictation accuracy) significantly explained unique variance in reading and its contribution was independent of phonological processing. It was a significant predictor of reading accuracy as well as fluency. When entered into the regression model alone, the predictive variance of the dictation accuracy was 22% and 26% for word and paragraph reading accuracy respectively and 27% and 23% for word and paragraph reading fluency respectively. When entered into the regression model after controlling for phonological processing, it remained the only variable that explained the variance in reading accuracy significantly. It was also a significant unique contributor to reading fluency along with RAN and *syllable deletion*.

When phonological processing measures were entered into the regression model alone, it significantly predicted the variance in reading accuracy as well as fluency that ranged between 13 to 35%. However, when variables were entered into the regression model after controlling for orthographic measures (*dictation* and *matra identification*), none of the phonological processing measures predicted unique variance in reading accuracy. Only *RAN* significantly predicted the unique variance in reading fluency along with *syllable deletion* after controlling for orthographic knowledge. Forward digit span and *matra identification* remained non-significant in predicting reading.

Discussion

The focus of the present study was to investigate the relative contribution of phonological processing and orthographic knowledge to the 4th Grade children' Hindi reading ability. *Phonological awareness, phonological short-term memory* and *RAN* were considered under the umbrella of phonological processing despite the fact that *RAN* is fairly debated to be regarded as an independent predictor of reading (Vaessen, Gerretsen, & Blomert, 2009; Wile & Borowsky, 2004; Wolf & Bowers, 1999). Studies that suggested *RAN* as an independent predictor of reading observed moderate correlations with phonological awareness but the stronger association with visual orthographic processing and automaticity in reading (Ibrahim, 2015; Norton & Wolf, 2012; Wile & Borowsky, 2004). Nonetheless, the present study considered *RAN* as a part of phonological processing because there is a dearth of findings from Hindi orthography that may explain the precise nature of *RAN* and its contribution in Hindi reading. Secondly, our focus was to see the comparative contributions from phonological processing and orthographic knowledge to reading rather than to investigate the precise nature of *RAN* and lastly, even after considering *RAN* within phonological processing, it was still possibile to see its specific contribution to reading.

In many consistent and inconsistent languages the pivotal role of phonological processing in reading is acknowledged (Furnes & Samuelsson, 2012; Goldrick & Rapp, 2007; Seidenberg, 1985; Swan & Goswami, 1997). However, the consistent grapheme-sound mapping of Hindi language and the large visual orthographic inventory made us hypothesize that although Hindi readers will depend on phonological processing skills, the dependence would be greater on the orthographic knowledge. Our results have also illustrated that, within phonological domain, *RAN* emerged as the most significant predictor of reading speed followed by *phonological awareness*. Although *Phonological awareness* did not emerge as a significant predictor of reading accuracy (both, for word as well as paragraph reading) but was a significant predictor of paragraph reading speed. This does not go along with the findings of others that noted *phonological awareness* as a significant predictor of reading (Castles & Coltheart, 2004; Loui, Kroog, Zuk, Winner, & Schlaug, 2011; Wagner et al., 1997). One of the reasons could be that the task that measured *phonological awareness* in the present study assessed syllabic segmentation ability of the participants, whereas, in most of the alphabetic languages, phonemic processing is documented as an important predictor of reading. *Phonological short-term memory* remained non-significant in explaining reading in this study. This pattern of association has been reported in several previous studies (de Jong & van der Leij, 1999; Georgiou et al., 2008; Landerl et al., 2013; Moll et al., 2014; Ziegler, Pech-Georgel, et al., 2010).

Our finding has supported the fact that despite phonological consistency, mastering orthographic knowledge is an important aspect of reading, owing to the orthographic complexity of the language. Although Hindi is said to show consistent phonology to orthographic mapping, it has some irregularities in grapheme-phoneme mapping. For example, graphemes representing some of the consonant conjuncts, क्ष [kʃə], त्र [trə], ज्ञ [gŋjə] and श्र [ʃrə] do not give any clue that they represent three phonemes. Within one word, there can be different akshara and each of them may represent a single phoneme, a syllable or a conjuncts, for example, words such as /अभिप्राय/ [əbhipra:jə], (meaning ‘intention’) and /क्षत्रिय/ [kshətrIjə], (meaning ‘a type of warrior community’). In the former word, the first grapheme represents a single phoneme, the second grapheme is a syllable with two phonemes and the last akshara is a conjunct representing three phonemes. The readers need to attend to each grapheme carefully and keep shifting from fine grain mapping (in case of primary vowel allographs) to coarse grain mapping (consonants with an inherent schwa) to further coarser grained ligatures and conjuncts (consonants with vowel ligatures and consonant clusters). In other words, orthographic knowledge requires fine phonemic parsing ability on the part of readers.

Orthographic knowledge measured through *dictation* was the strongest predictor of reading accuracy as well as fluency and the other two measures; *akshara* and *matra identification* tasks were non-significant in explaining the variance in reading. Although the *dictation task* explained significant variance in reading accuracy, average accuracy for *dictation* was very low (M = 7.97) out of a total of 16 words, with the lowest score touching the floor in few cases. The low accuracy might be the result of the complex aspects of the language that was included in the *dictation task* (aksharas with consonant clusters). Previous findings in similar other orthographies suggest that certain complex aspects of language are mastered very late that continues even in Grade 4 and onwards (Nag, 2007, 2011; Nag & Sircar, 2008; Nag & Snowling, 2011b). In contrast, participants' performance on both *akshara* and *matra identification* tasks was near-perfect. Out of a total of 16 aksharas given to the participants for identification, average correct identification was13; with minimum and maximum score of 12 and 15 respectively. One of the reasons could be that unlike English alphabets, the name and sound of akshara are same in Hindi producing lesser confusion for the readers in memorizing the akshara symbols. However, word reading still is a challenging task as it requires higher order cognitive and orthographic skills. It includes visual sequential processing, phonemic level parsing abilities, and joining indivisual aksharas to make meaningful utterances (Arnell, Joanisse, Klein, Busseri, & Tannock, 2009; Georgiou, Parrila, Cui, & Papadopoulos, 2013; Moll et al., 2014). An additional burden could be related to Hindi reading in particular that demands constant set-shifting to tap the changing granular structure of akshara within words.

Further analysis of the akshara identification errors revealed that identification was poorer only for conjunct akshara representing two or three sounds or the visually and phonologically similar akshara. There was an average decline in performance for the target akshara (क्ष) [kshə] presented in the row number 6 which was a consonant conjunct. It is possible that children in Grade 4 still struggle to master visually difficult and coarser grained aksharas. Performance on consonant akshara with secondary vowel allographs was equally good; out of 9 akshara, average correct identification was 6. However, there was better identification of akshara with an inherent schwa than the akshara with vowel ligatures (matra). The problem in identification of akshara with vowel ligatures was more apparent in the case of the long and the short vowel /i/ placements, for example, री [ri:], सी [si:] and बि [bI], चि [tʃI]. This aspect is visually and temporally challenging to Hindi readers mentioned in the previous findings as well (Gupta, 2004; Gupta & Jamal, 2006). Average reading accuracy for word (*M* = 92.9 out of 100) words as well as paragraph reading (*M* = 129 out of 132 words) is quite high with small standard deviation. The same result was not noted for reading speed. Time taken to complete word and paragraph reading showed a lot of variation among readers. It ranged between 62-342 (in seconds) for word reading and 38-180 (in seconds) for paragraph reading. This may be the result of greater reliance on consistent grapheme to sound mapping and consequent sequential decoding of words while reading. It can also be inferred that in the identification of poor and dyslexic readers the fluency aspect should be considered more seriously.

The *spoonerism* task used in this study could be attempted only by 2-3 participants with very few correct answers. In the findings of some of the transparent orthographies, typical readers were found to be remarkably good performers on the task of spoonerism, whereas dyslexic readers performed poorly (Wimmer & Schurz, 2010). The surprisingly weak spoonerism performance of our Hindi readers may be explained by the properties of Hindi phonology. Ohala & Ohala, (1992) found that Hindi speakers do not make phonological speech errors like spoonerism due to the flat prosodic structure of Hindi words. She hypothesized that Hindi, despite having properties of the syllabic writing system, lacks word prosody. Likewise, in her earlier study (Ohala, 1994), she presented words like अखरोट [əkhrōt], छलिका [tʃhIlka:], पवन [pəwən], इश्वर [Iʃwər], बादल [ba:dəl] orally, giving her participants a choice to break them either into *head* and *coda* or *onset* and *rhyme*. She found that her participants had no significant preference for either of those divisions. It led her to conclude that the Hindi language does not have a hierarchical structure like English. Even stress in Hindi is not so important unlike English where the stress can change the meaning of the words (Agnihotri, 2013).

The result of the present study brought forth some of the new complex aspects of Hindi language that needs further exploration. The orthographic complexity aspects of Hindi mentioned in the literature is not limited to the visual complexity but also associated with the phonological temporal analysis of sound. The complexities of vowel ligatures, consonant clusters and consonant conjuncts were puzzling for normal readers which can be further challenging for poor and dyslexic readers. Our future goal would be to explore in depth, about some of these complexities as well as their pedagogical implications. One of the limitations of the current study is our failure to include a comprehensive set of tests to study the phonemic level segmentation ability of children which will be our future endeavour.

References

Agnihotri, R. K. (2013). *Hindi: An essential grammar*. Routledge.

Arnell, K. M., Joanisse, M. F., Klein, R. M., Busseri, M. A., & Tannock, R. (2009). Decomposing the relation between Rapid Automatized Naming (RAN) and reading ability. *Canadian Journal of Experimental Psychology*, *63*(3), 173–84. https://doi.org/10.1037/a0015721

Aro, M. (2004). *Learning to read: The effect of orthography*. Jyväskylän yliopisto.

Bright, W. (1996a). The Devanagari script. In P. T. Daniels & W. Bright (Eds.), *The world's writing systems* (pp. 384–390). New York & Oxford: Oxford University Press.

Bright, W. (1996b). *The world's writing system*. New York, NY: Oxford University Press.

Bright, W. (2000). A matter of typology: Alphasyllabary and Abugida. *Studies in the Linguistic Sciences*, *30*, 63–71.

Caravolas, M., Lervåg, A., Mousikou, P., Efrim, C., Litavsky, M., Onochie-Quintanilla, E., … Hulme, C. (2012). Common patterns of prediction of literacy development in different alphabetic orthographies. *Psychological Science*, *23*(6), 678–686. https://doi.org/10.1177/0956797611434536

Carroll, J. M. (2004). Letter knowledge precipitates phoneme segmentation, but not phoneme invariance. *Journal of Research in Reading*, *27*(3), 212–225. https://doi.org/10.1111/j.1467-9817.2004.00228.x

Castles, & Coltheart. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition*, *91*(2003), 77–111. https://doi.org/10.1016/S0010-0277(03)00164-1

Coltheart, M., Raste, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A duel route cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108*(1), 204–256. https://doi.org/10.1037//0033-295X.108.1.204

Daniels, P. T. (1996). The study of writing systems. In P. T. Daniels & W. Bright (Eds.), *The world's writing systems* (pp. 3–17). New York & Oxford: Oxford University Press.

Daniels, P. T., & Bright, W. (Eds.). (1996). *The world's writing systems*. New York & Oxford: Oxford University Press.

Das, T., Bapi, R. S., Padakannaya, P., & Singh, N. C. (2011). Cortical network for reading linear words in an alphasyllabary. *Reading and Writing*, *24*(6), 697–707. https://doi.org/10.1007/s11145-010-9241-3

de Jong, P. F., & van der Leij, A. (1999). Specific contributions of phonological abilities to early reading acquisition: Results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology*, *91*(3), 450–476. https://doi.org/10.1037//0022-0663.91.3.450

Elbro, C., & Petersen, D. K. (2004). Long-term effects of phoneme awareness and letter sound training: An intervention study with children at risk for dyslexia. *Journal of Educational Psychology*, *96*(4), 660–670. https://doi.org/10.1037/0022-0663.96.4.660

Furnes, B., & Samuelsson, S. (2012). Phonological awareness and rapid automatized naming predicting early development in reading and spelling: Results from a cross-linguistic longitudinal study. *National Institute of Health Access*, *21*(1), 85–95. https://doi.org/10.1016/j.lindif.2010.10.005. Phonological

Georgiou, G. K., Parrila, R., Cui, Y., & Papadopoulos, T. C. (2013). Why is rapid automatized naming related to reading? *Journal of Experimental Child Psychology*, *115*(1), 218–225. https://doi.org/10.1016/j.jecp.2012.10.015

Georgiou, G. K., Parrila, R., & Papadopoulos, T. C. (2008). Predictors of word decoding and reading fluency across languages varying in orthographic consistency. *Journal of Educational Psychology*, *100*(3), 566–580. https://doi.org/10.1037/0022-0663.100.3.566

Goldrick, M., & Rapp, B. (2007). Lexical and post-lexical phonological representations in spoken production. *Cognition*, *102*(2), 219–260. https://doi.org/10.1016/j.cognition.2005.12.010

Goswami, U. (2011). A temporal sampling framework for developmental dyslexia. *Trends in Cognitive Sciences*, *15*(1), 3–10. https://doi.org/10.1016/j.tics.2010.10.001

Gupta, A. (2004). Reading difficulties of Hindi-speaking children with developmental dyslexia. *Reading and Writing: An Interdisciplinary Journal*, *17*, 79–99.

Gupta, A., & Jamal, G. (2006). An analysis of reading errors of dyslexic readers. *Asia Pacific Disability Rehabilitation Journal*, *17*(1), 73–86.

Hulme, C., & Snowling, M. J. (2009). *Developmental disorders of language, learning and cognition*. Oxford: Wiley-Blackwell.

Ibrahim, R. (2015). How does Rapid Automatized Naming (RAN) correlate with measures of reading fluency in Arabic. *Psychology*, *6*, 269–277.

Koul, O. N. (2009). *Modern Hindi grammar*. Indian Institute of Language Studies.

Landerl, K., Ramus, F., Moll, K., Lyytinen, H., Leppänen, P. H. T., Lohvansuu, K., … Schulte-Körne, G. (2013). Predictors of developmental dyslexia in European orthographies with varying complexity. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *54*(6), 686–94. https://doi.org/10.1111/jcpp.12029

Lindgren, S. D., Renzi, E. De, & Richman, L. C. (1985). Cross-national comparisons of developmental dyslexia in Italy and the United States. *Society for Research in Child Development*, *56*(6), 1404–1417.

Loui, P., Kroog, K., Zuk, J., Winner, E., & Schlaug, G. (2011). Relating pitch awareness to phonemic awareness in children: implications for tone-deafness and dyslexia. *Frontiers in Psychology*, *2*(111), 1–5. https://doi.org/10.3389/fpsyg.2011.00111

McDougall, S., Brunswick, N., & Davies, P. de M. (2010). The development of reading skills in different orthographies. In N. Brunswick, S. McDougall, & P. de M. Davies (Eds.), *Reading and dyslexia in different orthographies*. New York, NY: Psychology Press.

Moll, K., Ramus, F., Bartling, J., Bruder, J., Kunze, S., Neuhoff, N., … Landerl, K. (2014). Cognitive mechanisms underlying reading and spelling development in five European orthographies. *Learning and Instruction*, *29*, 65–77. https://doi.org/10.1016/j.learninstruc.2013.09.003

Nag, S. (2007). Early reading in Kannada: the pace of acquisition of orthographic knowledge and phonemic awareness. *Journal of Research in Reading*, *30*(1), 7–22. https://doi.org/10.1111/j.1467-9817.2006.00329.x

Nag, S. (2011). The akshara languages: What do they tell us about children's literacy learning? In R. K. Mishra & N. Srinivasan (Eds.), *Language-cognition interface: state of the art* (pp. 291–310). Lincom: GmbH.

Nag, S., & Perfetti, C. A. (2014). Reading and writing: Insights from the alphasyllabaries of South and Southeast Asia. *Writing Systems Research*, *6*(1), 1–9. https://doi.org/10.1080/17586801.2014.883787

Nag, S., & Sircar, S. (2008). *Learning to read in Bengali: report of a survey in five Kolkata primary schools*. Bangalore: The Promise Foundation.

Nag, S., & Snowling, M. J. (2011a). Cognitive profiles of poor readers of Kannada. *Reading and Writing*, *24*(6), 657–676. https://doi.org/10.1007/s11145-010-9258-7

Nag, S., & Snowling, M. J. (2011b). Reading comprehension, decoding skills and oral language. *English and Foreign Language*, *2*(2), 73–93.

Nag, S., & Snowling, M. J. (2012). Reading in an alphasyllabary: Implications for a Language Universal Theory of Learning to Read. *Scientific Studies of Reading*, *16*(5), 404–423. https://doi.org/10.1080/10888438.2011.576352

Norton, E. S., & Wolf, M. (2012). Rapid automatized naming (RAN) and reading fluency: Implications for understanding and treatment of reading disabilities. *Annual Review of Psychology*, *63*, 427–52. https://doi.org/10.1146/annurev-psych-120710-100431

Ohala, M. (1994). Experiments on the syllables in Hindi. Paper presented at *Third International Conference on Spoken Language Processing (ICSLP 94) Yokohama, Japan* (pp. 487–490). Yokohama.

Ohala, M., & Ohala, J. J. (1992). Phonetic universals and Hindi segment duration. In *ICSLP 92* (pp. 831–834). Edmonton: University of Alberta.

Park, H. R., & Uno, A. (2015). Cognitive abilities underlying reading accuracy, fluency and spelling acquisition in Korean Hangul learners from grades 1 to 4: A cross-sectional study. *Dyslexia*, *21*(3), 235–253. https://doi.org/10.1002/dys.1500

Patel, T. K., Snowling, M. J., & de Jong, P. F. (2004). A cross-linguistic comparison of children learning to read in English and Dutch. *Journal of Educational Psychology*, *96*(4), 785. https://doi.org/10.1037/0022-0663.96.4.785

Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003). Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. *Brain*, *126*, 841–865. https://doi.org/10.1093/brain/awg076

Rogers, H. (2004). The Indian Abugida and other Asian phonographic writing. In H. Rogers (Ed.), *Writing systems: A linguistic approach* (pp. 199–232). Blackwell Publishing.

Scheerer, E. (1986). Orthography and lexical access. In A. Gerhard (Ed.), *New trends in graphemics and orthography* (pp. 262–286). Berlin: Walter d Gruyter & CO.
Schneider, W., Roth, E., & Ennemoser, M. (2000). Training phonological skills and letter knowledge in children at risk for dyslexia: A comparison of three kindergarten intervention programs. *Journal of Educational Psychology*, *92*(2), 284–295. https://doi.org/10.1037//0022-0663.92.2.284
Seidenberg, M. S. (1985). The time course of phonological code activation in two writing systems. *Cognition*, *19*, 1–30.
Seymour, P. H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology*, *94*, 143–74. https://doi.org/10.1348/000712603321661859
Shanbal, J. C., Goswami, S. P., Chaitra S, & Prathima, S. (2010). Phonological awareness skills and reading in children who are at risk for learning disability: Role in the Indian context? *Journal of All India Institute of Speech & Hearing*, *29*(2), 204–214.
Shankweiler, D. (1999). Words to meanings. *Scientific Studies of Reading*, *3*(2), 113–127.
Shaywitz, S. E., Morris, R., & Shaywitz, B. A. (2008). The education of dyslexic children from childhood to young adulthood. *Annual Review of Psychology*, *59*, 451–475. https://doi.org/10.1146/annurev.psych.59.103006.093633
Shaywitz, S. E., & Shaywitz, B. A. (2008). Paying attention to reading: The neurobiology of reading and dyslexia. *Development and Psychopathology*, *20*(4), 1329–1349. https://doi.org/10.1017/S0954579408000631
Siddaiah, A., & Padakannaya, P. (2015). Rapid automatized naming and reading: A review. *Psychological Studies*, *60*(1), 70–76. https://doi.org/10.1007/s12646-014-0280-8
Sircar, S., & Nag, S. (2014). Akshara-syllable mapping in Bengali: A language-specific skill for reading. In H. Winskel & P. Padakannaya (Ed.), *South and Southeast Asian Psycholinguistics* (pp. 202–211). New York, NY: Cambridge University Press.
Swan, D., & Goswami, U. (1997). Phonological awareness deficits in developmental dyslexia and the phonological representations hypothesis. *Journal of Experimental Child Psychology*, *66*(1), 18–41. https://doi.org/10.1006/jecp.1997.2375
Uno, A., Wydell, T. N., Haruhara, N., Kaneko, M., & Shinya, N. (2008). Relationship between reading/writing skills and cognitive abilities among Japanese primary-school children: Normal readers versus poor readers (dyslexics). *Reading and Writing*, *22*, 755–789. https://doi.org/10.1007/s11145-008-9128-8

Vaessen, A., Bertrand, D., Tóth, D., Csépe, V., Faísca, L., Reis, A., & Blomert, L. (2010). Cognitive development of fluent word reading does not qualitatively differ between transparent and opaque orthographies. *Journal of Educational Psychology*, *102*(4), 827–842. https://doi.org/10.1037/a0019465

Vaessen, A., Gerretsen, P., & Blomert, L. (2009). Naming problems do not reflect a second independent core deficit in dyslexia: double deficits explored. *Journal of Experimental Child Psychology*, *103*(2), 202–21. https://doi.org/10.1016/j.jecp.2008.12.004

Vaid, J., & Gupta, A. (2002). Exploring word recognition in a semi-alphabetic script: The case of Devanagari. *Brain and Language*, *81*(1–3), 679–690. https://doi.org/10.1006/brln.2001.2556

Wagner, R., Balthazor, M., Hurley, S., Morgan, S., Rashotte, C., Shaner, R., … Stage, S. (1987). The nature of prereaders' phonological processing abilities. *Cognitive Development*, *2*(4), 355–373. https://doi.org/10.1016/S0885-2014(87)80013-8

Wagner, R., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, *101*(2), 192–212. https://doi.org/10.1037//0033-2909.101.2.192

Wagner, R., Torgesen, J. K., & Rashotte, C. A. (1994). Development of reading-related phonological processing abilities: New evidence of bidirectional causality from a latent variable longitudinal study. *Developmental Psychology*, *30*(1), 73–87. https://doi.org/10.1037//0012-1649.30.1.73

Wagner, R., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., Burgess, S. R., … Garon, T. (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: A 5-year longitudinal study. *Developmental Psychology*, *33*(3), 468–79.

Wile, T. L., & Borowsky, R. (2004). What does rapid automatized naming measure? A new RAN task compared to naming and lexical decision. *Brain and Language*, *90*(1–3), 47–62. https://doi.org/10.1016/S0093-934X(03)00419-X

Wimmer, H., & Schurz, M. (2010). Dyslexic in regular orthographies: Manifestation and causation. *Dyslexia*, *16*, 283–299. https://doi.org/10.1002/dys

Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology*, *91*(3), 415–438.

Wydell, T. N., & Butterworth, B. (1999). A case study of an English-Japanese bilingual with monolingual dyslexia. *Cognition*, *70*(3), 273–305.

Ziegler, J. C., Bertrand, D., Tóth, D., Csépe, V., Reis, A., Faísca, L., … Blomert, L. (2010). Orthographic depth and its impact on universal predictors of reading: a cross-language investigation. *Psychological Science*, *21*(4), 551–9. https://doi.org/10.1177/0956797610363406

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: a psycholinguistic grain size theory. *Psychological Bulletin*, *131*(1), 3–29. https://doi.org/10.1037/0033-2909.131.1.3

Ziegler, J. C., Pech-Georgel, C., Dufau, S., & Grainger, J. (2010). Rapid processing of letters, digits and symbols: what purely visual-attentional deficit in developmental dyslexia? *Developmental Science*, *13*(4), F8–F14. https://doi.org/10.1111/j.1467-7687.2010.00983.x