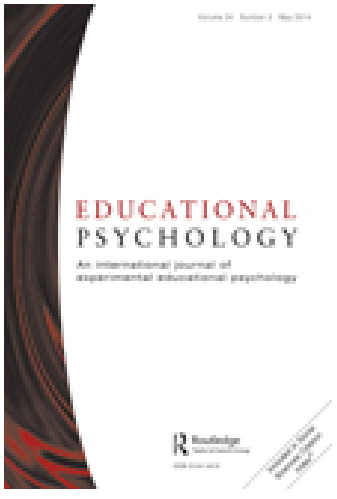

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Identification of the patterns of Chinese character recognition in students with learning disabilities requiring Tier-2 support: a Rasch analysis

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This study investigates the Chinese reading patterns of students with learning disabilities (LD). The performances of students with LD in reading the three categories of Chinese characters were particularly analysed: regular, irregular, and pseudo-characters. Fifty-three students with LD in reading and 44 students without LD of Year 4 were selected from five Hong Kong primary schools. Their abilities for reading Chinese characters were measured using Rasch analysis. Both types of students found regular characters as the easiest to read. Students without LD showed better performance in reading irregular characters than pseudo-characters, whereas students with LD exhibited no significant performance difference in reading these two categories. The implication of these results is that the students without LD might rely on using the orthographic processing than that of phonological processing to read. On the other hand, students with LD might not have the preference of using the orthographic processing.

Keywords: reading; learning disabilities; primary

In 2004, the Hong Kong Education Bureau recommended a three-tier intervention model for ordinary schools to help plan support programmes for students with special needs. Tier-1 support consists of quality teaching in the regular classroom to support students with transient or mild learning difficulties. For those with persistent difficulties, Tier 2 is an add-on intervention, which can be conducted through in-class support, withdrawal for small group teaching, placement in a class with significantly improved teacher/pupil ratio, and withdrawal for 1:1 support, among others. Tier 3 includes the creation of an Individual Education Plan as intensive individualised support for students with severe learning disabilities (LD) (see Education Bureau, 2008, May 23). Generally, students with LD are eligible for Tier-2 support. The schools are given a grant of HK$10,000 per annum for each student requiring Tier-2 support. In 2005, children with LD numbered 27,765 (Ip, 2006). Students with LD have the highest percentage among various categories of disabilities in Hong Kong. Lyon and Moats (1997) estimated that at least 80% of students with LD encounter problems in reading. In Hong Kong, such students could number over 20,000 (Ho, 2003). Early identification of these students and

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appropriate intervention is important. The current paper aims to determine the specific difficulties of students with LD who encountered problems in reading, and design remedial methods catering to their diverse needs.

Needs of readers

In addition to the classification of students with reading disabilities according to severity, researchers (e.g. Castles & Coltheart, 1993; Hoien & Lundberg, 2000) used the property of regularity to differentiate reader sub-types. The implication is that the causes for students' reading difficulties could be different. Different causes may also lead to the implementation of different instructional programmes for their utmost benefit. Designing these programmes thus requires a keen understanding of the success or failure of reading.

Reading researchers (e.g. Coltheart, 1987; Cunningham & Stanovich, 1993; Stanovich & West, 1989) suggested that two general procedures are potentially operative when a reader recognises printed words. Phonological processing assembles word pronunciation through symbol-sound correspondences to letters and letter clusters of varying sizes, whereas orthographic processing involves reading aloud through the lexical procedure to retrieve word pronunciation using the orthographic word pattern. Tasks such as naming pronounceable non-words define phonological processing, whereas those such as reading irregular words or identifying homophones define orthographic processing.

In the English language, phonological awareness skills are reported as highly important in successful reading acquisition (e.g. Vandervelden & Siegel, 1995). As the explicit awareness of the phonological word structure, phonological awareness includes phonemic segmentation of words and pseudo-words (pronounceable non-words); phoneme blending; phoneme deletion; and phoneme substitution (Torgesen, Wagner, & Rashotte, 1994). Phoneme awareness highly correlates with the successful learning of reading English (Cunningham, 1990).

The traditional view of Chinese reading involves the use of orthographic processing. Reading in Chinese mainly depends on visual orthographic processing without the need to recognise the phonological structure of characters (Sasanuma, 1974). Until recently, research still supported the view that a direct visual access to meaning for written Chinese is the major route for reading (Ho, Chan, Lee, Tsang, & Luan, 2004; Meng, Tian, Jian, & Zhou, 2007; Zhou, Marslen-Wilson, Taft, & Shu, 1999; Zhou, Shu, Bi, & Shi, 1999). However, these researchers did not rule out the possibility of phonological mediation in Chinese. Other researchers (e.g. Chow, McBride-Chang & Burgess, 2005; McBride-Chang & Chen, 2003; McBride-Chang & Ho, 2005) challenged the traditional view. A further review of the role of phonological and orthographic processing in Chinese reading may provide clues to identify the core deficits of students with LD in reading Chinese characters.

Role of phonological processing and orthographic processing in Chinese

Perfetti, Zhang and Berrent (1992) suggested that the use of phonology is a general reading characteristic that exists across writing systems. Encountering printed characters in any writing system automatically arouses their associated phonological properties. However, phonological processing abilities are predictive of reading acquisition in Chinese logographic writing system (Chow et al., 2005;

McBride-Chang & Ho, 2005; McBride-Chang & Chen, 2003). Activation of the phonological property of a Chinese character would likely be faster than that of its orthographical or semantic property. An example is 生, which could mean fresh, new, birth, and so on. This character shares a similar graphic appearance with主, 王, and 住. However, the pronunciation of this character 生 is restricted to sang[1]. This is one of the major proofs that using phonological processing to read Chinese is a faster route compared with using orthographic processing.

On the other hand, other studies (e.g. Ho et al., 2004; Meng et al., 2007) showed that orthographic processing has a significant role in lexical access to Chinese reading. Tan, Spinks, Eden, Perfetti, and Siok (2005) also argued that phonological awareness has a minor role in Chinese reading, emphasising that the simpler symbol-sound correspondences in Chinese compared with English causes relatively less reliance on phonological processing (Zhou, Shu et al., 1999).

Ho and Bryant (1997) suggested at least two possible ways of using phonological processing to read Chinese: (i) the reader directly uses the sound of the phonological component for the whole character, for example 青 (tsing[1]) in 清 (tsing[1]); or (ii) the reader compares characters to similar radicals for the pronunciation of the target character, for example 燥 (tsou[3]) for 噪 (tsou[3]); and 躁 (tsou[3]). In this paper, Cantonese is used to indicate the characters' pronunciations as it is the most common dialect in Hong Kong, In the syllable (tsing[1]), /ts/ is the onset, /ing/ is the rime, and '1' means that the syllable is in the first tone, that is a high level tone. Reading Chinese does not require analysing phonemes in consonant-vowel-consonant-consonant and consonant-consonant-vowel-consonant words (Huang & Hanley, 1995). Thus, a deficit in using phonological processing might not cause a serious reading difficulty in reading Chinese characters compared to reading English words.

Analysis of Chinese characters would not be as abstract as that of English words, which might require phoneme segmentation. However, numerous Chinese phonological components are pronounced differently from the whole character, such as 青 (tsing[1]) in 倩 (sin[3]). A character can be considered regular depending on whether it contains any phonological component analogous to other characters.

Phonological components provide the full pronunciation in about 25% of compound Chinese characters (Hoosain, 1991), and only guide the sound in 39% of compound Chinese characters (Perfetti et al., 1992). The correspondence between phonological components to the sound of the whole character is not entirely transparent nor completely reliable (Shu & Anderson, 1997; Shu, Anderson, & Wu, 2000). Such statistics show that a large proportion of Chinese characters is irregular, the reading of which depends entirely on the use of orthographic processing.

Furthermore, the visual information embedded in the characters is nonlinear, causing highly complex graphic forms of characters. The number and patterns of compound radicals can indicate the complexity level for character identification.

Configured into particular positions within Chinese compound characters are components, each with its own fixed or legal position. Deciding on the component placement, such as on the right or left side, or on the top or the bottom part, is important. The radical 日in 晴 is legal, whereas the radical 日in 青日 violates its positional constraint and is thus an illegal character. According to Tse (2002), these patterns of geometric configuration in Chinese can be summarised in at least 12 different ways. Leong, Cheng, and Lam (2000) called such patterns the GEONS. The 晴 (left-right) and 菁 (top-bottom) have different patterns of geometric configurations. Among the 8300 compound phonograms, 75% have their semantic

components on the left and their phonetic components on the right (Perfetti & Tan, 1999). Compound characters with the left-right pattern are usually stimulus materials for investigating word identification in Chinese (Chan & Nunes, 1998), which have about 200 semantic radicals and 800 phonetic radicals (Hoosain, 1991; Shu, Chen, Anderson, Wu, & Xuan, 2003). The view that orthographic processing skills might be even more crucial in learning Chinese characters than words written in an alphabetic system has supporting evidence. Understanding the graphic structure of Chinese characters is important for readers to effectively use orthographic processing in reading.

In brief, the most distinguishing characteristic of children with LD in reading appears to be their phonological processing deficits (e.g. Bradley & Bryant, 1983; Wolf & Bowers, 1999; Ziegler, Grainger, & Brysbaert, 2010). However, the views about core deficits in Chinese significantly vary. Orthographic deficiency is one of the reported prominent problems faced by Chinese children with reading disabilities (Ho et al., 2002, 2004; Ho & Siegel, 2012; Huang & Hanley, 1995; Leck, Weekes, & Chan, 1995). Myers, Taft, and Chou (2007) suggested the possible existence of both situations (i.e. identifying Chinese characters with and without phonological mediation). The relative importance of the roles of orthography and phonology in reading Chinese characters is not entirely resolved.

Testing the Reading Patterns of Students with LD in Reading

The property of characters regularity is used to test the importance of different processing modes on different reader types (see Castles & Coltheart, 1993). In general, both phonological and orthographic processing can be used to read regular characters, whereas only phonological processing is used for pseudo-characters and only orthographic processing for irregular characters.

Regular characters follow the rule of symbol-sound correspondences, whereas irregular characters do not. Pseudo-characters are constructed to follow this rule, but they are neither real characters nor carry any meaning; they are created as they contain obvious phonetic clues that readers can use to sound out the characters correctly. In the present study, the list of pseudo-characters was constructed to be consistent with those of regular and irregular Chinese characters in terms of radicals and number of strokes. Thus, these pseudo-characters are assumed to have no lexical representation in the participants' lexicon.

Examination of orthographic processing used irregular single characters, and that of phonological processing used pseudo-characters. Deriving the pronunciation of irregular characters was assumed possible only through orthographic processing. Having no phonological information to hint at their pronunciation, these characters must be recognised through a direct visual pathway. In contrast, pseudo-characters are sounded out through their phonological clues, thus using phonological processing.

In English-writing system, the young students with LD in reading tend to use the orthographic processing for the compensation of their deficit in phonological processing (see Siegel, 1993). A greater performance discrepancy in reading between irregular words and pseudo-words may thus occur, wherein such students could rely on using the orthographic processing and better read the former category of words.

This pattern of performance might not be observed in Chinese writing system The core deficit of the students with LD in Chinese writing system could be

different from that of English-writing system. Because of the complexity of the graphic structure of Chinese characters, students with a deficit in using the orthographic processing may encounter a problem in reading. On the hand, the phonological structure of Chinese characters is not as complex as that of English. The deficit in phonological processing might not cause the difficulty as serious as the deficit in orthographic processing. Students with LD in Chinese might, therefore, not be reluctant to use the phonological processing. The debate on the importance of phonological and orthographic processing in reading Chinese characters is still ongoing. The performance of students with LD in irregular and pseudo-characters reading might give clues for the evaluation of the relative importance of phonological and orthographic processing in Chinese reading.

This study investigates the reading patterns of students with LD in reading Chinese, specifically the three categories of characters. The reading performances of students without LD were also collected for comparison. The study aims to determine the relative importance of phonological and orthographic processing for students with LD. An additional purpose is to evaluate the levels of difficulty of the three categories of characters (i.e. regular, irregular and pseudo-characters). Achieving these objectives would obtain information to help teachers design effective reading programmes.

Method

Participants

Teachers of five primary schools in Hong Kong randomly selected 53 students with LD and 44 students without LD of Year 4 (ages 9–10 years). The students with LD were those who required remedial support and obtained grade level scores two years behind their peers in the Hong Kong Attainment Tests in Chinese. Students without LD were selected based on their average reading abilities.

Student performances in Chinese Language were compared through their scores in the Hong Kong Attainment Tests (see Table 1 for the participants mean chronological age and scores for the Hong Kong Attainment Test in Chinese Language), which are standardised tests used to assess students in three key learning areas (Chinese, English and Mathematics). The students without LD and those with LD showed no significant difference in age, $t(95) = -3.70$, $p = .72$, but had a significant difference in the Hong Kong Attainment Test in Chinese Language, $t(95) = 21.82$, $p < .0001$.

Stimulus materials

Poon and Hong (2003) suggested that school students should recognise three thousand basic characters in their primary education. These characters are categorised

Table 1. Mean chronological age and Hong Kong attainment test percentile scales (Chinese) of all participants.

	Without LD ($n = 44$) Mean (SD)	LD ($n = 53$) Mean (SD)
Age	9.03 (1.13)	9.11 (1.08)
HK attainment test (Chinese)	68.60 (9.39)	28.73 (8.59)

from the property of frequency and that of difficulty level. Poon and Hong (2003) recommended that a number of 508 characters should be taught for Primary One, 716 characters for Primary Two, 632 characters for Primary Three, 558 characters for Primary Four, 412 characters for Primary Five and 174 characters for Primary Six.

The stimulus characters in the present study were chosen from A Study of the Chinese Characters Recommended for the Subject of Chinese Language in Primary Schools (Poon & Hong, 2003) and the Chinese Vocabulary Used in Primary Schools in Hong Kong (Educational Research Establishment, Education Department, 1979). The test consisted of three sets of 30 single Chinese characters in each category: regular (characters that give phonetic clues); irregular (characters that do not give phonetic clues); and pseudo-characters (characters that follow the Chinese character formation rule and give phonetic clues, but do not contain any meaning; see Table 2). Ninety characters were printed on a 6 cm × 6 cm white paper laminated with plastic.

Variables, such as frequency, radical, and number of strokes, were controlled during the selection of regular and irregular characters, which were matched as closely as possible so that the performance of reading recognition skills could be

Table 2. Three types of characters.

No.	Regular	Frequency	No.	Irregular	Frequency	No.	Pseudo-word
1	誅	4553	31	詫	4080	61	言冬
2	祥	1332	32	祝	1228	62	裙
3	碼	1836	33	碰	1266	63	石希
4	碳	1886	34	硬	1458	64	碘
5	瀕	2646	35	灑	2044	65	氵鮮
6	澈	2580	36	潰	2226	66	澉
7	援	1085	37	揮	1222	67	揲
8	係	877	38	俗	1341	68	俍
9	倖	3747	39	借	1188	69	亻林
10	倘	2662	40	偽	2395	70	倗
11	伴	1431	41	伐	1646	71	亻民
12	仲	1945	42	仇	1984	72	亻久
13	儀	1498	43	億	1610	73	僩
14	咐	2864	44	咀	2814	74	咪
15	叮	2005	45	吹	1007	75	口久
16	娥	1990	46	娛	2489	76	女求
17	媚	3046	47	媒	3045	77	媚
18	妨	1858	48	妬	2557	78	女白
19	姑	1366	49	妙	1392	79	女丙
20	妮	2411	50	姚	2912	80	姒
21	扶	1885	51	挑	1860	81	扌永
22	摧	2838	52	撮	2689	82	扌原
23	滄	3253	53	溺	3175	83	滴
24	伸	1062	54	伊	1042	84	佃
25	伙	2170	55	伏	1908	85	佁
26	俱	2972	56	俘	2130	86	亻朋
27	誌	2443	57	詭	3078	87	言更
28	址	1775	58	埋	1710	88	垙
29	洞	1051	59	涼	1178	89	洓
30	稀	1728	60	租	1639	90	禾吾

attributed to the effect of regularity. Wilcoxon Signed Ranks Test compared the frequency of the 30 regular characters and that of the 30 irregular characters, and detected no significant difference ($p = .26$).

Legal, pronounceable non-characters were constructed based on the principle that the pseudo-characters contained obvious phonetic cues. The participants could sound out the characters correctly if they used the phonological structure. In the current study, the list of pseudo-characters was constructed to be consistent with the lists of regular and irregular characters in terms of radicals and number of strokes. However, several infrequent characters were used and served as pseudo-characters. These infrequent characters were selected based on their correspondence to regular and irregular characters in the semantic radicals as well as the number of strokes.

Students who read relying on orthographic processing and show a deficit in phonological processing are predicted to demonstrate little difference between reading both regular and irregular characters but would read only a few pseudo-characters with great difficulty. Students relying on the phonological processing and showing a deficit in orthographic processing will read regular characters easier than irregular ones, and should be able to read pseudo-characters.

The card were shuffled and presented to each participant one at a time in random order.

Procedure

Testing consisted of two sessions. The first session required students to read the lists of regular, irregular and pseudo-characters. The stimuli appeared randomly one at a time, without time pressure and mispronunciations were recorded. Each child was withdrawn from class for individual testing, for a period of approximately 25 min. Students sat opposite the investigator in a quiet room, and were asked to read aloud the 90 characters on the laminated cards. The following instructions were given to students prior to testing:

> 'I am going to show you some cards. Each card has a character printed on it. I want you to read out loud. You are not expected to know them all. Some of them are really difficult (show them one) as these characters are chosen from textbooks in secondary level. I want you to try and read these just like the other characters. OK?'

Instructions were repeated if the students appeared confused. The students then proceeded to read aloud the characters. Feedback on correctness of response was not provided, and no time limit was imposed upon the students.

The second session required students to orally define each of the regular and irregular characters upon presentation. The purpose of this session was to ensure that poor performance on irregular characters was not because of a general language deficit. Prior to testing, each student was given the following set of instructions:

> 'I am going to read some characters out loud to you. I want you to tell me what each character means. If you can, give me a definition of the character, like what you might find in a dictionary. If you cannot, try and use it in a sentence. Some characters might have more than one meaning, and I want you to tell me as many meanings for the character as you can think of when this happens. OK?'

Instructions were repeated if the child appeared confused. After the children confirmed that they understood the task, the characters were read out loud to them.

Data analysis

The collected data were analysed using the Rasch model, which was mainly based on two considerations (see Rasch, 1980). First, raw data (the frequency of correct answers in this case) are ordinal data, which only indicate ordering without any proportional meaning (Bond & Fox, 2007). Therefore, applying some traditional statistics (e.g. ANOVA) that requires interval data (Wright, 1997) is inappropriate. However, Rasch analysis can transform ordinal raw data into interval measures, which can then be used in further analysis (Linacre, 2006). Second, Rasch analysis can calibrate personal abilities and item difficulties on the same uni-dimensional latent trait scale, facilitating comparisons between persons and items (Bond & Fox, 2007). Rasch analysis has been extensively utilised to measure reading abilities of students with or without LD (e.g. Foorman, Francis, Fletcher, & Lynn, 1996; Randall & Engelhard, 2010; Rawls, 2009), and the above-mentioned advantages have been echoed in these studies.

The person measures reflect student abilities in reading different categories of characters. In addition, the Rasch-calibrated person measures were analysed using a two-way ANOVA, with reader type and character type varied among subjects. The reading abilities of both types of students in the three character categories could be compared, and any specific performance pattern was revealed. The difficulty estimates of individual characters might provide further information to investigate specific character features that form obstacles for students in processing reading tasks.

Results

Rasch analysis using WINSTEPS 3.70.0 was used to measure the ability levels of the two types of students as well as the difficulty levels of the three character categories. In order to make comparisons between two types of students on their abilities on reading three categories of characters, three separate analyses were conducted for regular, irregular and pseudo-characters with data from students with LD and students without LD combined. Therefore, each student has an ability measure on reading each character category. Table 3 and Figure 1 present the mean estimates of student abilities associated with standard errors.

The two-way ANOVA of Rasch-calibrated person measures showed a significant main effect for reader type, $F = 149.26$, $p < .01$, and for character type, $F = 36.15$, $p < .01$. In general, students without LD have reading abilities that are significantly higher than those of their peers with LD in all three character categories. The differences in ability estimates between the two types of students are substantial compared to measurement error size, which is indicated by vertical bars in Figure 1. The differences in ability levels on reading different categories of characters are statistically significant for both types of students.

Although the two-way ANOVA showed no significant interaction between reader type and character type, interesting findings emerged upon closer look at the performance pattern for students without LD and those with LD. Repeated measure ANOVA indicated that students without LD and those with LD had different

Table 3. Estimates of the abilities of students without LD and students with LD on reading the three word categories.

	Student without LD				Student with LD			
	N	Mean score[a]	Mean measure[b]	Std. error	*N*	Mean score[a]	Mean measure[b]	Std. error
Regular	44	23.82	2.39	.16	53	18.23	.69	.17
Irregular	44	19.00	1.43	.18	53	12.66	−.87	.24
Pseudo-words	44	19.14	.87	.18	53	11.68	−.75	.17

Note: [a]The raw score out of the total mark (30); [b]The measures are in logits.

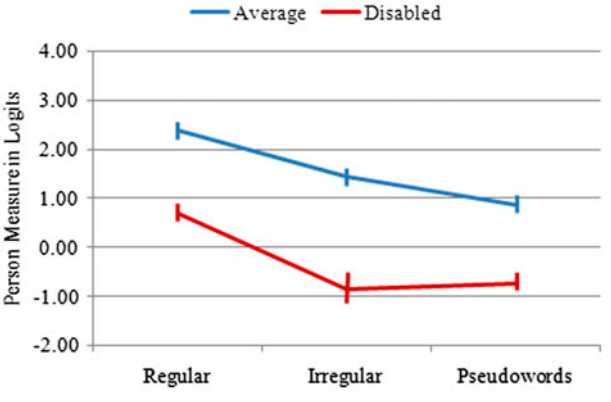

Figure 1. Estimates of the abilities of students without LD and students with LD on reading the three word categories.

patterns of performance in reading the three character categories. Students without LD had the best performances in reading regular characters, followed by irregular characters and then pseudo-characters. Paired comparisons showed the statistically significant differences of their performances ($p < .01$ for differences between reading regular and irregular characters, and $p < .05$ for differences between reading irregular characters and pseudo-characters). Students with LD showed their best performances on reading regular characters, followed by pseudo-characters, and then irregular characters. Paired comparisons showed a statistically significant difference in their performances on reading regular characters and pseudo-characters ($p < .01$), but the difference in reading pseudo-characters and irregular characters was not statistically significant.

Significant differences among the reading abilities on the three character categories for students without LD showed that they found pseudo-characters as the most difficult category to read. Students without LD tended to use orthographic processing to read, although they were assumed to be efficient in using both phonological and orthographic processing. Students without LD would doubt the existence of characters with a strange combination of phonetic and semantic components and were often reluctant to respond to these characters. Reading pseudo-characters would normally be more difficult. However, students with LD showed no significant difference between the performances of irregular and pseudo-characters, in contrast

to the reading pattern of students without LD. Students with LD had difficulty in reading both irregular and pseudo-characters and could not effectively use the orthographic processing to read irregular characters the same way as their non-LD peers.

In order to investigate whether the same character shows different difficulty levels to the two types of students, all characters in three categories were calibrated together for each student type separately. This is different from the scales used for measuring students' abilities where three categories of characters were calibrated separately with data from two types of students combined. Table 4 presents the mean estimates of the difficulty levels of different character categories for each student type; Figure 2 shows difficulty estimates of each character for students without LD, and Figure 3 for students with LD.

Table 4 presents mean estimates of the character difficulty of different categories for the two types of students, which are consistent with findings revealed by person measures mentioned in the above sections. Regular characters are the easiest to read for both types of students. Irregular characters are easier to read than pseudo-characters for students without LD, whereas these two categories have very similar difficulty levels for students with LD.

Figures 2 and 3 present the item map for students without LD and students with LD, respectively. Characters and students are aligned on the common variable ruler in this map. On the right side are characters and on the left are students. The characters with the highest difficulty estimates and the most capable students are located at the top, whereas the easiest characters and least capable students are at the bottom. Codes represent the characters (Table 2) and are grouped into three columns according to the categories to which they belong. Several character codes followed by the Chinese character act as examples for later discussion.

With an inspection of Figures 2 and 3, regular characters such as R02, R03, R11, R19, R21 and R29 are the easiest characters for both students without LD and those with LD. Characters I31, I36, I41 and I48 as well as R7, I31, I36, I41, I48, I50, I51, I57 and P87 are supposed to be difficult for students without LD and students with LD, respectively. Stimulus materials from I31 to I60 are irregular characters. Both student types found some irregular characters as the most difficult to read, although these characters had mean estimates of difficulty lower than those of pseudo-characters.

The character difficulty levels were separately calibrated with data from students without LD and those with LD, and thus each character has two Rasch-calibrated estimates of difficulty as shown in Figures 2 and 3. The invariance of difficulty estimates for each character across two types of students could be examined using the method suggested by Bond and Fox (2007, pp. 96–99). Difficulty estimates for each

Table 4. Estimates of the difficulty of the three word categories for students without LD and students with LD.

		Mean estimate of difficulty*	
	Number of words	Student without LD	Student with LD
Regular	30	−1.67	−1.06
Irregular	30	−.43	.50
Pseudo-words	30	.06	.54

*Note: All measures are in logits.

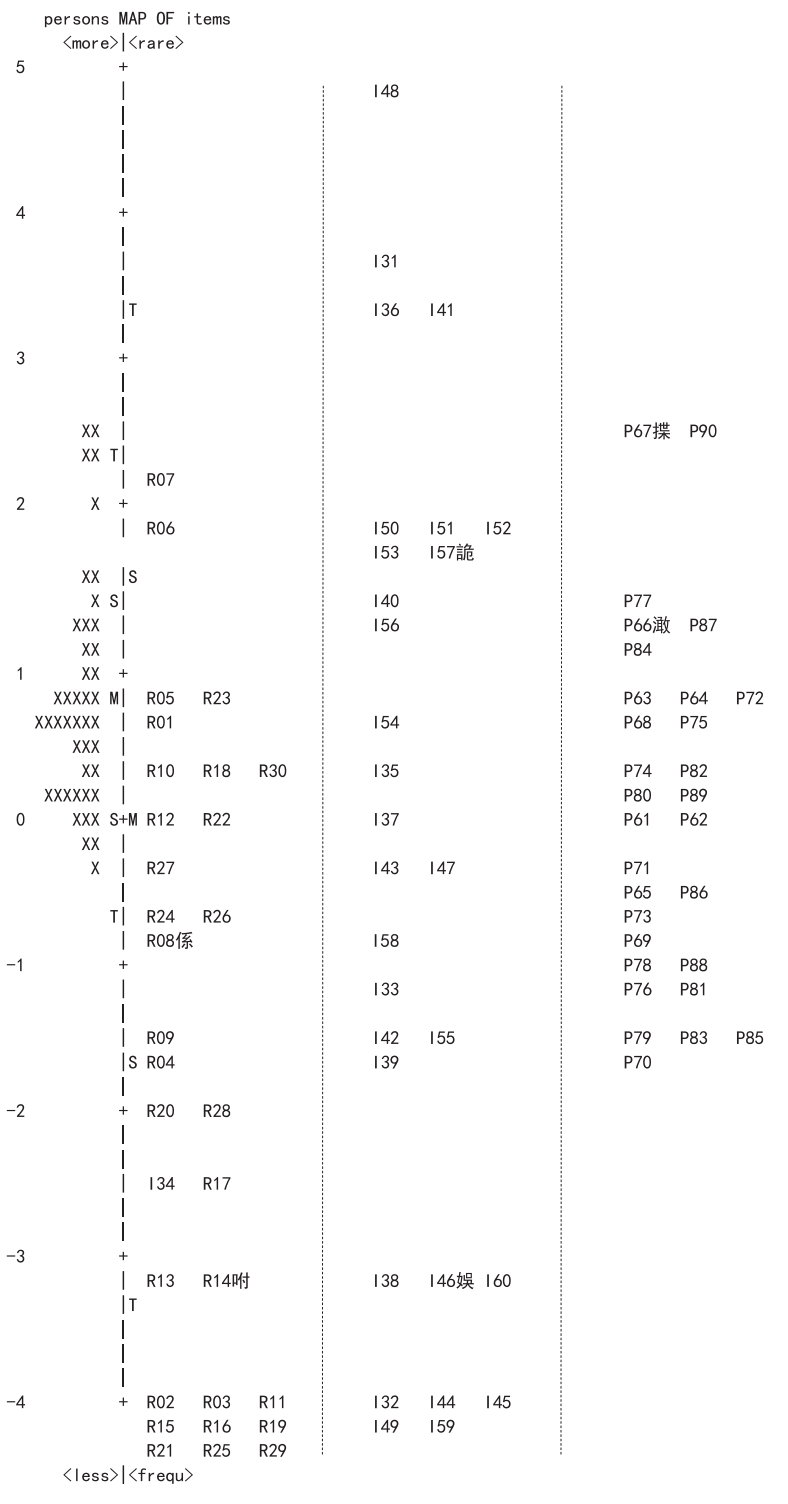

Figure 2. Estimates of the difficulty of characters for students without LD.

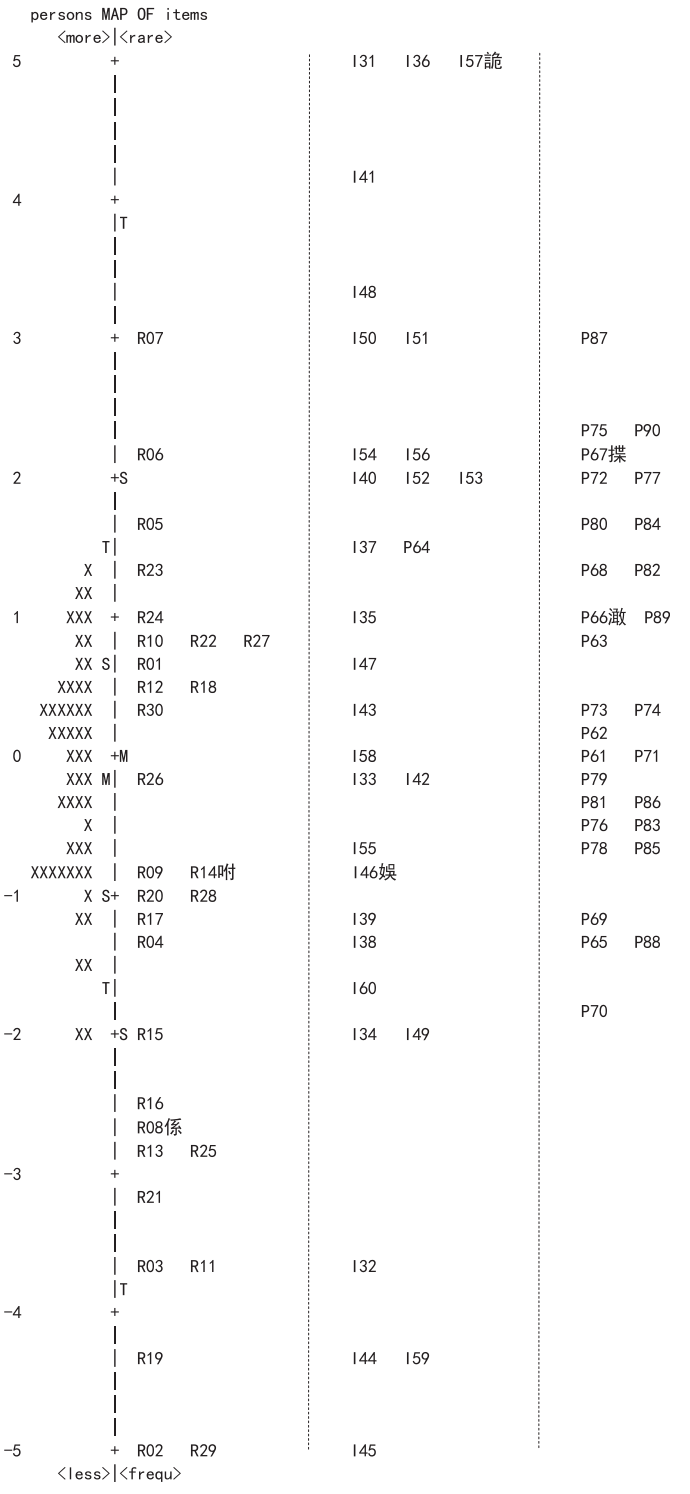

Figure 3. Estimates of the difficulty of words for students with LD.

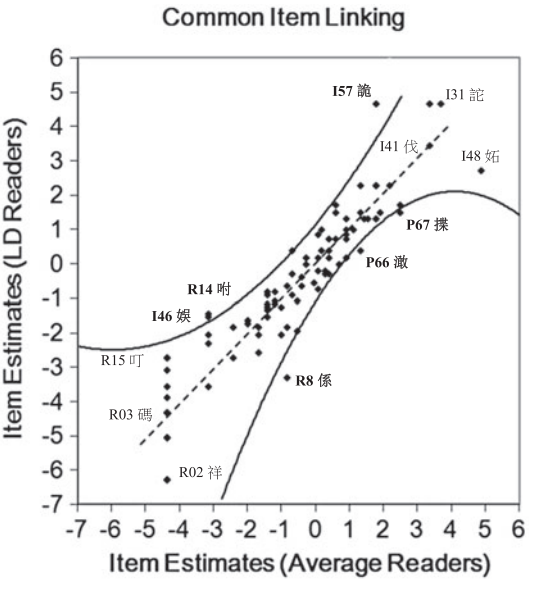

Figure 4. Comparison of word difficulty for students without LD and students with LD.

character were imported into an Excel spreadsheet and plotted in Figure 4. The *x* represents difficulty estimates of characters for students without LD; *y* represents the difficulty estimates of characters for students with LD. The estimates for students with LD were adjusted to make sure they are in the same scale for that of students without LD for the sake of difficulty invariance check. The dotted line is diagonal, and the solid lines represent quality control, which were constructed with error estimates for each character. Each plotted point represents a character, and those in the area between quality control lines could be regarded as invariant in terms of difficulty between two types of students, within the limits of measurement errors. Points outside the area have measurably different difficult estimates for the two student types.

Based on the comparisons of character difficulty levels that were calibrated using Rasch analysis separately for the two groups of students, six characters appear outside the invariant area (see Figure 4). Compared with students without LD, students with LD had difficulties recognising one regular character (R14) and two irregular characters (I46 and I57) since, as shown in Figure 4, these characters have measurably higher Rasch-calibrated difficulty levels for students with LD than those for students without LD. In contrast, students without LD showed higher difficulty reading one regular character (R8) and two pseudo-characters (P66 and P67) since these characters have measurably higher Rasch-calibrated difficulty levels for students without LD than those for students with LD. These findings show that students with and without LD have different strengths in reading some irregular and pseudo-characters.

Discussion

The ultimate goal of identifying the reading patterns of different student types is to provide teachers the most accurate information to design a learning programme that

can cater to the diverse needs of their students. The strengths and weaknesses of both student types in using the phonological and orthographic processing were discussed. In addition, the difficulty levels of the three character categories were analysed.

Performance of students with and without LD in reading Chinese characters

This study supports the view that students without LD tend to use orthographic processing, whereas students with LD have no particular preference for either orthographic or phonological processing in reading Chinese characters.

In using orthographic processing, students have to identify the characters as visual wholes. The graphic structure of Chinese characters is very complex. Those in the character list of this study can have a composition ranging from four strokes, for example. 仇 (sau^4) [enemy] to over 20 strokes, for example 灑 (sa^2) [spray]. The character components can be constructed in different geometric patterns (e.g. top-down, left-right, triangle, and so on). Strokes and components have their legal positions; difficulty in recognising such positions would cause a difficulty in reading Chinese characters efficiently and effectively.

In general, students without LD read irregular characters better than pseudo-characters, which could be attributed to their preference for orthographic processing. Although the graphic structure of Chinese characters is complex, students without LD were capable of using orthographic processing for character identification. These students were accustomed to identifying characters as visual wholes. On the other hand, their relative poor performance in reading pseudo-characters could be explained by their sensitivity to violations of legal combinations of semantic and phonological components in Chinese language. They often showed reservations in responding to characters that seemed unreal to them.

Students with LD showed no difference in reading irregular and pseudo-characters. It is difficult to suggest that students with LD in Chinese language would have a preference for either orthographic or phonological processing.

However, the analysis in Figure 4 shows that students with LD had a more accurate response rate than students without LD in reading some pseudo-characters (P66 and P67). This implies that students with LD were more effective than students without LD in using phonological processing to read some pseudo-characters. As suggested by Siegel (1993), the young students with LD in English writing system would use orthographic processing to compensate for their difficulties in efficiently using the phonological processing. In line with this principle, the better performance of students with LD in reading some pseudo-characters might be attributed to their relative willingness in using phonological processing and the reluctance of the students without LD to respond to characters violating the formation rules.

In summation, the preference for orthographic processing was observed in students without LD but not in students with LD. This finding can be an evidence to show that the complexity of the graphic structure of Chinese characters might be a hindrance for students with LD to use orthographic processing. Though there is no observed preference for students with LD in using either orthographic or phonological processing, it was shown that students with LD can use phonological processing more efficiently than students without LD to read some pseudo-characters.

Difficulty levels of the three categories of Chinese characters

The difficulty levels of the three categories of Chinese characters showed that regular characters are the easiest category to read for both types of students. Irregular characters are less difficult than pseudo-characters for students without LD, whereas these two categories have very similar difficulty levels for students with LD. These results also show that it was more advantageous for students without LD to use orthographic processing. This advantage, however, was not observed in students with LD.

Both types of students found that irregular characters I31, I36, I41, I48, I50, I51, and I57 were more difficult to read than the other characters. This outcome appears inconsistent with the finding that, in normal cases, pseudo-characters were the most difficult category of characters to read. An explanation could be that this list of irregular characters has a wider range of difficulty. In usual practice, the right component of a character of left-right pattern is the phonetic component. The right components of irregular characters do not provide the correct pronunciations of the whole characters. However, these components can be the sound clues for the pronunciations of other regular characters. For example, 青 (tsing^{1}) is the right component of 清 (tsing^{1}) and that of 倩 (sin^{3}). 清 is regular and 倩 is irregular. A detailed inspection of the difficult irregular characters in this study revealed that the right components of these characters are also some common components for the sound clues of frequent regular characters. The pronunciation of these right components would mislead students in pronouncing the irregular characters.

The findings in the present study showed that the reading patterns of students with LD as well as the regularity property of Chinese characters should be taken into consideration for the design of learning programmes. Designing learning programmes with both analytic and whole-word approaches would be useful for the instruction of different character categories (see Ho & Siegel, 2011). The whole-word method, which does not require an explicit analysis of sounds, is the traditional approach for teaching Chinese characters. In the stock of well-known words, children will gradually discover recurring elements that will enable them, by analogy, to read new words without help (Chartier, 2004). The analytic method used in Chinese is different from that of English. A common analytic method in English for word identification consists of extracting the larger-unit (rime) and smaller unit (initial letter-sound) of spelling-to-sound patterns. The method focuses on the training of phonological awareness. The analytic method in Chinese mainly consists of the analysis of the functions of components radicals, that is to find out the semantic radicals and phonological radicals embedded in the characters. Students with strength in using orthographic processing would benefit more from the whole-word approach whereas those with a strength in using phonological processing would benefit more from the analytic approach. In preparing instructional programmes for students with and without LD, identifying the reading pattern is important.

References

Bond, T. G., & Fox, C. M. (2007). *Applying the Rasch model: Fundamental measurement in the human sciences* (2nd ed.). Mahwah, NJ: Erlbaum.

Bradley, L., & Bryant, P. E. (1983). Categorizing sounds and learning to read: A causal connection. *Nature, 301*, 419–421.

Castles, A., & Coltheart, M. (1993). Varieties of developmental dyslexia. *Cognition, 47*, 149–180.
Chan, L., & Nunes, T. (1998). Children's understanding of the formal and functional characteristics of written Chinese. *Applied Psycholinguists, 19*, 115–131.
Chartier, A. (2004). Teaching reading: A historical approach. In T. Nunes & P. Bryant (Eds.), *Handbook of children's literacy* (pp. 511–538). Dordrecht: Kluwer Academic.
Chow, B. W.-Y., McBride-Chang, C., & Burgess, S. (2005). Phonological processing skills and early reading abilities in Hong Kong Chinese kindergarteners learning to read English as a second language. *Journal of Educational Psychology, 97*, 1–87.
Coltheart, M. (1987). Varieties of developmental dyslexia: A comment on Bryant and Impey. *Cognition, 27*, 97–101.
Cunningham, A. E. (1990). Explicit versus implicit instruction in phonemic awareness. *Journal of Experimental Child Psychology, 50*, 429–444.
Cunningham, A. E., & Stanovich, K. E. (1993). Children's literacy environments and early word recognition skills. *Reading and Writing: An Interdisciplinary Journal, 5*, 193–204.
Education Bureau. (2008, May 23). *Enhancement of the new funding mode for primary schools*. Retrieved June 7, 2010, from http://www.edb.gov.hk/FileManager/EN/Content_7433/edbc08010e.pdf
Educational Research Establishment, Education Department. (1979). *A study of the Chinese vocabulary used in primary schools in Hong Kong*. Hong Kong: Education Department.
Foorman, B. R., Francis, D. J., Fletcher, J. M., & Lynn, A. (1996). Relation of phonological and orthographic processing to early reading: Comparing two approaches to regression-based, reading-level-match designs. *Journal of Educational Psychology, 88*, 639–652.
Ho, C. S. H. (2003). *Identification and assessment of children with specific learning difficulties in Hong Kong: Main research findings*. Paper presented in the seminar of Hong Kong Psychological Society and Psychology Department, University of Hong Kong on From research to educational practice: What have we learned about specific learning difficulties, Hong Kong.
Ho, C. S. H., & Bryant, P. (1997). Development of phonological awareness of Chinese children in Hong Kong. *Journal of Psycholinguistic Research, 26*, 109–126.
Ho, C. S. H., Chan, D. W. O., Lee, S. H., Tsang, S. M., & Luan, V. H. (2004). Cognitive profiling and preliminary subtyping in Chinese developmental dyslexia. *Cognition, 91*, 43–75.
Ho, C. S. H., Chan, D. W. O., Tsang, S. M., & Lee, S. H. (2002). The cognitive profile and multiple-deficit hypothesis in Chinese developmental dyslexia. *Developmental Psychology, 38*, 543–553.
Ho, F. C., & Siegel, L. (2011). Identification of sub-types of students with learning disabilities in reading and its implications for Chinese word recognition and instructional methods in Hong Kong primary schools. *Reading and Writing: An Interdisciplinary Journal, 25*, 1547–1571.
Hoien, T., & Lundberg, I. (2000). *Dyslexia: From theory to intervention*. Dordrecht: Kluwer Academic.
Hoosain, R. (1991). *Psycholinguistic implications for linguistic relativity: A case study of Chinese*. Hillsdale, NJ: Lawrence Erlbaum Associates.
Huang, H. S., & Hanley, J. R. (1995). Phonological awareness and visual skills in learning to read Chinese and English. *Cognition, 54*, 73–98.
Ip, B. (2006, July). *Special education policy development and direction of Hong Kong*. Keynote presented at the UK SEN Conference. Retrieved November 20, 2006, from EMB website: http://emb.gov.hk/FileManager/EN/Content_2555/uksemshow_4.ppt
Leck, K. J., Weekes, B. S., & Chan, M. J. (1995). Visual and phonological pathways to the lexicon: Evidence from Chinese readers. *Memory and Cognition, 23*, 468–476.
Leong, C. K., Cheng, P. W., & Lam, C. C. C. (2000). Exploring reading-spelling connection as locus of dyslexia in Chinese. *Annals of Dyslexia, 50*, 239–259.
Linacre, J. M. (2006). *A user's guide to WINSTEPS/MINISTEP: Rasch-model computer programs*. Chicago, IL: Winsteps.com.
Lyon, G. R., & Moats, L. C. (1997). Critical conceptual and methodological considerations in reading intervention research. *Journal of Learning Disabilities, 30*, 578–588.

McBride-Chang, C., & Chen, H. C. (Eds.). (2003). *Reading development in Chinese children*. Westport, CT: Praeger.
McBride-Chang, C., & Ho, C. S.-H. (2005). Predictors of beginning reading in Chinese and English: A 2-year longitudinal study of Chinese kindergartners. *Scientific Studies of Reading, 9*, 117–144.
Meng, X., Tian, X., Jian, J., & Zhou, X. (2007). Orthographic and phonological processing in Chinese dyslexic children: An ERP study on sentence reading. *Brain Research, 1179*, 119–130.
Myers, J., Taft, M., & Chou, P. (2007). Character recognition without sound or meaning. *Journal of Chinese Linguistics, 35*, 1–57.
Perfetti, C. A., & Tan, L. H. (1999). The constituency model of Chinese word identification. In J. Wang, A. W. Inhoff, & H. C. Chen (Eds.), *Reading Chinese script: A cognitive analysis* (pp. 115–134). Mahwah, NJ: Lawrence Erlbaum Associates.
Perfetti, C. A., Zhang, S., & Berent, I. (1992). Reading in English and Chinese: Evidence for a 'universal' phonological principle. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 227–248). Holland: Elsevier Science.
Poon, W. Y., & Hong, P. M. (2003). *A study of the Chinese characters recommended for the subject of Chinese language in primary school*. Hong Kong: Hong Kong Baptist University.
Randall, J., & Engelhard, G. (2010). Using confirmatory factor analysis and the Rasch model to assess measurement invariance in a high stakes reading assessment. *Applied Measurement in Education, 23*, 286–306.
Rasch, G. (1980). *Probabilistic models for some intelligence and achievement test* (Expanded ed.). Chicago, IL: University of Chicago Press.
Rawls, A. M. W. (2009). *The importance of test validity: An examination of measurement invariance across subgroups on a reading test* (Unpublished PhD dissertation). Carolina: University of South Carolina.
Sasanuma, S. (1974). Kanji vs. kana processing in alexia with transient agraphia: A case report. *Cortex, 10*, 89–97.
Siegel, L. S. (1993). The development of reading. In H. Reese (Ed.), *Advances in child development and behaviour* (Vol. 24, pp. 63–97). Orlando: Academic Press.
Shu, H., & Anderson, R. C. (1997). Role of radical awareness in the character and word acquisition of Chinese children. *Reading Research Quarterly, 32*, 78–89.
Shu, H., Anderson, R. C., & Wu, N. (2000). Phonetic awareness: Knowledge of orthography-phonology relationships in the character acquisition of Chinese children. *Journal of Educational Psychology, 92*, 56–62.
Shu, H., Chen, X., Anderson, R. C., Wu, N., & Xuan, Y. (2003). Properties of school Chinese: Implications for learning to read. *Child Development, 74*, 27–47.
Stanovich, K. E., & West, R. F. (1989). Exposure to print and orthographic processing. *Reading Research Quarterly, 24*, 402–433.
Tan, L. H., Spinks, J. A., Eden, G. F., Perfetti, C. A., & Siok, W. T. (2005). Reading depends on writing, in Chinese. *PNAS, 102*, 8781–8785.
Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (1994). Longitudinal studies of phonological processing and reading. *Journal of Learning Disabilities, 27*, 276–286.
Tse, S. K. (Ed.). (2002). *Effective teaching and learning of Chinese characters*. Hong Kong: Green Field.
Vandervelden, M. C., & Siegel, L. S. (1995). Phonological recoding and phonemic awareness in early literacy: A developmental approach. *Reading Research Quarterly, 30*, 854–875.
Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology, 91*, 415–438.
Wright, B. D. (1997). A history of social science measurement. *Educational Measurement: Issues and Practice, 16*, 33–45.
Zhou, X., Marslen-Wilson, W., Taft, M., & Shu, H. (1999). Morphology, orthography, and phonology in reading Chinese compound words. *Language and Cognitive Processes, 14*, 525–565.

Zhou, X., Shu, H., Bi, Y., & Shi, D. (1999). Is there phonologically mediated access to lexical semantics in reading Chinese? In J. Wang, A. W. Inhoff, & H. C. Chen (Eds.), *Reading Chinese script: A cognitive analysis* (pp. 511–538). Mahwah, NJ: Lawrence Erlbaum Associates.

Ziegler, J. C., Grainger, J., & Brysbaert, M. (2010). Modelling word recognition and reading aloud. *European Journal of Cognitive Psychology, 22*, 641–649.