HK J Paediatr (new series) 2008;**13**:90-98

Towards Early Identification of Dyslexia in Chinese Preschool Children: A Study on Reading and Cognitive Profile in Children with Genetic Risk of Dyslexia in Hong Kong

FWF **Lam,** C **McBride-Chang,** CCC **Lam,** SWL **Wong,** Y **Chow,** S **Doo**

Abstract

Dyslexia is a common developmental condition of neurobiological basis. It has profound implications for the psychosocial development and academic achievement of affected individuals. Its prevalence is around 10% across nations and is higher in the population with family history of dyslexia. Recent studies have demonstrated that intervention is effective and that prevention of reading failure is possible if preschool children at risk of dyslexia are identified and offered timely and evidence-based training. **Objective:** To examine the discriminative cognitive measures that might distinguish Chinese preschool children at genetic risk of dyslexia from their typically developing peers; to examine how these abilities correlate with reading in Chinese and with literacy related skills in English. **Methods:** Eighty younger siblings of children diagnosed with dyslexia were tested on Chinese word recognition, English letter naming, nonverbal IQ and a constellation of cognitive tasks tapping phonological awareness, automaticity, visual-spatial skills and morphological awareness. Controls were typically developing children with no such risk factors and were matched by age, IQ, and parents' education. **Results:** Compared to controls, at-risk group performed significantly worse in Chinese word recognition and English letter naming. The at-risk group also performed significantly worse in visual-spatial skills, rapid number naming and morphological awareness. Chinese word recognition was found to be significantly correlated with all cognitive measures studied. English letter naming was most strongly correlated with rapid number naming. **Conclusion:** We demonstrated that early literacy related skills of children with genetic risk of dyslexia were significantly weaker than their typically developing peers. We identified the cognitive measures that discriminated the two groups as early as five-year-old. Further follow-up study on reading perfomance of our cohorts when they reach their school age will be crucial to validate our present findings and to justify the construction of an assessment tool for early identification of at-risk children.

Key words Chinese preschool children; Cognitive measures; Dyslexia; Genetic risk

Child Assessment Service, Department of Health, Hong Kong, China

FWF **Lam**（林蕙芬） *MRCP, FHKCPaed*
CCC **Lam**（藍芷芊） *MBBS, FRCP(Edin), FHKAM(Paed)*
S **Doo**（杜蘊瑜） *MRCPCH, MSc(Epidemiology & Biostatistics)*

Department of Psychology, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China

C **McBridge-Chang** *PhD*
SWL **Wong**（黃緯立）*MPhil(HKU)*
Y **Chow**（周玉兒） *BSocSc(HKU)*

Correspondence to: Dr FWF **Lam**

Received October 8, 2007

Background

Dyslexia, or specific reading disability, is a common developmental condition characterised by discrepant difficulties in word recognition and reading in the context of normal general intelligence, adequate motivation and effective education. Prevalence of dyslexia is estimated to be around 10% across nations.[1-4] In Hong Kong school age children, the prevalence of dyslexia is estimated to be 9.7-12% and the male to female ratio is around 1.6:1.[4] In 1995, dyslexia was first defined as a constitutional language-based disorder, focusing on underlying insufficient phonological processing skills (referring to the use of sounds of oral language in processing written and oral language) that led to difficulties in single word decoding and the manifestation of problems with reading, spelling and writing.[5] This definition was subsequently elaborated to explicitly state that secondary consequences, including problems in reading comprehension and reduced reading experience, can impede growth of vocabulary and background knowledge.[6] Dyslexia also has significant resource implications in education settings as it accounts for 80% of specific learning difficulties (SLD);[7] and creates a substantial psychological burden on affected children and their parents, who struggle to cope with overwhelming academic demands in modern societies. If undiagnosed and untreated, dyslexia may lead to avoidance of learning and repeated frustrations,[8] and the dire consequence of behavioural and social problems. A study on sixty-two P.3 and P.4 students in Schools for Social Development in Hong Kong, which accommodate students with severe emotional and behavioural problems, showed that prevalence of dyslexia was 61% there, in contrast to around 10% in the general population.[9]

On the other hand, success in prevention of at-risk cases developing reading failure and favourable outcome of remediation of dyslexia was demonstrated by evidence from methodologically rigorous studies.[10] Intensive, explicit teaching of rules on manipulation of sounds in a language, preferably using a multi-sensory approach, was effective to enable at-risk kindergartners to develop normal reading accuracy and fluency when re-evaluated at fourth grade.[11] On the other hand, older children diagnosed dyslexia should be given appropriate accommodation and training in educational settings so that they may apply their unimpaired higher cognitive functions to compensate for their specific difficulty in reading and achieve satisfactory attainment in education. As prevention was demonstrated to be more effective than remediation, young children at risk of dyslexia should be identified early and offered evidence-based training. Its relatively high prevalence further justifies careful surveillance of at-risk cases from a public health economy perspective.

However, diagnosis of dyslexia is complicated, despite the fact that its neurobiological basis is well established. Shaywitz et al[12] used fMRI to study one hundred and forty four right-handed children and demonstrated that normal children demonstrated significantly greater brain activation during phonological analysis, in left hemisphere sites including the left inferior frontal, superior temporal, parieto-temporal regions and area between middle temporal to middle-occipital gyri. Interestingly, given the complex visual form of the Chinese logographic written language, visual-spatial deficit was specifically implicated in reading impairment in Chinese. This hypothesis was confirmed by compelling fMRI evidence that activation of the right occipital and parietal regions were different between normal and dyslexics in Chinese.[13,14] Recent fMRI studies showed that the left middle frontal gyrus (a region above Broca's area) showed peak activation in the processing of Chinese characters.[15] It was postulated that the left middle frontal gyrus coordinates and integrates various information from phonological and visual-spatial processes to form verbal and spatial working memory.

Genetic basis of developmental dyslexia was first implied by population based family aggregation and twin studies showing higher prevalence among family members. Pennington and Gilger[16] demonstrated the rate of dyslexia among siblings to be approximately 40% and among parents to be 27-49%. Twin studies showed a higher concordance rate in monozygotic (84-100%) compared with dizygotic (20-35%) twins.[17] Now dyslexia is considered a complex trait and a genetically heterogeneous condition that does not concur with any classical Mendelian inheritance. Although the identification of susceptibility genes of dyslexia (ROBO1, DYX1C1, DCDC2 and KIAA0319)[18,19] is alluring in molecular genetics, until the genotype-phenotype correlations are clearly defined, it is not possible to diagnose dyslexia using genetic studies per se. Therefore the mainstay of diagnosis of dyslexia is still clinical assessment of the behavioural phenotype using standardised psychometric tests by experienced clinicians. Locally dyslexia is diagnosed by standard criteria using "the Hong Kong Test of Specific Learning Difficulties in Reading and Writing"[20] provided that IQ is above 80 as measured by the Hong Kong-Wechsler Intelligence Scale for Children[21] in school age children. In preschool children, "the Hong Kong Learning Behaviour Checklist for Preschool Children"[22] is a questionnaire for parents and teachers but there is no individually administered psychometric test customised to assess their risk of developing dyslexia. This situation can be attributed to the lack of understanding of the cognitive profile and developmental characteristics of Chinese preschool children at risk of dyslexia. In this paper, we describe the collaborative study between Child Assessment Service, Department of Health, Hong Kong and Department of Psychology, The Chinese University of Hong Kong. The objective of the present study is to compare the performance on the discriminative cognitive measures between Chinese preschool children at-risk for dyslexia and their typically developing peers, and to examine how these abilities are correlated to early reading in Chinese and literacy related skill in English.

Method

Approval for research was obtained from the Ethics Committee of Department of Health and written parental consent was obtained from all participants. This study is part of a longitudinal cohort study on early identification of children at risk for dyslexia and the final outcome, the diagnosis of dyslexia, will be assessed when the participants complete Grade 1 at primary school in mid 2008.

Participants

With the high recurrence risk in younger siblings of individuals with dyslexia, longitudinal follow up focusing on this group of children allows us to prospectively examine their cognitive development at an early age and to correlate the findings at younger age to subsequent reading ability. Here, inclusion criteria of our participants were children with elder siblings who were diagnosed to have dyslexia by the Child Assessment Service; and were completing the second year of kindergarten at the time of study. Children with significant behavioural problems including autism, excessive hyperactivity or with known developmental delay were excluded. Controls were age, nonverbal IQ and parental education matched typically developing children, and were selected from participants in an on-going study of language and literacy development under the initiatives of the second author.

Procedure

Testing for the at-risk subjects was performed individually by trained Psychology Major students and developmental paediatricians at seven Child Assessment Centres in Hong Kong. All children were tested on the same set of reading and cognitive tasks, and testing was administered by using standard booklets, standard oral instructions in Cantonese, and recordings from MP3. All procedures were performed according to strict protocol. Testing on all at-risk subjects and controls was performed during the months June through July to ensure consistent environmental and education background.

Measures

Whereas the potential early markers of reading difficulties in young Chinese children were largely unknown, we reviewed literature on cognitive deficits of dyslexia in literature on English- and Chinese-speaking children in order to design our test constructs. In older subjects with dyslexia in an alphabetical script such as English, difficulties with accurate and/or fluent word recognition associated with poor spelling and decoding abilities are the hallmark clinical phenotype.[6] These difficulties typically result from deficits of phonological processing skills, which included phonological awareness, automaticity and verbal memory. Phonological awareness refers to the ability to compare, segment, and discriminate spoken words on the basis of the sound structure of one's language.[23] This awareness that all spoken words can be decomposed into basic phonological segments known as phonemes and that each alphabetical letter represents an arbitrarily assigned phoneme allows the reader to relate the letter strings (the orthography) to the corresponding units of speech they represent. For example to read the word "cat", the reader has to be aware that it comprises three phonemes "kuh" "aah" and "tuh" and then blend them together to pronounce it. By associating the written form of a word to its spoken form and then to its meaning, the word is decoded. Another phonological skill important to reading is called "phonological recoding in lexical access"[24] and is related to automaticity.[25] In normal readers, the above cognitive processes of reading occur automatically, without the speaker or listener consciously processing the information and allow reading to be fluent and uninterrupted. Automaticity can be measured by Rapid Automatised Naming (RAN) , which was found to strongly distinguish children with dyslexia from those without dyslexia across a variety of alphabetic orthographies.[26] The last phonological skill involved is short term verbal memory,[24] which allows the reader to remember and retain the sounds being read long enough to associate meanings with the sentences or paragraphs that are read, is therefore critical in successful processing of information and reading comprehension.

How about reading Chinese script in Cantonese? Do our children learning to read Chinese make use of the same cognitive skills as their counterparts learning alphabetical scripts?

Chinese script is morphosyllabic, meaning that each character represents both a syllable and a basic unit of meaning known as a morpheme; and is logographic given its unique visual form. In those Chinese characters that are derived from figures of real objects, for example "山"(pronounced as "saan" meaning mountain), the configuration of a character directly implies its underlying meaning. Studies on Chinese children have demonstrated some association of pure visual and orthographic processing and visual skills predicted reading success at lower grades,[27,28] and suggested that early visual skills are crucial in reading Chinese, which contains rich visual-spatial information. On the other hand, increasing evidence showed that phonological processing skills were also critical in reading Chinese.[29-31] In our study *syllable deletion* and *tone detection* were tasks specifically designed to examine phonological awareness in Chinese. McBride-Chang et al had consistently demonstrated that *syllable deletion* was one of the strongest predictors of Chinese word recognition on typically developing Chinese kindergartners.[29,32] This phenomenon can be explained by the unique nature of Chinese language in which syllable is the basic unit of Chinese spoken language and is the basic unit to be manipulated in reading. *Tone detection* is especially pertinent to reading Chinese. Whereas the number of syllables used in Chinese is limited to about 1300, the number of commonly used morphemes is about 5000. In Cantonese, each syllable can be spoken in six contrastive tones and each tone of the same syllable can represent a distinct meaning. Therefore the awareness of this subtle difference in tone is important to accurately label a Chinese character in spoken form. Another phonological processing skill, automaticity as measured by *rapid automatic naming*, is also critical in reading logographic language like Chinese.[33] Finally, another language-related cognitive skill, *morphological awareness* (defined as the consciousness of the morphemic structure of words and the ability to reflect on and manipulate that structure) was found to be a core cognitive construct for explaining variability in reading Chinese in preschool and school age children[34,35] as in other alphabetical languages. Actually a lot of Chinese compound words are made up of two word parts that each contains a morpheme and therefore the ability to manipulate morphemes is especially important in reading Chinese characters.

After reviewing the cognitive underpinnings of learning to read Chinese language in normal and dyslexic children and incorporating clinical experience, we decided to test the participants on *Chinese word recognition and English letter naming* as an indication of early literacy related tasks and a battery of cognitive tasks encompassing S*yllable deletion, Tone detection, Rapid number naming, Visual skill and Morphological awareness*. Details on standardised procedure for administering the test constructs were depicted in Appendix 1.

Results

Eighty younger siblings of children who were diagnosed as having dyslexia by Child Assessment Service were recruited as participants of the present study. These younger siblings (43 boys, 37 girls) were studying at the second year of kindergarten at the time of the study and their mean age was 60.97 months (SD=4.03 months). A group of 80 children (37 boys, 43 girls, mean age=60.85 months, SD=3.64 months) were matched to these at-risk children based on age, parents' educational levels, and nonverbal intelligence, using the score of *Coloured Progressive Matrices*. The controls were selected from a larger group of two hundred and fifteen typically developing children who were participants in an on-going longitudinal study of language and literacy development under the direction of the second author. Data on age, nonverbal IQ and parental education of the 2 comparison groups are summarised in Table 1.

Table 1 Mean scores and standard deviations of age, nonverbal IQ and parents' education of two groups of participants (at genetic risk of dyslexia and normally-achieving) and the *p* values for test of group differences by *t*-test

Group/Task	**Genetic risk N=80**	**Normally achieving N=80**	***t*-value**	***p*-value**
	Mean (S.D.)	*Mean (S.D.)*	*df*=158	
Age (month)	60.97 (4.03)	60.85 (3.71)	-0.20	0.75
Nonverbal IQ (raw scores of Raven)	11.48 (2.49)	10.98 (2.04)	-1.39	0.24
Parents' education*	3.66 (1.17)	3.64 (1.17)	-0.10	0.96

Note : *1: primary school or below to 7: postgraduate

We first compared the performance on *Chinese word recognition* and *English letter naming* of the two groups of subjects. Analysis of covariance (ANCOVA) controlling for the effects of age, nonverbal IQ and parents' education showed that children at genetic risk of dyslexia performed significantly worse than the control group in *Chinese word recognition* (F [1, 155] = 15.77, p<0.001) and *English letter naming* (F [1, 155] = 55.90, p<0.001). Next, a 2 (group) × 5 (task) between-subjects multivariate analysis of covariance (MANCOVA) controlling for age, nonverbal IQ and parents' education revealed that there was a main effect for group (F [1, 155] = 4.35, p<0.01). Then five separate ANCOVAs controlling for the effects of age, nonverbal IQ and parents' education were computed for the cognitive tasks. The F-values and descriptive statistics are shown in Table 2. Compared to controls, children with genetic risk of dyslexia performed significantly worse in *Visual-spatial relationship*, *Rapid number naming* and *Morphological awareness*. The scores of children with genetic risk of dyslexia in *Syllable deletion* and *Tone detection* were comparable to those of normally achieving children.

Table 3 shows the inter-correlations among all measures, controlling for the effects of age, nonverbal IQ and parents' education. *Chinese word recognition* was significantly and moderately associated with *English letter naming* (correlation coefficient 0.46) and all cognitive measures (absolute value of correlation coefficients ranged from 0.31 to 0.39). *English letter naming* was significantly and moderately correlated with all cognitive measures except tone detection. The power of the correlation coefficients in the partial correlation analyses was satisfactory. As shown in Table 3, the correlation coefficients are in the range of 0.16 and 0.46 and according to Algina and Olejnik's formulation,[36] the power we obtained (0.40-0.90) was considered strong for our study, in which a 0.05 test of the null hypothesis (a correlation coefficient is zero), was conducted.

Table 2 Mean scores and standard deviations of early literacy skills and cognitive tasks of two groups of participants (at genetic risk of dyslexia and normally achieving) and the F values for analysis of covariance (ANCOVA) controlling for age, nonverbal IQ and parents' education

Group/Task	**Genetic risk N=80**	**Normally achieving N=80**	***F*-value**
	Mean (S.D.)	*Mean (S.D.)*	*F* (1, 155)
Early literacy-related skills			
Chinese word recognition (max=211)	34.98 (20.48)	48.47 (24.83)	15.77***
Letter naming (max=26)	21.50 (5.56)	26.00 (0.00)	55.90***
Cognitive tasks			
Syllable deletion (max=13)	10.30 (3.79)	11.18 (3.17)	3.78 (p = 0.05)
Tone detection (max=36)	33.28 (4.44)	34.13 (5.17)	1.88
Rapid number naming (second)	25.20 (13.17)	19.67 (5.29)	14.23***
Visual-spatial relationships (max=16)	9.61 (4.05)	10.45 (4.20)	4.86*
Morphological awareness (max=15)	6.99 (3.70)	8.39 (4.08)	8.53**

*Note: *p<0.05; **p<0.01, ***p<0.001*

Table 3 Partial correlations among different measures partialing for children's age, nonverbal IQ and parents' education (n=160)

Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Chinese word recognition	—						
2. Letter naming	0.46***	—					
3. Syllable deletion	0.39***	0.26**	—				
4. Tone detection	0.35***	0.09	0.37***	—			
5. Rapid number naming	-0.31***	-0.47***	-0.35***	-0.16*	—		
6. Visual-spatial relationships	0.32***	0.24**	0.22**	0.23**	-0.18*	—	
7. Morphological awareness	0.33***	0.22**	0.41***	0.47***	-0.19*	0.20*	—

*Note: *p<0.05; **p<0.01, ***p<0.001*

Discussion

This study is among the first attempts to study the cognitive development of Chinese children at risk of dyslexia by virtue of family history at preschool stage. It is also the first research in this area to be interdisciplinary. Such approach has the strength of combining the theoretical expertise of developmental psychologists with clinical expertise of developmental paediatricians.

To set the scene for early identification of children who are at risk of dyslexia, it is critical to distinguish correlates from causes of dyslexia in young children. The cognitive factor correlated with reading performance may not necessarily be the underlying cause of dyslexia. First, the causal correlation between performance of the cognitive measures and the reading ability observed can be bi-directional. For example, in trying to explain for the association of visual-spatial skill with reading performance, we may argue that Chinese children who show early difficulties in reading Chinese words and English letters tend to score relatively low on *visual-spatial relationships* because they have a lack of exposure to pre-reading teaching materials or prints. This lack of exposure causes underdevelopment of visual-spatial skills. In another word, inadequate experience with pre-reading visual-spatial training materials or print may be the common cause of low scores in early literacy-related skills (*Chinese word recognition* and *English letter naming*) and *visual spatial relationships*. It is also possible that another variable that is not measured in our study is actually mediating both reading performance and visual spatial relationships. Second, the acquisition of reading is a developmental process and therefore poor performance in a reading test and cognitive testing in preschool does not inevitably suggest dyslexia at school age. Afterall the children being tested are only five year olds and have had relatively little experience with print. As a corollary to late talker and late walker, the group showing delay at the time of testing may catch up with reading skills and cognitive skills. Therefore it is critical for us to follow up the participants to school age and measure the outcome of dyslexia, by standardised tests. By then we would be able to calculate the sensitivity and specificity of the battery of test and contemplate on assessing the at-risk children at preschool age if it is justified. Those children identified at preschool should be offered timely and evidence based training to prevent reading failure at school age. They should be also referred to the Education Department for Early Identification and Intervention (EII) program immediately when school term begins, instead of waiting for the child's academic performance and psychological well-being to falter before the referral system being activated.

Our results demonstrated that among the genetic risk group and the controls, who did not have significant difference in nonverbal IQ (Table 1), a discrepancy in the development of early literacy related skills was clearly demonstrated (Table 2) as early as five years of age. The at-risk group performed significantly worse in both Chinese word recognition and letter naming. This finding concurred with the notable Jyväskylä Longitudinal Study of Dyslexia,[37] which sought to identify early precursors of dyslexia by looking at Finnish children with familial risk, using a plethora of assessment including electrophysiological study in infants, assessment of auditory-phonic and linguistic skills, comprehensive developmental assessment from birth through early childhood and letter knowledge in preschool years. Among all the measures, Lyytinen et al concluded that low letter knowledge was the best single predictor of early reading failure in alphabetical language. Letter naming is a foundation decoding ability and was found to be significantly different between the familial risk group and the control group as early as 4.5 years. Though conceptually and theoretically elusive, it would be interesting to find out how English letter naming at preschool stage will correlate with subsequent Chinese literacy (which is the mainstay of diagnostic criteria of dyslexia in Hong Kong) when our cohorts reach school age.

When scores of the discriminative cognitive measures were compared among the two groups of participants (Table 2), statistically significant difference was demonstrated in *rapid number naming* ($p<0.001$), *morphological awareness* ($p<0.01$) and *visual-spatial relationships* ($p<0.05$). That phonological tasks namely *tone detection* and *syllable deletion* were not statistically significant in discriminating the two groups, was incompatible with existing literature on dyslexia in Chinese children. Upon detailed analysis of the raw data, we found that the level of difficulty of these tasks may be too low and the items need to be improvised in future testing. For example, in syllable deletion, mean score of the at-risk group was 10.3 (SD=3.79) and that of the control group was 11.18 (SD=3.18) while the maximum score was 13. For tone detection, at risk group scored 33.28 (SD=4.44), the control group scored 34.13 (SD=5.17), while the maximum score was 36. Therefore many children in both groups actually scored full marks in *syllable deletion* and *tone detection* tasks.

When combining both the at-risk and control group together, which rendered the sample over-represented by at-risk children when compared to the general population, *Chinese word recognition* correlated significantly with all cognitive measures that were tested (Table 3), implying that phonological processing, automaticity, visual-spatial skills and morphological awareness were important in reading Chinese. This finding reconciled with previous neuropsychological, neurophysioloigcal and neuroimaging studies that a broad range of cognitive functions is involved in reading Chinese. On the other hand, *English letter naming* was moderately correlated with all cognitive measures except *tone detection*. There was a relatively stronger correlation between *English letter naming* and *rapid number naming* (Table 3), which is in agreement with existing evidence that automaticity strongly distinguishes children with dyslexia from the control group across languages.[26] Moreover the degree of correlation between *Chinese word recognition* and other cognitive factors are stronger than that for *English letter naming*.

There are several limitations of our study. First, our constellation of cognitive measures is not exhaustive. Other unknown cognitive skills underlying reading acquisition should continue to be explored and studied. Moreover, dyslexia is a language-based condition. Should resource allow, standardised receptive and expressive language assessment, which is pertinent in identification of precursors of dyslexia in young children, would have been applied in this study. Second, as dyslexia is commonly associated with other developmental conditions, such as Specific Language Impairment, Attention Deficit Hyperactive Disorder and Developmental Coordination Disorder, our at-risk group does not represent a homogeneous population that is at risk of dyslexia alone. In the at-risk group, other higher cognitive functions such as attention and memory may interact in the participants' developing brains to various degrees and affect the acquisition of reading. We should evaluate the outcome of dyslexia with or without comorbidity in the longitudinal follow up of our at-risk group to ascertain the effect of comorbidity in early reading.

Finally, environmental factors invariably interact with the genetic predisposition in explaining the observed difference in cognitive measures and early literacy related skills between the at-risk group and the controls. A recent twin study from the UK addressed the genetic and environmental origins of learning abilities and disabilities in the domains of English (which include reading, writing and speaking), mathematics and science, in young school age children.[38] The estimated heritability (averaged over groups) for the English domain was 0.64 for 7-year-old, 0.64 for 9-year-old and 0.62 for 10-year-old. The whole parallel environmental estimates were 0.18, 0.14 and 0.18 accordingly. The authors suggested that genes largely contribute to similarity in performance within and between the three domains and with general cognitive ability, whereas the environment contributes to differences in performance. Here in our study, environmental issues like heterogeneity of pre-school curriculum, intensity of parental coaching, psychological development of the child affecting the interest to read may confound their early "reading" experience. Inadequacy of these factors may have caused the observed poorer reading performance and underdevelopment of cognitive skills in the at-risk children on top of the genetic difference.

In conclusion, our results provided intriguing evidence that Chinese children at genetic risk of dyslexia demonstrated significant differences in reading performance and reading-related cognitive measures as early as the preschool stage. They provided pertinent information for delineating the early developmental trajectory in acquisition of reading in young children at risk of dyslexia, in the context of the unique logographic and morphosyllabic nature of Chinese language. Our study also established a direction for future construction of a clinical tool for screening children who are at risk of dyslexia in local setting, where children are learning both English and Chinese language in kindergarten. Future studies on outcome of dyslexia when the participants reach school age, will unravel the validity of the tasks performed in this study as constructs of a tool for early identification of at-risk children at preschool stage.

Acknowledgement

This project was supported by RGC4257/03H from the Chinese University of Hong Kong. The authors would like to acknowledge Child Assessment Service colleagues who contributed to recruit cases and materialise the field-testing of this study and to thank Ms KL Lam for her coordination work with parents.

References

1. Shaywitz SE. Dyslexia. N Eng J Med 1998;338:307-12.
2. Lindergren SD, De Renzi E, Richman LC. Cross-national

comparisons of developmental dyslexia in Italy and the United States. Child Dev 1985;56:1404-17.
3. Lyytinen H, Aro M, Holopainen L. Dyslexia in Finland. In: Smythe I, Everatt J and Salter R, editors. International book of Dyslexia: A Guide to Practical and Resources. England: John Wiley & Sons Ltd, 2004;92-5.
4. Chan W, Ho CSH, Tsang SM, Lee SH, Chung KHK. Prevalence, gender ratio and gender differences in reading-related cognitive abilities among Chinese children with dyslexia in Hong Kong. Educ Stud 2007;33:249-65.
5. Lyon GR. Toward a Definition of Dyslexia. Ann Dyslexia 1995; 45:3-27.
6. Lyon GR, Shaywitz SE, Shaywitz BA. Defining dyslexia, comorbidity, teachers' knowledge of language and reading. A definition of dyslexia. Ann Dyslexia. 2003;53:1-14.
7. Lerner JW. Educational interventions in learning disabilities. J Am Acad Child Adolescent Psychiatry 1989;28:326-31.
8. Poskiparta E, Niemi P, Lepola J, Ahtola A, Laine P. Motivational-emotional vulnerability and difficulties in learning to read and spell. Br J Educ Psychol 2003;73(Pt 2):187-206.
9. Chan CK. Identification study on students with Specific Learning Difficulties in Schools for Social Development of the Society of Boys' Centres. In Shek DTL, editor. Adolescents with emotional and behavioural problems: Residential and educational services in Chinese Societies. Hong Kong: The Commercial Press; 2004.
10. Alexander AW, Slinger-Constant AM. Current Status of Treatments for Dyslexia: Critical Review. J Child Neurol 2004; 19:744-58.
11. Torgesen JK, Wagner RK, Rashotte CA, et al. Preventing reading failure in young children with phonological processing disabilities: Group and individual responses to instruction. J Educ Psychol 2003;24:405-428.
12. Shaywitz SE, Gruen JR, Shaywitz BA. Management of Dyslexia, its rationale, and underlying neurobiology. Pediatric Clin N Am 2007;54:609-23.
13. Tan LH, Liu HL, Perfetti CA, Spinks JA, Fox PT, Gao JH. The Neural System Underlying Chinese Logographic Reading. Neuroimage 2001;13:836-46.
14. Chan CCH, Leung AWS, Luo Y, Lee T. How do figure-like orthographs modulate visual processing of Chinese words? Neuroreport 2007;18:757-61.
15. Siok WT, Perfetti CA, Jin Z, Tan LH. Biological abnormality of impaired reading is constrained by culture. Nature 2004; 431:71-6.
16. Pennington BF, Gilger JW. How is dyslexia transmitted? In Chase CH, Rosen GD, Sherman GF eds., Developmental dyslexia. Neural, cognitive, and genetic mechanisms. Baltimore, MD: York Press,41-61. Cited by Shaywitz SE, Shaywitz BA. Biol Psychiatry 2005;57:1301-9.
17. Bakwin H. Reading disability in twins. Dev Med Child Neurology 1973;15:184-7. Cited in Démonet J-F, Taylor MJ, Chaix Y. Developmental Dyslexia. Lancet 2004;363:1451-60.
18. Johns Hopkins University. Online Mendelian Inheritance in Man [Online]. Available from: http://www.ncbi.nlm.nih.gov/sites/entrez?db=omim [cited 20 September 2007].
19. Galaburda AM, LoTurco J, Ramus F, Fitch RH, Rosen GD. From genes to behavior in developmental dyslexia. Nat Neurosci 2006;9:1213-7.
20. Ho CSH, Chan DWO, Tsang SM, Lee SH. The Hong Kong Test of Specific Learning Difficulties in Reading and Writing. Hong Kong: Hong Kong Specific Learning Difficulties Research Team, 2000.
21. The Psychological Corporation. Hong Kong Wechsler Intelligence Scale for Children manual. New York: Hong Kong Government Printer, 1981.
22. Wong EYF, Ho CSH, Chung KKH, Chan DWO, Tsang SM, Lee SH. The Hong Kong Learning Behaviour Checklist for Preschool Children Manual. Hong Kong: Hong Kong Specific Learning Difficulties Research Team, March 2006.
23. Bishop DV, Snowling MJ. Developmental dyslexia and specific language impairment: same or different? Psychol Bull 2004; 130:858-86.
24. Wagner RK, Torgesen JK. The Nature of phonological processing and its causal role in the acquisition of reading skills. Psychol Bull 1987;101:192-212.
25. Logan G. Automaticity and reading: Perspectives from the instance theory of automatization. Reading and Writing Quarterly: Overcoming Learning Disabilities 1997;13:123-46.
26. Wolf M, Bowers. The double-deficit hypothesis for the developmental dyslexia. J Educ Psychol 1999;91:415-38.
27. McBride-Chang C, Chang L. Memory, print exposure, and metacognition: components of reading in Chinese children. Int J Psychol 1995;5:607-16.
28. Siok WT, Fletcher P. The role of phonological awareness and visual orthographic skills in Chinese reading acquisition. Dev Psychol 2001;37:886-99.
29. McBride-Chang C, Ho CSH. Predictors of Beginning Reading in Chinese and English: A two year longitudinal study of Chinese Kindergartners. Scientific Studies of Reading 2005;9: 117-44.
30. Lee CY, Tsai JL, Kuo WJ, et al. Neuronal correlates of consistency and frequency effects on Chinese character naming: an event related fMRI study. Neuroimage 2004;23:1235-45.
31. Ho CS, Chan DW, Tsang SM, Lee SH. The Cognitive Profile and multiple-deficit hypothesis in Chinese developmental dyslexia. Dev Psychol 2002;38:543-53.
32. Chow BWY, McBride-Chang C, Burgess S. Phonological processing skills and early reading abilities in Hong Kong Chinese kindergartners learning to read English as a second language. J Educ Psychol 2005;97:81-7.
33. Ho CS, Chan DW, Lee SH, Tsang SM, Luan VH. Cognitive profiling and preliminary subtyping in Chinese developmental dyslexia. Cognition 2004;91:43-75.
34. McBride-Chang C, Shu H, Zhou A, Wat CP, Wagner RK. Morphological awareness uniquely predicts young children's Chinese character recognition. J Educ Psychol 2003;95: 743-51.
35. Shu H, McBride-Chang, C, Wu S, Liu H. Understanding Chinese developmental dyslexia: Morphological awareness as a core cognitive construct. J Educ Psychol 2006;98:122-33.
36. Algina J , Olejnik S. Sample size table for correlation analysis with applications in partial correlation and multiple regression analysis. Multivariate Behav Res 2003;38:309-23.
37. Lyytinen H, Aro M, Eklund K, et al. The development of children at familial risk for dyslexia: birth to school age. Ann Dyslexia 2004;54:184-220.
38. Kovas Y, Haworth C M A, Dale P S, Plomin, R. The genetic and environmental origins of learning abilities and disabilities in the early school years. Monographs of the Society for

Research in Child Development, 2007;72:105-23.
39. Ho CSH, Bryant P. Different visual skills are important in learning to read English and Chinese. Educ Child Psychol 1999; 16:4-14.
40. Ciocca V, Lui JYK. The development of the perception of Cantonese lexical tones. J Multiling Commun Disord 2003;1: 141-7.
41. Gardner MF. Test of Visual-Perceptual Skills (non-motor). Burlingame, CA: Psychological and Educational Publications; 1996.
42. Raven JC. Coloured Progressive Matrices. Oxford: Psychologists Press, 1956.

Appendix 1

Chinese word recognition: Children were asked to read a list comprised of 27 one-character and 34 two-character simple words designed for Hong Kong kindergartners.[39] If the children failed to read aloud 10 consecutive items on this task correctly, testing stopped. Otherwise, the Chinese word reading subtest of the Hong Kong Test of Specific Learning Difficulties in Reading and Writing[20] was then presented. The internal consistency reliability of this combined measure of Chinese word recognition was 0.96.

English letter naming: Children were asked to name randomly arranged English capital letters presented on a single sheet of paper. All 26 English letters were presented. Its internal consistency reliability was 0.94.

Syllable deletion: children were asked to take away one syllable from a three-syllable phrase presented orally in Cantonese (e.g., say /din6 daan1 ce1/"電單車" without /din6/"電" would be /daan1 ce1/"單車"). There were 13 items requiring the deletion of the first syllable, last syllable, or middle syllable. The internal consistency reliability of this task was 0.85.

Tone detection: This test was adapted from tone detection task in a study previously perfomed by Ciocca and Lui.[40] The stimuli used in this task were derived from two monosyllables /ji/ and /fu/, and were divided into two sets of six Cantonese tones. The stimuli of the monosyllable /ji/ included /ji1/ 衣 (clothing), /ji2/ 椅 (chair), /ji3/ 意 (first character of spaghetti), /ji4/ 兒 (son), /ji5/ 耳 (ear), and /ji6/ 二 (two), and those of the monosyllable /fu/ were /fu1/ 膚 (skin), /fu2/ 虎 (tiger), /fu3/ 褲 (trousers), /fu4/ 符 (symbol), /fu5/ 婦 (woman), and /fu6/ 父 (father). Children were taught the twelve tones in association with descriptive pictures of the Chinese word. In the testing phase, the children were then given a booklet in which each page contained two descriptive pictures. In each trial, children were asked to listen to a stimulus and then select the corresponding one from the two descriptive pictures. All auditory stimuli were played for the children from an MP3 player to a pair of headphones. The internal consistency reliability for this task was 0.64.

Rapid number naming: Prior to testing, children were asked to name five numbers ("5", "4", "3", "1", "8") to ensure that all of these stimuli were familiar to them. Children were then presented with a sheet of paper containing five rows of numbers in which the five numbers were arranged in different orders. Children were instructed to name all the digits accurately at their fastest speed, and two trials were given to obtain the average time used, which was measured by the clinician using a stop-watch. The test-retest reliability for this task was 0.88.

Visual-spatial relationships: This skill was assessed using the standardised test "Visual Spatial Relationships subtest of Gardner's Test of Visual-Perceptual Skills (non-motor) (1996) Revised".[41] which mainly tests visual-spatial neuropsychological functioning. All subjects were asked to identify the one having a different orientation from a set of five visual foms. The test consisted of one practice item and 16 test items. Testing stopped when the child missed four out of five items consecutively. The internal consistency reliability for this task was 0.87.

Morphological awareness: In this test, children were asked to create new tems (made up of a combination of Chinese morphemes) based on their understanding of the basic unit of meaning implicated in the given Chinese tem. For example: *If we see a web that is made by a spider (we call it a spider web 蜘蛛網). What should we call a web made by an ant?* (the correct answer should be *ant web* 螞蟻網). The trial items and the first three test items were presented with pictures to enhance learning. The internal consistency reliability of this task was 0.79.

Nonverbal intelligence: Nonverbal intelligence was measured by using the *Coloured Progressive Matrices,*[42] which is a multiple choice test of abstract reasoning. In each test item, the child is asked to identify the missing segment required to complete a larger pattern.