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(Dis)connections between specific language impairment and dyslexia in Chinese

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Abstract Specific language impairment (SLI) and dyslexia are found to co-occur in school-aged children learning Chinese, a non-alphabetic language (Wong, Kidd, Ho, & Au in Sci Stud Read 14:30–57, 2010). This paper examined the 'Distinct' hypothesis—that SLI and dyslexia have different cognitive deficits and behavioural manifestations (e.g., Catts, Adolf, Hogan, & Weismer in J Speech Lang Hear Res 48:1378–1396, 2005) in Chinese children in Primary 1. Ninety-four six- to seven-year-old Chinese children completed a norm-referenced test for oral language and for literacy, as well as cognitive tasks related to reading development. Based on results from the norm-referenced tests, 40 children fell in the typically-developing Control group, 10 children in the dyslexia-only (D) group, 19 in the SLI-only group and 25 children in the SLI-D group. Orthographic skills and lexical access and retrieval skills were found to be associated with dyslexia. Phonological memory and morphological awareness were associated with SLI. Phonological awareness was associated with both SLI and dyslexia. SLI and dyslexia in Chinese did not seem to be distinct disorders as they were both characterized by a deficit in phonological awareness. Implications for clinical practice were discussed.

Keywords SLI · Dyslexia · Comorbidity · Chinese · Cantonese

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Introduction

SLI, dyslexia and phonological processing

Specific language impairment (SLI) and dyslexia are language-learning impairments observed in individuals without intellectual, hearing or psychosocial disabilities who have had adequate exposure to oral language and literacy instruction respectively. Children with SLI are impaired in oral language (semantics, syntax, discourse), whereas children with dyslexia are impaired in reading development—especially in written-word decoding. SLI and dyslexia co-occur in school-age children and co-morbidity estimates in English range from 17 % (Catts, Aldof, Hogan, & Weismer, 2005) to 75 % (McArthur, Hogben, Edwards, Heath, & Mengler, 2000).

Despite differences in behavioral manifestations, separate lines of research reveal that children with SLI and children with dyslexia have both been found to show deficits in phonological processing (e.g., Bishop and Snowling, 2004 for review), which includes the ability to manipulate different speech units (phonological awareness), to encode and temporarily store phonological information (phonological short-term memory), and to quickly access and retrieve routinized phonological information from the lexicon. In much of the published research, however, the children with dyslexia were not tested for the presence of SLI, and vice versa.

In more recent studies, groups of children who had SLI alone, dyslexia alone, or both SLI and dyslexia, were directly compared on phonological processing. Some comparisons included two (Bishop, McDonald, Bird, & Hayious-Thomas, 2009; Catts et al., 2005; Eisenmajer, Ross & Pratt, 2005; Fraser, Goswami, & Conti-Ramsden, 2010), some all three (McArthur & Castles, 2013), and others a composite, of the three phonological processing skills (Ramus, Marshall, Rosen & van der Lely, 2013). In Ramus et al. (2013), the SLI-only and the dyslexia-only group did not differ in performance, and both groups scored worse than the typically-developing controls. The findings of the remaining five studies were mixed. For children with SLI, Fraser et al. (2010) reported problems in phoneme awareness and phonological short-term memory, while the other four studies reported an absence of phonological processing deficits. For children with dyslexia, some studies reported age-appropriate levels of performance on phoneme awareness (Eisenmajer et al., 2005) and phonological short-term memory (Eisenmajer et al., 2005; McArthur & Castles, 2013), while others reported problems in different combinations of the three phonological processing skills. Of note is that deficits in lexical access and retrieval—(as often measured by rapid automatized naming: RAN)—were found only in children with dyslexia (Bishop et al., 2009; McArthur & Castles, 2013). As McArthur and Castles (2013) pointed out, differences in the diagnostic criteria adopted for SLI and dyslexia, differences in the tasks used to examine phonological processing, and perhaps small sample size might have accounted for the mixed results. To date, there have not been studies using the same set of tasks to compare cognitive deficits in children with SLI or dyslexia learning a non-alphabetic written system such as Chinese. Given the lack of grapheme-phoneme correspondence, the nature of phonological processing can be different in non-alphabetic writing systems. The present study set out to fill this research gap in hopes of identifying the nature of the overlap between SLI and dyslexia in Cantonese Chinese, providing insights in diagnosis and intervention.

Catts et al. (2005) summarized three major hypotheses about the relationship between SLI and dyslexia in English-speaking children. The 'Distinct' hypothesis suggests that SLI and dyslexia are distinct disorders with different underlying cognitive deficits and behavioural manifestations (Catts et al., 2005): children with dyslexia showing deficits in phonological processing (phonological awareness and phonological memory) and children with SLI showing deficits in non-phonological aspects of language, including vocabulary and syntax. Data from Catts et al. (2005) generally support the distinct hypothesis. Of note is that the SLI group also had lower scores than the normal controls on phonological processing, although the difference was not statistically significant. Much of the empirical support thus far has focused on the relationship between SLI and dyslexia in English, phonological processing, and phonological representation (de Bree, Wijnen & Gerrits et al., 2010; McArthur & Castles, 2013; Ramus et al., 2013). This makes sense given that English written letters generally correspond to phonemes. How well will the 'Distinct' hypothesis hold up in non-alphabetic systems (e.g., Chinese) remains to be seen.

Dyslexia in Chinese: beyond phonological processing

In Chinese, the unit of writing is the character. Chinese characters map onto syllables and morphemes; they are typically made up of radicals (phonetic radicals, and semantic radicals), which in turn are composed of strokes. The stroke patterns are organized in a rectangular layout, rather unlike English and other alphabetic systems with a linear layout of letters. The Chinese and the English writing systems also differ in mapping principles (Perfetti, Cao & Booth, 2013). In alphabetic writing systems, graphic units are mapped to the segmental structure of speech. In Chinese, the structure of orthographic characters typically does not correspond to their phonemic sequences. For example, the character 花(flower) is pronounced as *faa1* in Cantonese. Despite this lack of correspondence, there are systematic regularities between phonological information in the Chinese character and its pronunciation. The phonetic radicals offer pronunciation hints for about 34 % of Chinese characters (Fung, 2009). In the above example, the phonetic radical 化*faa3* sounds similar to the word 花*faa1* except for its lexical tone. Phonological processing therefore is also engaged in Chinese reading (Perfetti et al., 2013). Chow, McBride-Chang and Burgess (2005) reported a moderate association between phonological processing and word reading in Chinese kindergarteners. Specifically, phonological awareness (as measured by syllable deletion) was a strong concurrent and longitudinal predictor of Chinese word reading. RAN was an equally strong concurrent predictor, but short-term verbal memory demonstrated no unique association with Chinese word reading. These results replicated McBride-

Chang and Ho (2000), in which phonological awareness and RAN, but not verbal short term memory, made a significant contribution to concurrent word reading.

For Chinese, the most prevalent cognitive deficits for dyslexia (in descending order) are: RAN (50 % of participating children), orthographic skills (39 %), phonological awareness (20 %) and phonological memory (14 %) (Ho, Chan, Tsang, & Lee, 2002; Ho, Chan, Lee, Tsang, & Luan, 2004). Orthographic skills refer to children's ability to identify the correct orientation of orthographic units, to pick out non-characters that violate the structure of Chinese characters, and to identify the typical position of radicals in a character. While RAN is the one phonological processing skill that is impaired in children with dyslexia across writing systems (Norton & Wolf, 2012), more Chinese children with dyslexia have problems in orthographic skills than in phonological awareness and phonological memory—likely due to the relatively opaque grapheme-phoneme mapping in Chinese.

SLI and dyslexia in Chinese

As in alphabetic languages, SLI and dyslexia also co-occur in Chinese. Wong, Kidd, Ho and Au (2010) found that 13 of the 30 children with SLI (43 %) also met diagnostic criteria for dyslexia, a prevalence rate about four times of that in community samples (9.7 %; Chan, Ho, Tseng, Lee, & Chung, 2007). The children with co-morbid SLI and dyslexia (SLI-D), but not those with SLI alone, had deficient orthographic skills (specifically, left–right reversal). Both groups, however, had subpar phonological processing—phonological awareness and memory, rapid automatized naming (RAN)—as well as morphological awareness compared to the normal controls. In the Wong et al. (2010) study, dyslexia was diagnosed using the Hong Kong Test of Specific Learning Difficulties in Reading and Writing for Primary School Students-Second Edition (HKT-P [II]; Ho et al., 2007b). According to HKT-P [II], a clinical diagnosis of dyslexia requires the child to score at or more than 1 SD below the mean (scaled score 7 or below with a mean of 10) on the literacy composite (Chinese word reading, 1-min word reading, and Chinese word dictation), and on at least one of the four cognitive composite scores (RAN, phonological awareness, phonological memory, and orthographic skills). Given that group comparisons were made on measures used to define the groups, the different cognitive profiles could have been an artifact of the definitions of the dyslexia and the SLI-D group.

Morphological awareness, although not included in the clinical diagnosis of dyslexia, has been found to predict Chinese word reading concurrently (Shu, McBride-Chang, Wu, & Liu, 2006) and longitudinally (Tong et al., 2011). Morphological awareness requires one to attend simultaneously to both the sound and meaning of language. In Chinese, homophones are prevalent given the small number of possible syllables relative to the number of characters used regularly (McBride-Chang, 2004). Syllables are therefore often combined to form multisyllabic or multi-morphemic word compounds. Morphological awareness in Chinese is typically assessed via manipulation of multi-morpheme compounds (e.g., produce "red–blue-light" based on "red–green light"). Deficits in this morphological awareness have been documented for dyslexia in Mandarin Chinese (Shu et al., 2006) and Cantonese Chinese (McBride-Chang et al., 2011; Wong et al., 2012).

One recent piece of evidence suggests that morphological awareness might actually be related to oral language impairment instead of dyslexia. In two studies, 5-year-old kindergarteners at risk for dyslexia in Cantonese Chinese (e.g., having an older sibling diagnosed with dyslexia, or having a language delay) were tested for dyslexia after finishing Primary 1 (i.e., first year in primary school) around age 7 (McBride-Chang et al., 2011; Wong et al., 2012). The dyslexic group, which was defined only on the basis of their word reading scores, had worse morphological awareness than the non-dyslexic group. But Wong et al. (2012) also found that among the children not meeting dyslexia criteria at age 7, those with language-delay had worse morphological awareness than those with dyslexia familial risk, hinting at morphological awareness being related to oral-language skills. Neither Wong et al.'s (2012) nor McBride-Chang et al.'s (2011) study reported children's oral language, or the diagnostic criteria for language delay. It therefore remains open whether the observed deficits in morphological awareness were associated with dyslexia per se, or with undiagnosed oral language deficits.

The present study

In the research literature and in clinical practice, children are not formally diagnosed as having dyslexia until the end of the first year, or the beginning of the second year, of primary school, with at least a year of formal reading instruction. The present study will examine morphological awareness and other cognitive skills (e.g., phonological memory and awareness) in Chinese children with clinically diagnosed SLI and/or dyslexia at the end of Primary 1. The timing of the study allows us to examine the effect of cognitive skills on word reading with the confounding effect of reading experience on the development of cognitive skills at its minimum. The study extends Wong et al.'s (2010) study in important ways. First, it uses a much larger sample (94 children, compared to 30 in Wong et al.'s (2010) study) from a narrower age group focusing on beginning readers. Second, it includes a critical group that was missing from that study—children with dyslexia but not SLI—to examine which deficits characterize which diagnosis and which characterize both diagnoses. Third, dyslexia is defined only by the children's literacy composite on the HKT-P [II] rather than by a combination of literacy deficits and cognitive deficits. The study followed a group of 5–6 year old children for a year and assessed them for both dyslexia and SLI at the end of Primary 1. The aim was to test the "Distinct" hypothesis. Specifically, based on Catts et al. (2005), we predicted that Chinese children with dyslexia and Chinese children with SLI would show distinct patterns of cognitive deficits, with the former showing problems in phonological awareness, RAN, and orthographic skills, and the latter showing problems in morphological awareness and phonological memory in addition to knowledge of vocabulary, grammar and discourse.

Method

Participants

The participants were seen twice, first in their final year of kindergarten and then a year later after they completed Primary 1. In the kindergarten year, 125 children (aged 5–6) participated. Figure 1 outlines the recruitment procedure.

Recruitment of children with SLI

The SLI group comprised 60 children. Fifty-two were referred by speech-language therapists in local child assessment centers as having oral language impairment and the other eight failed a language screening we administered (see details below). All 60 children received diagnostic testing at the time of the study and met the conventional criteria for SLI (Leonard, 1998): they performed below children at the same age in oral language, in the absence of a concomitant hearing loss, cognitive or

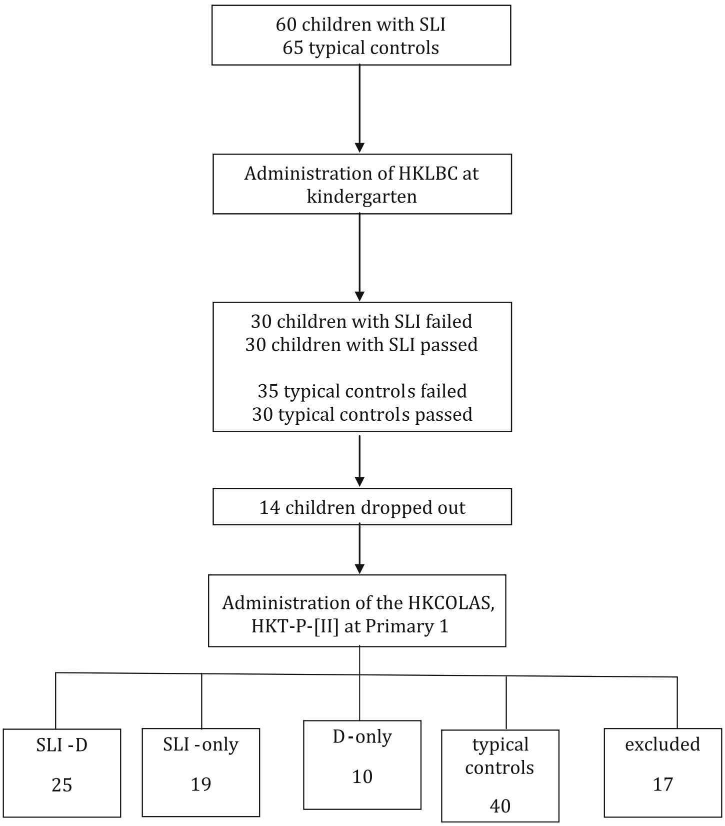

Fig. 1 A flow chart illustrating the participant recruitment process at two time points: kindergarten and primary 1

psychosocial impairment. Specifically, they scored 1.25 standard deviation below the mean for age on two or more of the six subtests in the Hong Kong Cantonese Oral Language Assessment Scale (HKCOLAS; T'sou et al., 2006). Using this criterion, HKCOLAS has been reported to have strong diagnostic accuracy with sensitivity equaled to 94.6 % (53/56) and specificity 98.2 % (55/56). Three children scored 79–83 on the locally-normed Raven's Standard Progressive Matrices; the remaining 57 children scored 85 (1 SD below on the mean) or above on this test of nonverbal cognitive abilities (Raven, 1986). They all passed a hearing screening. To ensure inclusion of children with co-morbid SLI and dyslexia, parents also filled out the Hong Kong Learning Behavior Checklist for Preschool Children (HKLBC; Wong, Ho, Chung, Chan, & Tsang, 2006)—a standardized screening tool for identifying kindergarteners at risk for learning disabilities. Despite doubts about the accuracy of parent-report preschool screening measures for dyslexia, the HKLBC's predictive reliability for dyslexia 1 year later in Primary 1 is acceptable though not very high, at around 0.70 (Ho et al., 2011). Of the 60 children diagnosed to have SLI, 30 were identified as at-risk for dyslexia according to the HKLBC. The criterion for "at risk" status was an average score of 3 or above on the 5-point scale.

Recruitment of children at risk for dyslexia and recruitment of typically-developing controls

In addition, all children from the 5- to 6-year-old class in 17 kindergartens across Hong Kong were screened with the HKLBC. All children classified as at-risk for dyslexia were invited, and 35 actually participated in the study. Thirty children who had passed the HKLBC screening were also recruited; they by-and-large matched those at-risk for dyslexia by age, gender, and school. These 65 children were then screened with HKCOLAS: 54 children, who had no prior history of language impairment, passed the oral language screening; specifically, they scored at or above the cutoff (i.e., −1.25 SD below the mean) on both the Cantonese Grammar and Nominal Expressive Vocabulary subtests in the HKCOLAS. The test developers recommended the use of these two subtests with preschool and first year primary school children when there is not enough time for administration of all six subtests (T'sou, Cheung, Lee, To, & Tung, n.d.). The remaining 11 children, who were reported to have an early history of oral language impairment, passed the screening and subsequently confirmed not meeting the diagnostic criteria for SLI (T'sou et al., 2006) upon completion of the entire test. The 65 children with normal language scored 85 or better on the Raven's Standard Progressive Matrices, except for three who scored 80.

Group classification at follow up

About 1 year later, 116 children returned after their first year in Primary School (Primary 1) for follow-up testing. The other nine children dropped out for various reasons: identified as being gifted and hence studying in Primary 2 (1), noncompliance in testing (1), withdrawal (5), loss of contact (2). Five further children were excluded because they were subsequently diagnosed as having attention deficit (2) and/or hyperactivity disorder (2), or being bilingual with English as the dominant language (1). In sum, 111 children completed follow-up testing.

All 111 children were re-tested on their oral language with four HKCOLAS subtests: Cantonese Grammar, Nominal Expressive Vocabulary, Textual Comprehension, and Narrative Retell. Status of the children with SLI was considered confirmed if they scored more than 1.25 SD below the mean in at least two of these subtests, and status of the children with typically-developing language was considered confirmed if they did not fail more than one of these subtests. Among them, the language status of 17 children (15 from the SLI group and 2 from the TD group) could not be confirmed, and they were excluded from the study. Ultimately, 94 children were included for data analysis with 44 children meeting the criteria for SLI, and 50 children with typically-developing oral language.

All 94 children were also given the HKT-P [II] (Ho et al., 2007b). Because this study set out to examine whether SLI and dyslexia were characterized by distinct patterns of cognitive deficits, instead of the clinical criteria, we used only the literacy composite in the HKT-P [II] to define dyslexia. Children with a scaled score of 7 or lower on the literacy composite were considered to meet the criterion for dyslexia. This placed 40 children in the (typically-developing oral language and reading) Control group, 10 in the dyslexia only (D-only) group, 19 in the SLI-only group, and 25 children in the comorbid SLI-D group. They ranged in age from 6.7 to 7.11 (year.month) in follow-up testing after Primary 1. Ethics approval was obtained from the Research Ethics Committee at the University of Hong Kong, and written parental consent was obtained for child participation.

Procedures and tasks

The children were seen individually and completed all activities on two separate days. The assessment battery included the HKCOLAS for oral language and the HKT-P [II] for word reading and reading-related cognitive skills.

The HKT-P [II] is a norm-referenced standardized test of dyslexia that includes five domains: literacy, phonological awareness, phonological memory, RAN, and orthographic skills. The literacy domain has three subtests. Children read two-character words, write for dictation two-character words presented orally, and read as quickly as possible from a list of simple two-character words in 1 minute. In the user manual of the HKT-P [II], the reliability coefficient was reported at 6-month age intervals. The reliability coefficient for the groups between 6.1 and 7.6 was between .97 and .99, .99, and between .89 and .92 respectively for the three literacy subtests. For phonological memory, children were asked to repeat three- to seven-syllable nonsense words (pseudo-morphemes), which comprised either morphemes presented in two speeds (two syllables/second and one syllable/second for word repetition I and II respectively), or nonsense words (pseudo-syllables) with legitimate phonotactic characteristics in Cantonese-Chinese presented in two syllables/second (nonword repetition). Responses were scored in terms of accuracy and ordering of individual syllables. For nonword reliability I, the coefficient ranged from .79 to .91, for non-word repetition II, the coefficient ranged from .82 to .87, and for word repetition, the coefficient ranged from .81 to .87.

The phonological awareness domain contained rhyme detection and onset detection. For rhyme detection, the reliability coefficient was between .55 and .75, and for onset detection, the coefficient ranged from .45 to .56. For RAN, the children named five digits randomly arranged in eight rows as quickly and as accurately as possible—twice. The average time taken in the two trials was computed. For RAN, the reliability coefficient ranged from .78 to .93. The orthographic skills domain contained three subtests: identifying numbers and characters improperly organized in the left–right orientation (i.e., left–right reversal), distinguishing non-characters (i.e., characters with misplaced radicals) from rare characters (lexical decision), indicating the accurate position of some Chinese radicals (radical position). One point was given for each correct judgment (Ho et al., 2007b). For left–right reversal, the reliability coefficient ranged from .91 to .93, for lexical decision, it ranged from .73 to .84, and for radical position, it ranged from .76 to .86.

Morphological awareness was assessed with two tasks (Chung et al. 2008). (1) The morphological construction task asked children to construct novel compound words by analogy (e.g., "Here is a traffic light. It has red and green and we call it red-green light—*hung4luk6dang1* in Cantonese. Now this traffic light has blue and green, what do we call it?", and the correct answer is blue-green light—*laam4luk6dang1*). There were 27 items and each carried one point; (2) The morphological identification task asked children to decide which two of the three orally presented two-character words contain a homophone with similar meaning [e.g., "Here are three words and they each contain *syu1*. Listen, *syu1gwai6* (bookcase), *syu1baau1* (bookbag), *syu1fuk6* (comfortable). Tell me, which two words contain the *syu1* with similar meaning." And the correct answer would be the first two words. There were 20 items and each carried one point. The Cronbach's alpha for morphological construction was .86 and that for morphological identification was .72.

The HKCOLAS is one of the two more recently standardized norm-referenced language tests developed for Cantonese Chinese children 5 years of age and above. There are six subtests. In some subtests, children are only administered items relevant to their age group, and we here report the number of items given to children between 5.08 and 6.07. Cantonese grammar assesses both comprehension (grammatical morphemes, syntax) and production (sentence construction) and there are a total of 79 items and 83 points. Textual comprehension assesses understanding of both literal meanings and inferences in two stories using 15 questions and the maximum number of points is 23. Narrative retell assesses comprehension and retelling of a complex story, and there are scores for story content (92 points), referencing (26 points), conjunctions (no maximum points) and sentence complexity (no maximum points). Lexical semantic relations (13 items, 29 points) and word definition (6 items and 48 points) assess the depth of expressive vocabulary knowledge. Expressive nominal vocabulary assesses expressive vocabulary size (100 items, 100 points) (For details, T'sou et al., 2006).

Sample characteristics

We first compared the groups on some background variables obtained in the kindergarten year, including maternal education, family income and nonverbal cognitive abilities, and their mean ages at Primary 1. Analysis of variance ANOVA revealed no significant differences between the groups in maternal education and family income (Table 1). The groups however differed in age and nonverbal cognitive abilities. Post-hoc pairwise analysis revealed that the co-morbid SLI-D group was older but scored lower than the Control group and the SLI-only group in

Table 1 Demographic information, literacy and oral language mean scores (standard deviation) in the four groups

	Controls (n = 40)	Dyslexic-only (n = 10)	SLI-only (n = 19)	Comorbid (n = 25)		
Measures					F(3, 90)	η^2
Age in months	84.93	87.20	84.66	86.8	2.74*	.08
	(3.06)	(3.97)	(3.21)	(4.17)		
Ravens	110.78	103.60	109.32	100.80	4.58**	.13
	(9.18)	(14.53)	(11.04)	(13.04)		
Maternal education in years	11.97	11.40	11.42	11.20	0.33	.01
	(2.97)	(4.38)	(3.34)	(3.04)		
Income	4.70	4.43	4.24	3.66	2.43	.08
	(1.52)	(1.26)	(1.40)	(1.66)		
					F(3, 88)	
Chinese word reading	86.98	44.60	64.42	30.44	42.74***	.59
	(24.01)	(23.65)	(17.39)	(19.51)		
One-minute word reading	59.87	36.40	49.79	31.08	28.18***	.49
	(15.49)	(14.89)	(11.21)	(12.52)		
Chinese dictation	30.80	13.60	30.84	10.20	25.05***	.46
	(12.10)	(7.82)	(14.69)	(6.03)		
Literacy average scaled score	11.57	5.67	9.61	4.87	67.70***	.69
	(2.33)	(1.50)	(1.95)	(1.52)		
Grammar	59.90	59.30	39.79	40.16	58.41***	.67
	(6.11)	(6.17)	(5.41)	(9.57)		
Textual comprehension	16.08	18.10	10.16	10.48	32.80***	.53
	(2.83)	(4.58)	(1.95)	(3.60)		
Narrative retell	102.18	94.40	65.84	59.80	41.23***	.58
	(15.90)	(14.37)	(18.80)	(14.22)		
Vocabulary	60.03	57.70	33.79	32.28	53.32***	.65
	(11.56)	(9.23)	(8.11)	(9.05)		
Oral average scaled score	11.86	11.25	5.83	5.43	117.98***	.80
	(11.57)	(1.40)	(1.41)	(1.77)		

Note * $p < .05$; ** $p < .01$; *** $p < .001$

the Raven's. Age and Raven's scores were used as covariates in subsequent analyses.

Results from the MANCOVA confirmed that the four groups differed on the literacy measures: Chinese word reading $F(3,88) = 42.74$, $p < .05$, partial$\eta^2 = .59$, 1-min word reading $F(3,88) = 28.18$, $p < .001$, partial$\eta^2 = .49$, and Chinese dictation $F(3,88) = 25.05$, $p < .001$, partial$\eta^2 = .46$ (Table 1). SLI-D and the D-only group scored significantly lower than both the Control group and the SLI-only group on all three literacy measures. The SLI-only group differed significantly from the Control group on Chinese word reading and 1-min word reading. Notably, the co-morbid SLI-D and D-only groups did not differ significantly ($p > .05$) on any of these literacy measures, suggesting that co-morbidity with SLI is not linked to severity in literacy deficits.

Table 2 Mean raw scores (standard deviation) of each group for phonological processing, orthographic skills, and morphological awareness, with results from statistical analyses

	Controls	Dyslexic-only	SLI-only	Comorbid		
Phonological awareness:					F(3, 87)	η^2
Rhyme detection	13.88	11.90	11.11	10.21	6.22***	.18
	(3.35)	(2.96)	(3.40)	(2.65)		
Onset detection	8.75	7.50	7.16	6.96	1.58	.05
	(3.11)	(3.78)	(3.04)	(2.65)		
Phonological memory:					F(3, 87)	
Word repetition I	98.65	92.70	72.79	70.92	12.42***	.30
	(15.50)	(25.57)	(18.00)	(26.54)		
Word repetition II	70.63	64.80	52.79	50.67	7.34***	.20
	(16.89)	(20.43)	(16.17)	(19.75)		
Nonword repetition	74.50	70.20	57.89	54.04	8.74***	.23
	(14.87)	(16.19)	(13.77)	(20.09)		
RAN:					F(3, 87)	
Digit number naming	22.17	28.22	22.30	27.28	5.17**	.15
	(6.72)	(9.27)	(6.50)	(6.04)		
Orthographic skills:					F(3, 87)	
Left right reversal	65.83	57.10	64.26	60.50	7.41***	.20
	(3.94)	(9.61)	(6.09)	(8.15)		
Lexical decision	50.90	47.90	49.16	45.04	2.42	.08
	(6.17)	(5.00)	(8.67)	(5.74)		
Radical position	17.43	16.90	17.11	15.13	1.94	.06
	(2.49)	(2.13)	(3.13)	(3.07)		
Morphological awareness:					F(3, 86)	
Morphological identification	15.83	14.40	11.67	10.54	15.83**	.36
	(2.70)	(3.92)	(3.78)	(2.96)		
Morphological construction	19.08	18.40	10.72	11.00	38.96**	.58
	(3.08)	(3.63)	(2.59)	(4.62)		

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

Results from MANCOVA indicated that the four groups also differed significantly on oral-language measures: Cantonese grammar $F(3, 88) = 58.41$, $p < .001$, partial$\eta^2 = .67$, text comprehension $F(3, 88) = 32.80$, $p < .001$, partial$\eta^2 = .53$, narrative retell $F(3,88) = 41.23$, $p < .001$, partial$\eta^2 = .58$, expressive vocabulary $F(3,88) = 53.32$, $p < .001$, partial$\eta^2 = .65$ (Table 1). As expected, the co-morbid SLI-D group and the SLI-only group scored significantly lower than the Control group and the D-only group on all four oral-language measures. The co-morbid SLI-D and the SLI-only group did not differ significantly from each other on any of these measures, suggesting co-morbidity with dyslexia is not linked to severity in oral-language deficits.

Analyses

For each domain (phonological awareness and memory, orthographic skills and morphological awareness),

MANCOVA was first conducted with the four groups as the independent variable, and scores for the tasks examining the domain as dependent variables. Box's test indicated that all MANCOVAs, except the one for orthographic skills, met the assumption for equality of covariance matrices. Each MANCOVA was followed up by one-way ANCOVAs. The Levene's test for homogeneity of variance was not significant for all tasks, except left–right reversal. Given that the children's Raven's scores were significantly correlated with most measures of interest (*r*s ranging .19 to .32) and given the children's variability in age, Ravens scores and age were included as covariates in all analyses. The degrees of freedom varied slightly across tests because of missing data due to technical problems.

Results

Phonological awareness

Table 2 illustrates the mean raw score of each group for the phonological processing, orthographic skills, and morphological awareness tasks, with results from statistical analyses. Results from MANCOVA revealed a significant group effect on the two phonological awareness tasks, Wilks's Lambda $F(6, 172) = 3.04$, $p < .01$, partial$\eta^2 = .01$. Follow-up ANCOVAs revealed a significant group effect for rhyme detection, $F(3, 87) = 6.22$, $p < .001$, partial$\eta^2 = .18$ and no significant effect for onset detection $F(3, 87) = 1.58$, $p > .05$. The SLI-D (M = 10.21, SD = 2.65) and the SLI-only (M = 11.11, SD = 3.40) group were significantly worse than the Control group (M = 13.88, SD = 3.35) in rhyme detection. The D-only group (M = 11.90, SD = 2.96) performed worse than the Control group as well, although the difference was not statistically significant due to the lack of power. Of note is that the D-only group had comparable means to the SLI-only group in rhyme detection. In fact, the effect size of the D-only and Control group comparison ($d = .63$) was similar to that of the SLI-only and Control group comparison ($d = .82$). Although group differences for onset detection were not statistically significant, the SLI-only (M = 7.16, SD = 3.04) and the D-only (M = 7.50, SD = 3.78) group again showed similar mean scores, and the same trend of performance across groups was observed. These results suggest that deficient phonological awareness is associated with SLI and dyslexia.

Phonological memory

Results from MANCOVA indicated a significant group effect, Wilks's Lambda $F(9, 207) = 3.83$, $p < .001$, partial$\eta^2 = .12$. Follow-up ANCOVA revealed a significant group effect on all three phonological memory measures (word repetition I, $F(3, 87) = 12.42$, $p < .001$, partial$\eta^2 = .30$; word repetition II, $F(3, 87) = 7.34$, $p < .001$, partial$\eta^2 = .20$; nonword repetition, $F(3, 87) = 8.74$, $p < .001$, partial$\eta^2 = .23$). Pairwise comparisons revealed that the Control group did better than the SLI-D and the SLI group on all three tasks. The D-only group did better than the SLI-D group on word repetition I (D-only: M = 92.70, SD = 25.57; SLI-D: M = 70.92, SD = 26.54) and nonword repetition (D-only: 70.20, SD = 16.19; SLI-D: M = 54.04, SD = 20.09). The D-only group also scored significantly higher than the SLI-only group on word repetition I (SLI: M = 72.79, SD = 18.00) and marginally on non-word repetition (SLI: M = 57.89, SD = 13.77) ($p = .055$). These results suggest that deficits in phonological memory are generally associated with SLI.

RAN

For RAN, a significant group effect was found $F(3, 87) = 5.17$, $p < .01$, partial$\eta^2 = .15$ in the ANCOVA. Pairwise comparisons indicated that the SLI-D (M = 27.28, SD = 6.04) and the D-only (M = 28.22, SD = 9.27) group did significantly worse than the Control (M = 22.17, SD = 6.72) and the SLI-only (M = 22.30, SD = 6.50) group. These results suggest that deficits in phonological access and retrieval are clearly associated with dyslexia.

Orthographic skills Results from MANCOVA indicated a significant group effect, Wilks's Lambda $F(9, 207) = 3.21$, $p < .01$, partial$\eta^2 = .10$. Follow-up ANCOVA revealed a significant group effect for left–right reversal $F(3, 87) = 7.41$, $p < .001$, partial$\eta^2 = .20$. Pairwise comparisons revealed that the SLI-D (M = 60.50, SD = 8.15) and the D-only (M = 57.10, SD = 9.61) group did worse than the Control (M = 65.83, SD = 3.94) and the SLI-only (M = 64.26, SD = 6.09) group. Group differences for lexical decision $F(3, 87) = 2.42$, $p > .05$ and radical position $F(3,87) = 1.94$, $p = .06$ were not statistically significant. Given that in the literature, children in the dyslexia group had not been tested for comorbid impairment in oral language, separate ANCOVAs were run with the SLI-D and the D-only group combined to test whether there was an indication of problems in lexical decision and radical position in children with dyslexia as previously reported. The combined group did significantly worse on lexical decision $F(1, 70) = 10.03$, $p < .01$, partial$\eta^2 = .125$ and marginally worse on radical position

Table 3 The number (and percentage) of children who succeeded in the tasks in each of the four groups

	Controls (n = 40)	D-only (n = 10)	SLI-only (n = 19)	Co-morbid (n = 25)
Phonological awareness	30 (75.0 %)	4 (40.0 %)	8 (42.1 %)	8 (32.0 %)
Phonological memory	26 (65.0 %)	5 (50.0 %)	2 (10.5 %)	7 (28.0 %)
RAN	26 (65.0 %)	3 (30.0 %)	13 (68.4 %)	6 (24.0 %)
Orthographic knowledge	34 (85.0 %)	5 (50.0 %)	14 (73.7 %)	10 (40.0 %)
Morphological awareness	35 (87.5 %)	9 (90.0 %)	4 (21.1 %)	3 (11.5 %)

$F(1, 70) = 3.92$, $p = .05$, partial$\eta^2 = .053$ than the Control group. The combined group, however, did not perform significantly worse than the SLI-only group on either tasks. Evidence from these tasks, left–right reversal in particular, suggests that deficits in orthographic skills are associated with dyslexia.

Morphological awareness Results from MANCOVA indicated a significant group effect, $F(6, 170) = 16.06$, $p < .01$, partial$\eta^2 = .36$. Follow-up ANCOVA revealed a significant group effect for both the morphological identification, $F(3, 86) = 15.83$, $p < .001$, partial$\eta^2 = .36$ and the morphological construction, $F(3,86) = 38.96$, $p < .001$, partial$\eta^2 = .58$ task. Pairwise comparisons revealed the same pattern in both tasks: the SLI-D (identification: M = 10.54, SD = 2.96; construction: M = 11.00, SD = 4.62) and the SLI (identification: M = 11.67, SD = 3.78; construction: M = 10.72, SD = 2.59) group did worse than the Control (identification: M = 15.83, SD = 2.70; construction: M = 19.08, SD = 3.08) and the D (identification: M = 14.40, SD = 3.92, construction: M = 18.40, SD = 3.63) group. This pattern of results suggests that deficient morphological awareness is associated with SLI.

Individual pattern analysis was conducted to ascertain results from the group analyses. Children who received a scaled composite score of ten or above were considered successful in the phonological awareness, phonological memory, RAN, and orthographic knowledge tasks. A z-score composite was calculated from the two morphological awareness tasks, and a score that was higher than 0 were considered successful. Table 3 illustrates the number and percentage of children who succeeded in these tasks. Of particular interest were results from the SLI-only and D-only group. There were fewer children in the D-only than in the SLI-only group who succeeded in RAN and orthographic knowledge tasks. There ware fewer children in the SLI-only than in the D-only group who succeeded in the phonological memory and morphological awareness tasks. There was no difference in the percentage of children in the SLI-only and the D-only group who succeeded in the phonological awareness tasks. Results were consistent with the those from the group analyses.

Discussion

Ninety-four Primary 1 children were classified into four groups, using their literacy composite scores in the HKT-P [II] and their performance in the HKCOLAS for diagnosis: SLI-only, D-only, co-morbid SLI-D, and typical-developing controls. Their performance on various cognitive tasks suggested that SLI and dyslexia in Cantonese Chinese were not exactly distinct disorders. They were both characterized by a deficit in phonological awareness, although each was associated with additional deficits. Specifically, deficits in phonological access and retrieval and orthographic skills belonged with dyslexia in Cantonese Chinese. By contrast, deficits in phonological memory and morphological awareness belonged with SLI. Some findings from this study could have been limited by the small sample size, particularly of the dyslexia-only group with 10 children. Findings could also have been confounded by the fact the SLI group was weak in word reading relative to the Control group, a finding not uncommon in this population of children.

Phonological memory

Phonological memory—typically assessed with nonword repetition—is crucial in establishing phonological representations and processing oral language (Gathercole, Willis, Emslie, & Baddeley, 1992). Substantial evidence (Estes, Evans, & Else-Quest, 2007; Montgomery, Magimairnj, & Finney, 2010 for review) has shown that English-speaking children with SLI have deficits in nonword repetition. Comparatively little is known about the repetition of nonsense words in children with SLI speaking Cantonese Chinese. In this study, the word repetition I, and marginally the nonword repetition task, demonstrated an association between phonological memory and SLI. The link between phonological memory and SLI uncovered in this study is consistent with Wong et al.'s (2010) findings based on a smaller sample of older school-age children comparing SLI-only with typically-developing controls. These findings are however inconsistent with another small-sample study on young preschool children with SLI which yielded null results (Stokes, Wong, Fletcher, & Leonard, 2006). One caveat: nonword repetition might not be a pure measure of phonological memory because it invokes long-term linguistic knowledge to some extent. Moreover, longitudinal studies on Chinese children are needed to sort out direction of the causal relationship between phonological memory deficits and SLI.

Nonword repetition has been reported to be difficult for Chinese children with dyslexia (Ho, Chan, Chung, Lee, & Tsang, 2007a; Ho, Law, & Ng, 2000), but meta-analyses of studies involving children learning different written systems have raised questions about a direct link between dyslexia and nonword repetition deficits (Melby-Lervag & Lervag, 2012; Melby-Lervag, Lyster, & Hulme, 2012). Melby-Lervag argued that because oral language was not systematically examined in those studies, the phonological memory deficits observed might well be due to co-morbid oral-language deficits. Nation and Hulme (2011) offered a different account. They found that reading in typically-developing children at 6 years of age predicted nonword repetition ability between 6 and 7 years, independent of the effects of oral language. The reverse was not the case: nonword repetition did not longitudinally predict the growth of reading, at least within the narrow age range examined. These results suggested that problems in learning to read lead to poor nonword repetition in children with dyslexia, but not vice versa.

Building on Seidenberg and Tanenhaus's (1979) idea that when a word is heard, orthographic information is automatically activated, Nation and Hulme (2011) hypothesized that orthographic information provides "an additional mnemonic cue" (p. 650) that helps to support nonword repetition. Given the weak correspondence between grapheme and phoneme in Chinese, orthographic information barely provides any mnemonic cue, and poor reading therefore should not have a strong effect on nonword repetition. Hence problems in nonword repetition were not observed in many of the Chinese children with dyslexia, and a difference between the D-only and the Control group was not observed in this study. That being said, given the small size of the D-only group, future longitudinal research will have to ascertain this, particularly to reconcile with findings from an epidemiological study (Catts et al., 2005) in which English-speaking children with dyslexia alone were found to have problems with nonword repetition and children with SLI (no dyslexia) were found to have a relatively mild deficit.

Morphological awareness

Morphological awareness has been linked to Chinese word reading concurrently (McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; Shu et al., 2006) and predictively (Tong et al., 2011), making a unique contribution to the variance above and beyond oral language. Several studies have also reported that Chinese children with dyslexia demonstrated subpar morphological awareness. Like phonological access and retrieval skills and orthographic skills, morphological awareness is among the strongest correlates of dyslexia in primary and secondary school children (Chung, Ho, Chan, Tsang, & Lee, 2010; Ho et al., 2002, 2004; Shu et al., 2006). These studies, however, did not systematically evaluate oral language, leaving it unclear how much the observed link between morphological awareness and dyslexia can be attributed to co-morbid oral-language deficits.

Morphological-awareness deficits have indeed been linked with SLI in English (Oetting & Rice, 1993; Smith-Lock, 1995; Van der Lely & Christian, 2000). On morphological construction tasks similar to that used in Cantonese Chinese (constructing novel word compounds such as *ghost-camel*), English-speaking children with SLI performed significantly worse than their controls, particularly in the correct ordering of the root noun and modifier (Grela, Synder, & Hiramatsu, 2005; McGregor, Rost, Guo, & Sheng, 2010). In Cantonese Chinese, children with co-morbid SLI-D or SLI-only also perform worse than those with normal language on morphological construction (Wong et al., 2010). Among children without dyslexia, those with oral language delays do worse than those without such delays (Wong et al., 2012).

Present findings on two different tasks further clarified that morphological-awareness deficits belong with SLI and not dyslexia for children between 6 and 7. It is however plausible that after some years of reading, with gains in their vocabulary breadth and depth, older children will have stronger morphological awareness, which in turn makes a reciprocal impact on word reading. In both the morphological identification and construction tasks, the SLI and the SLI-D group scored significantly worse than both the dyslexia and the Control group. This makes sense—with hindsight—because morphological awareness was assessed in Chinese here and in prior studies with strictly oral tasks (e.g., hearing one word compound, then constructing another by analogy) that require morphosyntactic and lexical knowledge rather than reading abilities. Note that homophones are highly prevalent in Chinese, and the morphosyntax of the word compounds helps interpret constituent morphemes. For example, *din6nou5* (literally meaning "electricity-brain") refers to "computer". The syllable *nou6* can also mean "old", which being an adjectival modifier usually occurs before the head noun rather than as the head noun. Success in this task therefore requires morphosyntactic knowledge, which for young children is typically acquired in oral language rather than reading.

Phonological awareness

The present study suggests that deficits in phonological awareness are associated with SLI and dyslexia in Cantonese Chinese. We will first discuss the association with SLI. In one of the two phonological awareness tasks, rhyme detection, the Control group did significantly better than both the SLI and the SLI-D group. No group difference was found for onset detection perhaps because it is a relatively difficult task and not a sensitive tool for these young children. Indeed, a review of the norm tables for children from age 6.1 to 10.6 (at 6-month interval) revealed that the scores for onset detection consistently lag behind rhyme detection in all age groups. Results from this study partially replicated that of Wong et al. (2010) on older children, where the SLI and the SLI-D group both scored worse than their age controls in the rhyme as well as the onset detection task.

This conclusion echos Catts et al.'s (2005) study documenting differences between children with SLI and age peers in one of the three grades examined. Theoretically the association between deficient phonological awareness and SLI uncovered in our study makes sense for two reasons. First, the lexical restructuring hypothesis (Metsala, 1997; Metsala & Walley, 1998) proposes that an increase in vocabulary size motivates a more segmental phonological representation of words. With a smaller vocabulary, children with SLI have less segmentation of words into syllables, onsets and rhymes, which then can result in poor manipulation of sublexical units and hence phonological awareness. Second, poor verbal short-term memory can lead to poor retention of phonological information for metalinguistic manipulation such as comparing two sublexical units.

Subpar phonological awareness was reported to be a core deficit of dyslexia in English (e.g., Adams, 1990; Bryant, Maclean, & Bradley, 1990; Catts, 1993; Chaney, 1998; Stanovich, 1993; Torgesen, Wagner, & Rashotte, 1994) and this has been confirmed in studies where children with dyslexia were tested for oral language deficits and children with language impairments were tested for word reading difficulties (e.g., Catts et al., 2005). The importance of phonological awareness to reading development in alphabetic writing systems can be explained by systematic mappings of phonemes and graphemes, but such mappings are far less reliable in Chinese.

Earlier studies (Ho et al., 2002, 2004) have hinted that phonological awareness is a non-core deficit for dyslexia in Cantonese Chinese because it is observed in only a small percentage of afflicted children. With our small sample of 10 children with only dyslexia, perhaps only very few had significant difficulties in rhyme detection. Results from this study suggest that deficits in phonological awareness might not be unique for dyslexia in Chinese. By contrast, tests of phonological awareness could identify children with SLI in Chinese.

Orthographic skills and RAN

Among the three orthographic skills tasks, left–right reversal showed the clearest pattern of association with dyslexia. In this task, the D-only group and the SLI-D group did significantly worse than both the Control and the SLI group. Evidence from the D-only and the SLI-D combined group suggested that lexical decision and radical position belonged with dyslexia. From the norm table in the user manual of the HKT-P [II], it was observed that children's scores for radical position lagged behind left right reversal for all age groups. In fact, in the upcoming third edition of the HKT for low elementary school children, radical position will be taken out (Ho, personal communication, 2014). The present study adds to Ho et al.'s (2002) finding that children with dyslexia have difficulties in analyzing the visual and compositional structure and in forming orthographic representations of Chinese characters. Importantly, these cognitive skills are not taught explicitly but instead learned through exposure to reading materials in the environment—rendering them robust predictors of dyslexia regardless of school teaching.

This study reported a clear association between phonological access and retrieval and dyslexia in Cantonese Chinese children. The D-only and the SLI-D group did significantly worse than both the SLI-only and the Control group on RAN. As Wolf, Bowers and Biddle (2000) pointed out, RAN and word reading share a complex set of attentional, perceptual, conceptual, lexical and motor processes. Poor lexical access and retrieval should therefore be observed in children with dyslexia who are learning different orthographies. It has been suggested that RAN was a protective factor against decoding deficits in children with SLI (Bishop et al., 2009). Given the small sample of Chinese children in the D-only group, research is needed to replicate this finding.

Conclusions

There have been arguments that dyslexia (Pennington, 2006) and SLI (Bishop, 2006) are characterized by multiple deficits. SLI and dyslexia in Cantonese Chinese seem to be linked to different clusters of underlying cognitive deficits: SLI with phonological memory and morphological awareness, and dyslexia with orthographic skills and RAN. These findings are consistent with the 'Distinct' hypothesis.

Evidence from phonological awareness however suggests that SLI and dyslexia might not be exactly distinct disorders. Children in both the dyslexia and the SLI group performed worse than the normal controls on rhyme detection. Given the small sample size, the comparison between the dyslexia and the control group was not statistically significant. Future studies are needed to clarify the role of phonological awareness in dyslexia for Chinese children in order to give a more rigorous test of the 'Distinct' hypothesis of dyslexia and SLI.

While dyslexia in English (or other alphabetic writing systems) is characterized by deficits in all three phonological processing skills (memory, awareness, retrieval), dyslexia in Cantonese Chinese seems to be only uniquely characterized by a deficit in lexical access and retrieval. The phonological dimension in theoretical models of dyslexia (e.g., Bishop and Snowling, 2004) therefore requires further distinction for different orthographic scripts.

This is the first study in dyslexia that included a sample of Chinese children whose oral language was systematically examined and SLI diagnosis was clinically made. Currently, diagnostic criteria for dyslexia in Cantonese Chinese, based on the HKT-P [II], include failure in the literacy composite and at least one of the four cognitive domains. Present findings revealed that two of those four cognitive domains turn out to be (also) relevant to SLI and rather than dyslexia alone. Future studies on a larger sample of children with dyslexia alone will inform us whether we could take them out from the dyslexia test battery for Cantonese Chinese children.

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