Read Writ (2011) 24:657–676
DOI 10.1007/s11145-010-9258-7

Cognitive profiles of poor readers of Kannada

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Published online: 21 September 2010

Abstract The alphasyllabary of Kannada comprises more than 400 symbols called *akshara;* each symbol is visuo-spatially complex with a consistent representation at the dual levels of the syllable and the phoneme. We investigated reading difficulties in Kannada among 8–12 year old children by conducting a between-groups followed by a case series analysis. We compared the children with reading difficulties with same age competent readers and younger readers who were similar in language level, matched on measures of vocabulary, syntactic processing, and morphological processing. Reading difficulties were characterized by poor akshara knowledge. Concomitant impairments were in syllable and phoneme level phonological skills, in rapid naming and in oral language skills. The case series analysis highlighted the variability of profiles among poor readers with the most common impairments being in akshara knowledge and phonological processing. Sub-groups of poor readers showed additional deficits in oral language, rapid naming, and visual processing skills. Together our findings indicate that the core deficit associated with reading difficulty in the alphasyllabary of Kannada is in the phonological domain. However, accompanying deficits in related skills, including visual processing, can further inhibit reading attainment. The findings from this study support a multifactorial model of reading development.

Keywords Akshara · Indian language · Reading difficulties · Visual processing skills · Oral language skills · Syllable processing

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At least among readers of English, the most likely cause of reading difficulties (dyslexia) is believed to be a deficit in phonological processing (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Much less well-specified are the developmental pathways that lead to such difficulties and the role of other risk factors such as additional cognitive or sensory deficits, that may contribute to heterogeneity in reading disorders. Such variation in the cognitive profiles of poor readers is the norm in English (Castles & Coltheart, 1993; Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996) and in other alphabetic languages (e.g., French: Sprenger-Charolles, Colé, Kipfer-Piquard, Pinton, & Billard, 2009).

There are a number of hypotheses regarding the *etiology* of different reading profiles. According to the double deficit hypothesis, reading difficulties may emerge either because of a difficulty in the phonological domain or in rapid naming or in both (Bowers, 1993; Wolf & Bowers, 1999) and further, Badian (1997) proposed that children with dyslexia can show difficulties with orthographic awareness, phonological awareness, and/or rapid naming. From the perspective of language impairment, Catts, Hogan and Fey (2003) proposed that heterogeneity among poor readers was associated with four different profiles: Children showed either poor word recognition, poor linguistic comprehension, impairments in both word recognition and linguistic comprehension or else they were described as *nonspecified* because, although they were poor readers, they experienced neither word recognition nor linguistic comprehension deficits.

Beyond alphabetic reading systems, Ho and colleagues reported that children learning to read in Chinese showed deficits in rapid naming (50%), orthographic processing (39%), visual processing (37%), and phonological processing (15%). Furthermore, more than half of the poor readers had cognitive deficits in three or four of these domains, whereas less than a quarter had difficulty in just one domain (Ho, Chan, Tsang, & Lee, 2002).

To accommodate such varied findings, explanatory models for reading difficulties (and more generally for learning disorders) are beginning to move away from deterministic, single causal models to more probabilistic multi-factorial models (Pennington & Bishop, 2009). Within this view, an accumulation of cognitive risk factors can cause poor reading. A corollary is that reading difficulties are more severe (and more likely to reach a diagnostic threshold) when multiple deficits are present rather than when deficits are restricted to a single cognitive domain (Pennington, 2006; Snowling, 2008). Moreover, the impact of a given risk factor on reading development may be moderated by cognitive factors that act as protective influences (Snowling, Gallagher, & Frith, 2003).

The present study considered the nature of reading difficulties in Kannada, an Indian alphasyllabary, and specifically, the range of cognitive profiles associated with poor reading skill. Kannada is a South Dravidian language, spoken in the southern Indian State of Karnataka. The language has a predominant CVCV syllable structure (C = Consonant, V = Vowel), though complex syllables are also present. There are very few one syllable words in Standard Kannada. The most frequent word length is two, three, and four syllable words, with longer polysyllabic words also available in the vocabulary. Words end with open syllables and loan words typically take on a vowel ending to fall in line with the phonology of the language.

Kannada is an agglutinative language (Sridhar, 1990) and words tend to have high morpheme length because of affixations (mainly suffixations). In addition, Kannada is considered a nominal language with only few cases of genuine adjectives or adverbs. Kannada, like many other Indian languages, also has a comparatively free word order. The writing system of the language has more than 400 symbols (orthographic units called the *akshara*) that may be divided into akshara with inherent vowels, akshara with other vowels, and akshara for consonant clusters (Nag, 2007). The akshara represent sound at the level of the syllable as well as marking the constituent phonemes. In Kannada for example, the akshara symbols for the syllable /ra:/ (ರಾ) and /ru/ (ರು) are represented by the base symbol /r/ (ರ್) and the vowel diacritics for /a:/ (ಾ) and /u/ (ು), with the first diacritic ligaturing to the top of the base but the second to the bottom (for more examples see Table 1). This representation of the phonemes in the akshara through a base symbol with added diacritic markers makes the orthographic units visuo-spatially detailed and complex.

Findings from surveys of reading difficulties in Kannada as well as in the alphasyllabary languages of Bengali, Hindi, and Tamil suggest that the causes of reading difficulties in these languages may be expected in multiple domains. A study in Kannada by Ramaa and colleagues reported that children with dyslexia had poor knowledge of the akshara of the language and additional difficulties in auditory sequential memory, syllable processing, visual-verbal processing, and visual processing (Ramaa, Miles, & Lalithamma, 1993). Difficulty with Kannada symbol learning has been replicated in other studies both with poor readers (Prema & Karanth, 2003; Purushothama, 1994) and typically developing children (Nag, 2007; Nag, Treiman, & Snowling, 2010). Similar findings have been reported in the alphasyllabary of Hindi (Gupta, 2004), suggesting that children with dyslexia show not only significantly lower reading accuracy and reading speed than typical readers but also associated difficulties with orthographic learning of the phonemic markers in the language. Taken together with the extensive size of the symbol set of the Indian

Table 1 A sample of Kannada akshara: the symbol set for the dental plosives shown with a selection of short and long vowels

consonants	vowels									
	/a/[1]	/a:/	/i/	/i:/	/u/	/u:/	/e/	/e:/	/o/	/o:/
/t/	ತ	ತಾ	ತಿ	ತೀ	ತು	ತೂ	ತೆ	ತೇ	ತೊ	ತೋ
/t^h/	ಥ	ಥಾ	ಥಿ	ಥೀ	ಥು	ಥೂ	ಥೆ	ಥೇ	ಥೊ	ಥೋ
/d/	ದ	ದಾ	ದಿ	ದೀ	ದು	ದೂ	ದೆ	ದೇ	ದೊ	ದೋ
/d^h/	ಧ	ಧಾ	ಧಿ	ಧೀ	ಧು	ಧೂ	ಧೆ	ಧೇ	ಧೊ	ಧೋ

[1] In the symbol for a consonant with the short vowel /a/, the vowel is inherent and in many cases is pronounced as /ʌ/. For all other vowels, the diacritic is added to the base consonant

alphasyllabaries (between 250 and 500 symbols), these findings suggest that the orthographic domain is a prime candidate area of difficulty for poor readers. Furthermore, it seems possible that an underlying difficulty with visual learning could cause such deficits in orthographic knowledge. Ramaa et al. (1993) found that, although there was a trend for visual processing skills to be less well developed in poor than competent readers, group differences did not reach statistical significance.

Case studies reported by Nag-Arulmani (2003) showed that in addition to difficulties in symbol knowledge, poor readers also experienced difficulties in aspects of phonological awareness, namely syllable and phoneme processing. Other researchers have proposed that the alpha-syllabic nature of the orthography impacts the development of phonological representations (e.g., Gupta, 2004; Karanth, 2002) though the nature of the interaction between the orthographic and phonological domains has not been specified. In addition, there have been reports of slower reading rate (Karanth, Mathew, & Kurien, 2004) and longer word naming latencies (Vaid & Gupta, 2002), suggestive of an underlying difficulty with speed of processing among poor readers of alphasyllabaries. Moreover, naming speed, along with orthographic knowledge and phonological skills at the level of the syllable as well as the phoneme, have all been reported to be independent predictors of individual differences among 9–12 year old Kannada readers (Nag & Snowling, submitted).

Turning to the broader oral language domain, Aaron (1982) reported that 10% of children learning to read in the alphasyllabary of Tamil, showed recurrent difficulties with inflections and suffixes during reading and Nag (2007) found lower reading attainments to be associated with lower scores in Kannada language proficiency as measured by comprehension of spoken statements and questions of increasing syntactic and narrative complexity. Several of the Indian alphasyllabaries are writing systems for languages that are agglutinative in nature, and not much is understood about the role of broader oral language skills in explaining variations in reading attainments in these languages. Even less is known about the nature of difficulties in this domain among poor readers.

Our study of the cognitive profiles of poor readers of Kannada was guided by previous research on the alphasyllabaries and what is known about the predictors of individual differences in reading skills in non-alphabetic languages. According to Nag and Snowling (submitted), the four main predictors of reading skills in middle school children are akshara knowledge, syllable awareness, phoneme awareness, and rapid naming. We expected that poor readers would have deficits in one or more of these domains, and arguably, more severe reading problems would be associated with multiple deficits. However, while the predictors of reading difficulties can give us clues as to likely risk factors for poor reading, its correlates may extend beyond these. Indeed, within a multi-deficit view, additional risk factors (or co-morbidities) may contribute to reading impairments. Accordingly (and based on clinical reports) we anticipated that some poor readers would show difficulties in visual sequential memory even though this was not a robust predictor of individual differences in Kannada reading skills. Further, given the role played by oral language skills in reading development (Snowling et al., 2003; Scarborough, 1991) and in particular in reading comprehension (Ricketts, Nation, & Bishop, 2007; Nation, Clarke, Marshall, & Durand, 2004), we expected to find that some poor readers would have language

impairments. Indeed, given that Kannada is a highly inflected language we expected that some poor readers may be struggling because of difficulties in inflection knowledge.

We took a mixed approach to investigate these issues. We began with between-groups analyses to highlight the differences between poor and typical readers across different candidate domains. We then proceeded to investigate individual differences using a case series approach. Case series analyses have been used to examine cognitive profiles in cases of atypical development (e.g., Towgood, Meuwese, Gilbert, Turner, & Burgess, 2009; Sprenger-Charolles et al., 2009) and are particularly useful when a complex pattern of deficits within and across different domains is expected.

Method

Participants

This study was part of a larger scale survey of literacy skills conducted in primary and middle schools in Chamarajanagar district, in the south of India. Consent had been obtained for the study from the local government authorities according to the norms set for research in school settings in the region. The survey sample comprised children from different socio-economic status (SES) backgrounds: 48.2% from lower, 50% from middle and 1.8% from upper SES. This mix of SES is representative of the profile of SES in the region, but under-representing the middle and higher SES when the profile of the entire State is taken into account.

All schools in the study were under one curriculum authority and followed a similar reading programme with one set of prescribed textbooks for each Grade. Formal literacy instruction for Kannada began in Grade 1, when children were typically 5 years old. The education policy at the time of the study also required schools to introduce English in Grade 3. As with Kannada, the English curriculum was standard across schools although some schools did not have the resources to introduce regular English teaching, and general English reading proficiency was low among all children in the study.

A total of 103 children (from an initial cohort of 411), now in Grades 4, 5, and 6, were assessed on the test battery described below. For the case series analysis 74 of these children formed a comparison group and we used the performance of this group across the measures studied to benchmark the level of performance expected in Grades 4, 5, and 6. For the purposes of the group comparisons, we identified 29 children whose reading skills fell below the 15th centile for their grade. Eight of these 29 children were exceptionally low in reading accuracy; we refer to these as Non-Readers and excluded them from the between-group comparisons. The remaining 21 children were the Reading Difficulties group.

In the group analysis the 21 children in the Reading Difficulties group (RD group) were compared with a younger group of 23 competent readers matched for language level (LL controls). Matching was achieved on each of the three tests of vocabulary, syntactic processing as measured by the sentence repetition task and morphological processing as measured by inflection knowledge (see Table 2). We chose to equate

Table 2 Means and standard deviations on the oral language measures of the reading difficulties group and competent readers matched for language level and chronological age

Area	Reading difficulties group		Language level controls		Chronological age controls		*F* tests(2,66) (Tukey's post hoc tests)	Cohen's d[a]
	Mean	*SD*	Mean	*SD*	Mean	*SD*		
Vocabulary	37.29	6.62	40.96	10.96	45.40	6.06	5.75 (RD = LL, both < CA)*	0.41
Sentence repetition	31.00	7.74	31.39	5.93	36.00	6.28	4.17 (RD = LL, both < CA)**	0.05
Inflection knowledge[b]	5.14	3.17	5.22	2.56	3.24	2.38	5.92 (RD = LL, CA; LL < CA)**	0.03

[a] For the reading difficulties and language level controls

[b] Higher score indicates lower inflection knowledge

* $p < .05$; ** $p < .001$

groups on language rather than reading level as might be more typical given the assumption that reading builds on a foundation of oral language skills. Since relatively little is known about component reading skills in Kannada, we felt it appropriate to leave reading level to vary while oral language differences between children were fixed. A third group of 25 children who had no reading difficulties formed a chronological age matched comparison group (CA controls). Through this matching process we aimed to specify the extent of delays in each of the components of reading when the contribution of broader oral language skills had been controlled. If group deficits remain significant in relation to younger language level matched children, then the evidence points in favour of a causal role for such deficits.

The LL controls were on an average 18 months younger than the RD group. The mean age of the RD group was 10.2 (SD = .81) and of the LL group was 8.8 (SD = .62). The mean age of the CA controls was 10 (SD = .76). The gender ratio in the RD group was 7 girls and 14 boys, the LL controls, 5 girls and 18 boys and CA controls, 9 girls and 16 boys. There were no significant group differences in general cognitive skills ($F(2, 66) = 1.24$, $p = .30$) or SES ($F(2, 66) = .45$, $p = .64$). Table 2 shows the performance of the RD group, the LL controls and the CA controls on the broader oral language measures. Tukey's post hoc tests confirmed that there were no differences between the RD group and the LL controls on the vocabulary, sentence repetition, and inflection knowledge measures. On the vocabulary and sentence repetition measures, both the LL controls and the RD group were significantly lower than the CA controls. On the inflection knowledge measure, while the LL controls were significantly lower than the CA controls, there was no significant difference between the RD group and the CA controls.

Tests and materials

Standardised tests of skills of interest to us were not available in Kannada. We instead drew upon tests developed for a survey in which children in this study had

been tracked over 4 years (TPF-NIAS, 2004-07). We report here details of the measures which were used for the current investigation.

Socio-economic status and general ability measures

Socio-economic status indicator (Arulmani & Nag, 2006)

This interview schedule cover the education level, occupation and income separately for the child's father and mother (or main caretakers), and the assets in the child's family home. Visits to approximately 10% of the children's homes confirmed that there was a high degree of accuracy in children's reporting of family details, particularly about family assets.

General cognitive ability

This was assessed using the Raven's Standard Progressive Matrices. Percentile scores are reported based on Indian norms developed by Deshpande and Patwardhan (2006).

Literacy tests

Akshara knowledge

A list of twenty akshara was presented on flashcards and children were asked to name them. The list comprised two primary vowels, seven CV akshara with inherent vowel /a/, five CV akshara with ligatured other vowels and six CCV akshara (Cronbach $\alpha = .819$).

Reading accuracy

Children were asked to read a list of words and nonwords and four passages and the accuracy was recorded. The word list comprised words of varying syllable lengths: three bi-syllabic, six tri-syllabic and one polysyllabic word. The nonword list comprised ten bi-syllabic, four tri-syllabic, and one polysyllabic nonword. The total number of words in the four passages was 80.

Reading comprehension

The test comprised six texts with two questions each. Length of texts ranged from 14 to 37 words with narrative styles covering fantasy, non-fiction, biography, and riddles. Comprehension questions assessed retrieval of stated information as well as inference making (Cronbach $\alpha = .624$).

Reading rate

The reading speed test was based on passages of 26, 14, 19, and 21 words. All four passages were taken from Grades 3 and 4 level texts (Cronbach $\alpha = .940$).

Spelling

This was an individually administered dictation task. The spelling list comprised 9 bi-syllabic words, 20 tri-syllabic words, and 1 four syllable word. Eighteen words had the simple CVCV structure (60%), with 18 instances of consonant clusters in the remaining 12 words on the list (Cronbach $\alpha = .940$).

Oral language tests

Vocabulary

Reading cards for Grades 3–5 (Chili Pili Cheela, 2007) were used to draw up a list of words for this test. The list included object names, non-object names, and words representing qualities, actions, states, time, place, and result. Children were asked to explain what the word means. Descriptions, examples or terms associated with the target word received a score of 1, sentential use of the word received a score of 2 and a definition or an equivalent word a score of 3 (Cronbach $\alpha = .822$).

Sentence repetition

This syntactic processing task had ten items of increasing sentence length, with longer sentences comprising substantive words and grammatical elements. Children were asked to recall the sentence as they had heard them. An accuracy score for word by word repetition of the sentence was computed (Cronbach $\alpha = .705$).

Performance on the Sentence Repetition task was also analysed for errors on the inflected words. A substitution or an omission of an inflected segment in a word was considered as an error in inflections.

Phonological awareness tests

A set of 37 bi-syllabic nonwords was developed from a list of common words by replacing one syllable in a word with another syllable from another word. The nonwords had either only CV clusters or one CCV cluster in a target position.

Syllable deletion

In this test the child had to delete the first, middle, and last syllable in a word. Deletions were with both simple (*siri, thwuthi*) and complex syllables (*dvetha*, *gitre*).

Syllable substitution

The target syllable for substitution was either in the initial or final position of bi-syllabic nonwords (*gnaapa* to *snepa; nruti* to *nruna*). There were 5 items with cluster endings (*paabda* to *paabche*).

Phoneme deletion

Manipulation was for the initial and final positions in bi-syllabic nonwords. For both positions, there were five sets of items with simple (*shavi, jnara*) and complex syllables (*tvaagi*, *mushti*). The schwa in consonants with inherent vowel has not been considered as a phoneme. For those word final CV and CCV clusters that were with inherent vowels, the phoneme substitution was with the final consonant.

Phoneme substitution

In this test, there were 5 initial manipulations (*kruya* to *sruya*) and 10 items for the final manipulation with simple (*snena* to sneya) and complex ending clusters (*viksha* to *vikna*).

Reliability was calculated separately for the four tasks (Cronbach α: syllable deletion, .662; syllable substitution, .731; phoneme deletion, .913; phoneme substitution, .883).

Naming speed and memory tests

Rapid automatized naming (RAN)

The items for this test were single digits with two syllable names (e.g., *muuru:* 3, *aidu:* 5). The numbers were presented in random order laid out on a A4 sheet in five rows of nine items each. Children were asked to read out the numbers one by one quickly and accurately. Naming speed was calculated by subtracting the number of items read out wrong from the total number of items and dividing this from the time taken. The test was modeled after the Denkla and Rudel (1976) task and several studies have reported a reliability coefficient of between .7 and .9 on tasks using this format (e.g. Wagner, Torgesen, & Rashotte, 1999).

Visual sequential memory

Five items, each of two and three symbol sequences, made up the test. The symbol sequence was presented on flashcards and the child had to reconstruct the sequence by picking out the appropriate symbols from a larger set of flashcards. The dyads had to be reconstructed from eight displayed symbols and the triads from ten symbols. Distracter symbols were either visually different in global details or shared a common base pattern with a target, but differed on one visual feature (Cronbach $\alpha = .568$).

Procedure

The children in this study were seen 4 months after entry into the current Grade. Children were tested individually in their schools in four sessions, each lasting 30–45 min. The battery of tests was grouped into four sets (1) literacy tasks (akshara, word and nonword reading, and spelling) and oral language tasks (vocabulary,

sentence repetition) together with the socio-economic status interview; (2) tests of general abilities, visual processing, RAN, and receptive phonology; a non-word repetition task, which is not reported in this study (3) syllable processing tasks and reading comprehension; and (4) phoneme processing tasks and reading speed. All tests within a set were administered in a fixed sequence but the sequence of administration of the sets changed at random across children.

Results

Comparison with younger readers matched on oral language skills

Table 3 gives details of the performance of the three groups on the literacy and processing measures, together with *F* values pertaining to the overall group effect and the results of Tukey's post hoc tests comparing the three groups. The scores on the phoneme substitution task were not normally distributed with the RD group performing least well with many children at floor; a Kruskal–Wallis test indicated the overall group differences were significant ($p = .010$). On tests of reading accuracy and reading speed, the RD group and the LL controls performed less well than CA controls and at a similar level to each other indicating that matching on language level had equated the groups for basic reading skills. A different pattern was seen for akshara knowledge, spelling, and reading comprehension, with the RD group performing significantly less well, not only than their age-peers but also the younger LL controls. Turning to the phonological awareness tasks, the RD group performed lower than the LL controls on tests of syllable and phoneme awareness but group differences did not reach statistical significance with low to medium effect sizes, except on the phoneme substitution task where the effect size for the difference was 1.05. In comparison to the CA controls, the RD group gained significantly lower scores on all four measures of syllable deletion, syllable substitution, phoneme deletion, and phoneme substitution. On naming speed (RAN), similar to the phonological awareness measures, the RD group was slower than CA controls but performed at a similar level to the LL controls. Contrary to expectation, there were no significant group differences in visual sequential memory.

Case series analysis

For the case series analysis, we examined the performance of each poor reader across five domains: akshara knowledge, phonological processing, oral language, visual processing, and naming speed. A difficulty in either or both syllable and phoneme processing was counted as a difficulty in the phonological domain. Similarly, difficulty in any one or more measures of vocabulary, sentence repetition, and inference making was taken as difficulty in broader oral language skills. For each domain, we defined *impaired performance* as a score on the relevant measures below a cut-off of -1 standard deviation relative to a chronological age comparison group of 74 children who were competent readers. In previous research, this criterion has been found to be useful in understanding subgroups of poor readers (e.g., Catts et al.,

Table 3 Means and standard deviations on measures of literacy, phonological awareness, visual processing and naming speed of the reading difficulties group (RD), the language level controls (LL) and the chronological age controls (CA)

Area (max. score)	Reading difficulties group		Language level controls		Chronological age controls		*F* tests (2,66) (Tukey's post hoc tests)	Cohen's d[a]
	Mean	SD	Mean	SD	Mean	SD		
Literacy measures								
Accuracy (105)	63.31	20.91	66.39	10.15	89.40	8.23	25.19 (RD = LL, both < CA)**	.18
Akshara knowledge (20)	12.48	3.53	15.52	2.49	17.28	2.03	18.15 (RD < LL, CA; LL = CA)**	.99
Reading speed	29.01	14.79	23.53	12.66	43.39	16.02	11.89 (RD = LL, both < CA)**	.39
Reading comprehension (12)	3.33	2.69	5.87	1.58	7.80	2.00	25.47 (RD < LL, CA; LL < CA)**	1.15
Spelling (30)	9.38	4.42	13.61	4.22	17.32	5.58	15.54 (RD < LL, CA; LL < CA)**	.98
Phonological measures (proportion scores)								
Syllable deletion	66.67	12.15	73.39	11.03	76.80	8.56	5.33 (RD = LL, both < CA)*	.58
Syllable substitution	44.76	21.41	48.12	21.27	62.67	17.74	5.29 (RD = LL, both < CA)*	.16
Phoneme deletion	9.90	8.91	12.87	10.44	29.60	24.19	9.78 (RD = LL, both < CA)**	.31
Phoneme substitution[b]	1.90	2.72	8.00	7.72	13.60	17.55	$p = .010$ on Kruskal–Wallis test	1.05
Visual processing measure								
Sequential memory	3.23	1.61	2.78	1.57	3.60	1.98	.53 (ns)	.28
Naming speed measure								
RAN	1.59	.45	1.82	.49	1.98	.43	5.28 (RD = LL, RD < CA, LL = CA)*	.49

[a] For the reading difficulties group and the language level controls

[b] Scores on this task were not normally distributed and a non-parametric test was used

* $p < .05$; ** $p < .05$

2003; Ramus et al., 2003). The results of the case series involving all 29 poor readers (21 RD group and 8 nonreaders) are shown in Table 4.

An isolated difficulty in only akshara knowledge was rare (only 2 of the 29 cases). Instead poor akshara knowledge typically co-occurred with difficulties in one or more other domains examined. We next made a tally for each individual of the number of domains of difficulties: 13.79% of children (4/29) showed difficulty in all five domains while 37.93% of children (11/29) showed delays in the four domains of akshara knowledge, phonological processing, oral language, and naming speed, but not in visual processing. Two other profiles of difficulties co-occuring with poor

Table 4 The domains of difficulties among children with reading difficulty (RD) and non-readers (NR) based on performance below 1 SD of the normative sample of competent readers

Child		Literacy			Orthographic domain	Phonological domain		Broader oral language domain			Visual processing	Naming speed	No. of deficit domains
Case detail[a]	Case no	Accuracy	Reading comprehension	Reading speed	Akshara knowledge	Syllable	Phoneme	Vocabulary	Sentence repetition	Inflection knowledge	Sequential memory	RAN	
RD	65	✔	✔	✔	✔	–	–	–	–	–	–	–	1
RD	232	✔	✔	✔	–	–	–	–	–	✔	–	–	1
RD	249	✔	✔	✔	✔	–	–	–	–	–	–	–	1
RD	62	✔	✔	–	✔	✔	–	–	–	–	–	–	2
RD	207	✔	✔	–	✔	✔	–	–	–	–	–	–	2
RD	242	✔	✔	✔	–	–	–	–	–	✔	–	✔	2
RD	289	✔	✔	✔	✔	–	–	–	–	–	–	✔	2
RD	291	–	✔	–	✔	–	✔	–	–	–	–	–	2
RD	222	✔	✔	✔	✔	✔	–	–	–	–	–	–	2
RD	279	✔	✔	–	✔	–	–	–	✔	✔	–	–	2
RD	215	✔	✔	✔	✔	–	–	–	–	–	–	✔	2
RD	51	✔	✔	✔	✔	✔	–	–	✔	✔	–	–	3
RD	135	✔	✔	✔	✔	✔	–	–	✔	✔	–	–	3
RD	26	✔	✔	✔	✔	✔	✔	✔	✔	✔	–	✔	4
RD	178	✔	✔	–	✔	✔	–	–	–	✔	–	✔	4
RD	247	✔	–	✔	✔	–	✔	–	✔	✔	–	✔	4
RD	287	✔	✔	✔	✔	✔	–	–	✔	–	–	✔	4
RD	129	–	✔	–	✔	✔	✔	✔	–	✔	–	✔	4
RD	29	✔	✔	✔	✔	✔	✔	–	✔	✔	–	✔	4
RD	28	✔	✔	✔	✔	✔	✔	✔	✔	–	✔	✔	5
RD	117	✔	✔	✔	✔	✔	–	–	✔	✔	✔	✔	5

Table 4 continued

Child		Literacy			Orthographic domain	Phonological domain		Broader oral language domain			Visual processing	Naming speed	No. of deficit domains
Case detail[a]	Case no	Accuracy	Reading comprehension	Reading speed	Akshara knowledge	Syllable	Phoneme	Vocabulary	Sentence repetition	Inflection knowledge	Sequential memory	RAN	
NR	60	✔	✔	✔	✔	✔	–	–	–	–	–	–	2
NR	54	✔	✔	✔	✔	✔	✔	–	✔	–	–	✔	4
NR	58	✔	✔	✔	✔	✔	–	–	✔	–	–	✔	4
NR	170	✔	✔	✔	✔	✔	✔	✔	✔	✔	–	✔	4
NR	230	✔	✔	✔	✔	✔	✔	–	✔	✔	–	✔	4
NR	319	✔	✔	✔	✔	✔	–	–	✔	✔	–	✔	4
NR	68	✔	✔	✔	✔	✔	✔	–	✔	✔	✔	✔	5
NR	172	✔	✔	✔	✔	✔	–	–	✔	–	✔	✔	5

[a] *RD* reading difficulties group, *NR* non-readers group. ✔ = attainments below 1 SD of the normative sample of competent readers

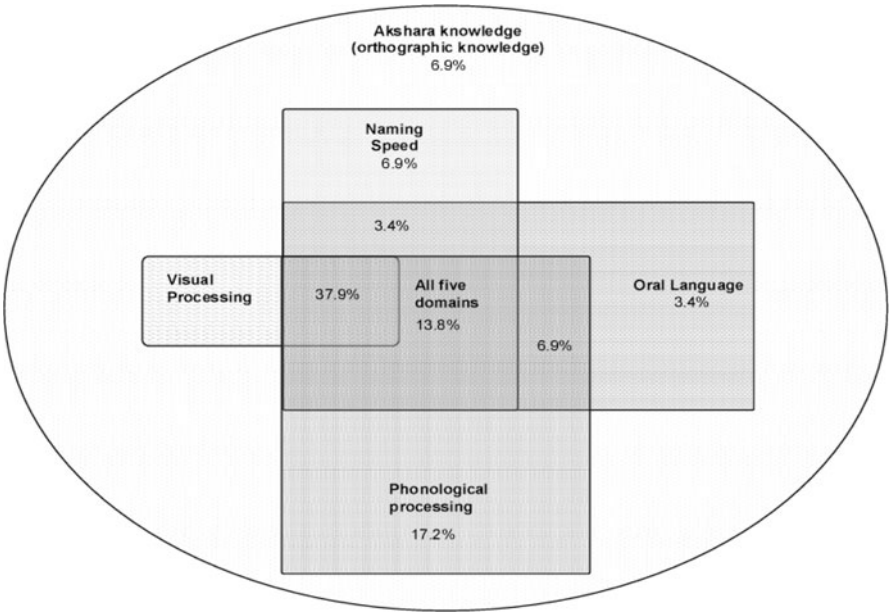

Fig. 1 Percentage of poor readers according to domains of difficulty

akshara knowledge are of interest; 17.24% showed difficulties only in the phonological domain (5/29) and 6.89% showed difficulties in both phonological processing and oral language domains (2/29). Apart from one poor reader who showed poor akshara knowledge and difficulties in the oral language domain, no other poor reader in this sample showed difficulties that were restricted to the oral language domain and visual processing domain, either singly or together. Figure 1 gives a schematic representation of these overlapping difficulties. Taken together, 75.8% of all cases showed difficulties in phonological processing, 68.9% showed difficulties in oral language and 62% showed difficulties in naming speed.

Discussion

We were interested to examine the profile of poor readers in Kannada, an Indian alphasyllabary. To study this we compared the profiles of children with reading difficulties with same age competent readers and younger readers matched on broader oral language measures. We also conducted a case by case analysis of domains of difficulty for all poor readers in the sample.

Multiple domains of difficulty

The most evident area of delay was akshara knowledge. The Kannada alphasyllabary comprises over 400 symbols and mastery levels of middle school poor

readers were significantly below those of readers who were approximately 18 months younger. Not surprisingly, the difficulty with symbol knowledge co-occurred with delays in all components of reading: poor accuracy, slow rate of reading, and more errors in reading comprehension. In alphabetic languages, letter knowledge is a predictor of individual differences (see Adams, 1990; Seymour, 2005 for reviews) and poor readers of alphabetic languages take longer to master the letter set (Gallagher, Frith, & Snowling 2000; Scarborough, 1990). Letter knowledge in alphabetic languages (i.e. symbol knowledge), however, is typically at asymptote (ceiling) by the time of the middle school years, arguably because the size of the symbol set is limited. In contrast, children continue to learn the extensive symbol set in Kannada throughout the primary school years (Nag, 2007). This study confirms our prediction that learning of orthographic units is slow among poor readers of Kannada with orthographic difficulties persisting well into middle school.

It can be argued that shaky akshara knowledge is underpinned by a less-than-detailed cognitive representation of the symbols. Poor readers show confusion with recognition during brief tachistoscopic exposures of akshara when compared to competent readers (Purushothama 1994) and spelling errors reveal confusion between the diacritic segments in an akshara (Nag et al., 2010). A fuzzy symbol representation of either the whole akshara or its phonemic segments could lead to miscues in reading. In parallel, reduced automaticity of symbol recognition would slow down speed of decoding and thus reading rate. Our group and individual analyses show that poor readers were struggling with both reading accuracy and reading speed.

We were also interested in comparing reading and spelling performance. Our results show that poor readers could read as accurately as younger typically developing children matched for oral language skills but their spelling was worse, in line with their poor akshara knowledge. Spelling requires a more highly specified representation of orthographic knowledge than reading. Thus, poor readers may be able to establish orthographic representations that can support reading (a recognition process that proceeds using partial cues; Frith, 1980) but which are insufficiently specified (or of poorer quality; Ehri, & Snowling, 2004; Perfetti, 2001) to support spelling. This dissociation between reading and spelling underlines the fact that, even though the Kannada writing system is regular and consistent, it is resource demanding.

Alongside deficits in akshara knowledge, we found impairments in the phonological domain. As discussed earlier, the nature of the writing system promotes syllable level representations while phoneme level processing being slower to emerge, perhaps through growing attention to phonemic markers as akshara knowledge increases (Nag, 2007). We found that poor readers had difficulty with both syllable and phoneme level processing tasks. Indeed, for many, performance on phoneme awareness tasks was close to floor. This finding extends reports of delays in phonological processing skills among poor readers of Kannada (Nag-Arulmani, 2003; Ramaa et al., 1993), other akshara languages (Gupta, 2004; Nag & Sircar, 2008) and other alphasyllabaries such as Korean (Kim, 2009; Kim & Davis, 2004). The syllable level difficulty seen among poor readers of alphasyllabaries raises the question of whether these children have a greater difficulty in

acquiring syllable awareness when compared to struggling readers in other languages and whether this may be because of the level of phonological representation of the orthography, the instruction methods used in these languages and/or features of the spoken language. This is a theoretically interesting issue but given the lack of a cross-linguistic perspective in our study it remains an empirical question.

A third domain of difficulty among poor readers of Kannada was naming speed. Difficulty with rapid automatized naming was also a recurrent feature in the case by case analysis of the profiles of poor readers, with 62% showing a difficulty in this domain. Taken together, this study extends to the Kannada alphasyllabary the finding that deficits in rapid automatized naming co-occur with reading difficulties in both consistent and inconsistent alphabetic languages (e.g., Nikolopoulos, Goulandris, Hulme, & Snowling, 2006; de Jong & van der Leij, 2003; Wimmer, Mayringer, & Landerl, 1998; Lovett, 1987) and the logographic Chinese (e.g., Ho et al., 2002).

The visuo-spatial complexity of the Kannada orthography makes the presence of a difficulty in visual processing an intriguing possibility. The group analysis in this study did not confirm that poor readers are significantly lower than same age competent readers in visual sequential memory. Rather, difficulties in visual memory were restricted to those poor readers (13.8%) who also showed difficulties in all the other domains studied. Our task was, however, of relatively low reliability and moreover, our study had only one test of visual processing. A wider range of measures of visual processing would be needed to gain a more accurate estimate of the importance of visual processing abilities in reading this visuo-spatially complex orthography. Based on these findings, we tentatively suggest that poor visual sequential memory may be a synergistic risk factor for poor reading which only has an impact when other more critical skills are impaired.

Oral language is the final domain of difficulty we report. The case series analysis confirmed that more than half of the poor readers (68.9%) were struggling with one or more aspects of oral language. Among the areas assessed, the largest numbers of poor readers were struggling with inflection knowledge, confirming our prediction about the importance of inflection knowledge in Kannada reading. A relatively smaller number of poor readers also showed difficulties in syntactic processing, with the least number showing delays in vocabulary.

A multi-factorial model for reading development

This paper characterizes the cognitive profiles associated with poor reading in Kannada, an alphasyllabary with a visuo-spatially complex symbol set. Many children showed an uneven pattern of performance across different cognitive domains with patterns of strength and/or weakness in symbol knowledge, phonological processing, oral language, and naming speed. In addition, some children showed additional difficulties in visual memory. The variety of profiles of poor reading that were observed makes it unlikely that there is a single cause of poor reading in the Kannada language.

What implications do these findings have for a model of alphasyllabary reading? In Fig. 2, we depict a framework for considering the skills involved in becoming a fluent reader of Kannada. When developing this model we excluded two domains examined in the study; visual memory because it is as yet unclear what role this set of skills play in Kannada reading development and naming speed because this domain is perhaps an index of the overall efficiency of a reading system (or a marker of the child's propensity to develop the visual-verbal mappings that underpin orthography learning) rather than a specific cognitive skill contributing to reading development. Key roles are hypothesized for akshara knowledge, phonological awareness, and broader oral language skills. Akshara knowledge and the dual processing at the syllable and phonemic levels are taken to indicate alphasyllabic competence (Nag & Snowling, submitted) while vocabulary, syntactic processing, and inflection knowledge are taken together to indicate broader oral language competence. We hypothesize further that these various skills have reciprocal links with each other, with the components they comprise and with reading development.

One suggested implication of this multifactorial model of reading development is that weakness in one domain would place a child at risk of reading difficulty but weaknesses in multiple areas would have a greater impact on reading outcome. We found a multi-deficit profile in four and more domains in about one-third of the children with reading difficulties (8/21) but nearly all children whom we had identified as non-readers (7/8; see Table 4). The model does not assume that all skills carry equal weight in the determination of reading (and reading difficulty). However, it offers direction for future longitudinal research to specify the relative importance of different domains of processing. We propose that a risk model for reading difficulties in the alphasyllabaries would involve delays in akshara knowledge, syllable and phoneme level awareness, and broader oral language skills through the extended period of orthographic mastery and for reading comprehension.

There are some practical implications from the findings in this study for the development of assessment and intervention programmes for children learning to

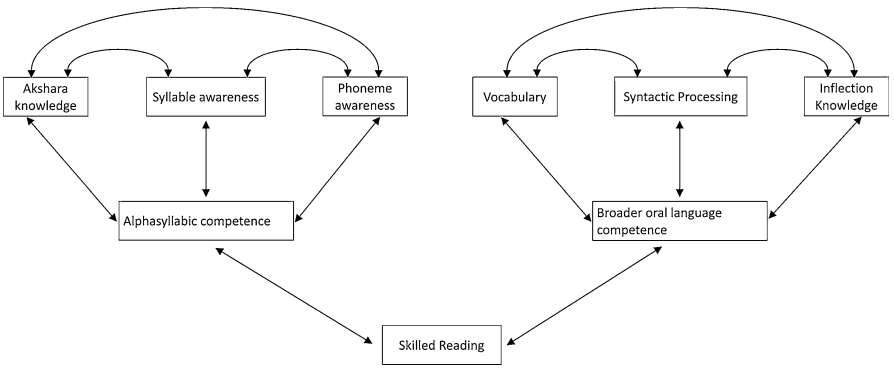

Fig. 2 A multi-factorial model for skilled reading in Kannada

read in an alphasyllabary. As in the alphabetic languages, identification of reading difficulties in the akshara languages is best done using a comprehensive profile of the three components of reading accuracy, reading rate, and reading comprehension. Skills in five further domains (akshara knowledge, phonological processing, broader oral language, naming speed, and visual memory) interact to produce a spectrum of delays and difficulties among poor readers. Importantly, akshara knowledge and syllable processing are essential measures for the identification of reading difficulties even in older children and we presume young adults (unlike in the alphabetic language where these skills reach competence level much earlier).

The study also has implications for the development of remedial programmes in the akshara languages. Akshara knowledge is pivotal for learning to read and an intervention therefore must prioritise akshara practice. The study has, however, also indicated that while akshara knowledge is crucial, it is not sufficient for ensuring higher reading attainment. A comprehensive programme with phonological games, focus on vocabulary, other oral language skills and exposure to multiple texts would better promote reading attainments.

Acknowledgments We would like to thank all the schools who have participated in this study and the assistance of partners who have made this study possible. We thank everyone at the Department of Education, Chamarajanagar district; the District Quality Education Programme team at the National Institute of Advanced Studies; The Promise Foundation team, especially Roopa Kishen, Jayashree Vyasarajan, Mohan Das, Mamtha Gupta and Kala B for data collection and management; Prof. R. Amritavalli for her inputs on the broader oral language tasks and Latha K. for her inputs on the Reading Comprehension task. The study was funded by a research grant from the British Academy.

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