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Is Chinese Dyslexia Similar Across Chinese Societies? Evidence from Hong Kong, Beijing, and Taipei

Zebedee Rui En Cheah
Department of Psychology, The Chinese University of Hong Kong, Ma Liu Shui, Hong Kong

Catherine McBride
Department of Human Development and Family Science, Purdue University, West Lafayette, Indiana, USA

Xiangzhi Meng
School of Psychological and Cognitive Sciences, Peking University, Beijing

Jun Ren Lee
Department of Educational Psychology and Counselling, National Taiwan Normal University, Taipei

Shuting Huo
Department of Applied Social Sciences, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

ABSTRACT

While previous research has documented the unique aspects of Chinese dyslexia as compared to dyslexia in alphabetic scripts, it remains unclear whether the difference in Chinese literacy experiences influences the manifestation of Chinese dyslexia. The present article first reviews the characteristics of Chinese languages and scripts, including important cognitive-linguistic correlates (rapid automatized naming, phonological, orthographic, and morphological awareness) of Chinese reading development and impairment. The diversity in Chinese literacy experiences of scripts, languages, and instructional practices, and consequently their impact on Chinese literacy acquisition across different Chinese societies are also reviewed. Using an equivalent Chinese assessment battery administered to 91 children with dyslexia from Hong Kong, Beijing, and Taipei, we examined the subtypes of Chinese dyslexia across these three societies concurrently. With the four cognitive-linguistic skills included as the clustering variable, the hierarchical cluster analysis revealed four cognitive subtypes of dyslexia: 38% mild orthographic deficit subtype (OD), 33% phonological deficit subtype (PD), 18% morphological deficit subtype (MD), and 11% global deficit subtype (GD)—each with their own set of cognitive-linguistic deficit profiles. Interestingly, all four subtypes of dyslexia manifested poorer orthographic skills as compared to the control group. Bayesian Analysis of Contingency Table further showed that the distribution of dyslexia subtypes remains similar across the three Chinese societies, suggesting invariance of the Chinese dyslexia construct. Findings highlight the importance of assessment in orthographic processing, rapid automatized naming, phonological awareness, and morphological awareness in order to understand Chinese dyslexia, both in a within and cross-cultural Chinese perspective.

Developmental dyslexia is a specific learning difficulty in which affected children have pronounced difficulties in their word decoding abilities, despite having normal intelligence, adequate schooling, and sufficient socio-economic opportunities (Lyon et al., 2003). In the past, developmental dyslexia was believed to be predominantly an issue for alphabetic learners but not for Chinese learners due to the unique nature of Chinese scripts (e.g., Chung & Ho, 2010). However, the increase in the appreciation and acknowledgement of Chinese dyslexia by researchers today has led to the recognition that the prevalence rate for Chinese dyslexia is similar to that in alphabetic readers (e.g., Zhang et al., 2023). Nevertheless, one central issue surrounding the understanding of Chinese dyslexia today is yet to be resolved: Do differences in Chinese literacy learning experiences across Chinese-speaking children of different societies influences the manifestation of dyslexia (McBride et al., 2018)?

Taking the perspective that dyslexia is an extreme word reading difficulty (McBride et al., 2018), we begin by first reviewing the

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characteristics of Chinese languages and scripts. We then discuss current diagnosis criteria for dyslexia, followed by some important cognitive-linguistic correlates of Chinese dyslexia. Next, utilizing a dataset that we have previously collected on Chinese children with dyslexia from Hong Kong, Beijing, and Taipei, we then test for the variance/invariance of Chinese dyslexia subtypes across Chinese societies. To conclude, we discuss some of the possible future directions to further unpack the complicated ecological influences on Chinese literacy development and, consequently, dyslexia.

Chinese Writing and Language

Chinese is a morpho-syllabic script whereby each character represents the basic unit of meaning, with each character corresponding to a single unit of syllable and morpheme (Mattingly, 1992). In Chinese, the phoneme is not directly represented in the Chinese writing system, thereby highlighting the role of syllable but not phoneme as the prominent unit of Chinese literacy acquisition (McBride-Chang et al., 2004). More than 80% of Chinese characters are ideophonetic compounds in which the characters are comprised of both semantic and phonetic radicals (Shu et al., 2003). The semantic radical functions to indicate something about the meaning of the Chinese character while the phonetic radical provides cues to the pronunciation of the Chinese character. Though cues of character pronunciation are provided by the phonetic radical, researchers have noted that these cues are not reliable (Shu et al., 2003).

Unlike some alphabetic scripts where the letters are arranged linearly, Chinese characters are more visually complex. Chinese characters are made up of different stroke patterns, and correspondingly the stroke patterns are combined to form different radicals and characters (McBride, 2016). Chinese characters are arranged in different orthographic structures of different position regularities of radicals of left–right (e.g., 河 [ho4], "river"), top-bottom (e.g., 草 [cou2], "grass") or even circular (e.g., 圈 [hyun1], "circle"). The legality of Chinese characters is determined by positional regularity (Ho et al., 2004). These complicated orthographic rules are not always taught explicitly (Ho et al., 2003).

Chinese contains a large number of homophones. There is a large discrepancy in the number of spoken syllables to the number of morphemes in Chinese (Tong et al., 2015), with around 700 syllables in Cantonese and 400 syllables in Mandarin; each corresponds to the 5000 commonly used Chinese characters (Tsou, 1976). For example, the Cantonese pronunciation of /seoi3/ could refer to the character 歲 (age); 碎 (broken) or even 稅 (tax), Chinese characters of different meanings. Possibly as a result, Chinese words are predominantly multisyllabic to counteract the effect of homophones via lexical compounding. For example, to differentiate between the sound /hei3/ in 氣 (air) and 器 (tool) via lexical compounding, speakers often expand to say the 2-morpheme words 器材 ([hei3 coi4], "tool-tool"; equipment) or 氣球 ([hei3 kau4], "air-ball"; balloon). An analogy in English might be that instead of saying simply "chord," one says "chord" as in "musical chord" and not as in "cord blood."

Other unique features of Chinese include both diversities in languages and scripts (e.g., McBride, 2016). For example, Mandarin, Wu, Min, Xiang, Gan, Hakka, and Yue (i.e., Cantonese) are the seven major dialects spoken among Chinese speakers. Additionally, these dialects are often mutually unintelligible. The phonological structure may be different across these major dialects too. For example, Cantonese is known to have around 627 basic syllables while Mandarin only has around 403 basic syllables before differentiation by tone (Zeng, 1994). Moreover, Cantonese's phonological structure has more final consonants which is associated with having 53 rimes, while there are only 36 rimes in Mandarin (Chen et al., 2004). Furthermore, Cantonese has a more complicated tonal structure, as Cantonese has more than six tones while Mandarin only has four tones (Zhang & McBride-Chang, 2011). Despite this diversity, however, written Chinese is primarily based on Mandarin (Cheung & McBride, 2022). In addition, there are two major scripts in Chinese, simplified, used in Mainland China and Singapore, and traditional, used in Hong Kong and Taiwan. Different histories in different Chinese societies have led to this diversity, which is discussed more below.

Dyslexia in Chinese

Identifying those with dyslexia in Chinese societies sometimes depends on different diagnostic criteria that are adopted across different places (see McBride et al., 2018). For example, there is not a single set criterion for dyslexia identification in Mainland China, leading to the adoption of different assessment criteria by researchers in different research studies. On the other hand, children with dyslexia in Hong Kong and Taiwan are identified via the usage of a standardized test, but again, the criteria are different: In Hong Kong, the discrepancy-plus model is adopted: That is, a child with dyslexia must have an IQ score within the normal range but perform at least one standard deviation below in the domain of both literacy itself (i.e., word reading or word writing) and, correspondingly, in one other cognitive-linguistic domain (Chung & Ho, 2010). Dyslexia in Taiwan is instead defined as follows: Despite normal intelligence and extra remediation effort, the child is still performing below the third to the fifth percentile rank of the national norm on their character identification or character writing ability (New Taipei City Office of

Education, 2020). Though the prevalence rate of Chinese dyslexia is believed to be between 4% and 10% (e.g., Zhang et al., 2023), the reported prevalence rate of Chinese dyslexia across Chinese societies varies. In Hong Kong, the prevalence rate of Chinese dyslexia has been suggested to be around 9.7% (Chan et al., 2007), while researchers in Mainland China believed that the prevalence rate is around 4.55% and 7.96% (Zhang et al., 1996) or even as high as 11% (e.g., Wang & Liang, 2022). In Taiwan, statistical reports from the Ministry of Education proposed that the prevalence rate of dyslexia has remained between 0.96 and 1.55% over the years (Lin, 2022), a figure that is much lower than in other Chinese societies. Notably, the proposed explanations for such a low prevalence rate in Taiwan were societal and cultural-specific reasons such as low compliance with referral procedures by teachers, the reluctance of parents to label their child as disabled and others (for a detailed account of the discussion, see Tzeng, 2007). Nevertheless, despite the differences in diagnostic criteria adopted, researchers have suggested that Chinese dyslexia is probably universally identified with attention to deficits in the cognitive-linguistic skills of rapid automatized naming, phonological, orthographic, and morphological awareness (e.g., McBride et al., 2018).

Rapid automatized naming, a reflection of the difficulty in learning the arbitrary association between print symbols and sounds (Manis et al., 1999) may be the dominant deficit in Chinese dyslexia (e.g., Ho et al., 2004; Li et al., 2022). Rapid automatized naming (RAN) tasks demand that children orally identify common symbols such as numbers or letters as quickly as possible. As is the case for dyslexia in alphabetic languages (e.g., Landerl et al., 2013), poor performance on the RAN task has been repeatedly demonstrated among Chinese children with dyslexia across Hong Kong, Beijing, and Taiwan (e.g., Ho et al., 2004; Liao et al., 2015; Shu et al., 2006).

In contrast, the relationship between phonological awareness and Chinese dyslexia is not consistently clear across research studies. Research in the area of dyslexia in alphabetic orthographies has repeatedly demonstrated that phonological processing is a core deficit that is manifested by children with dyslexia (Landerl et al., 2013). However, given the opacity and the unreliable phonological cues in the Chinese script (Shu et al., 2003), the role of phonological awareness in Chinese literacy may be diminished. At the same time, however, some researchers have demonstrated a phonological deficit in those with Chinese dyslexia (e.g., Ho et al., 2000; Shu et al., 2006); others have suggested that phonological skills in only related to early reading, but not later literacy development, in Chinese (e.g., Ye & McBride, 2022). Interestingly, a test of phonological awareness was not included in the first edition of the Hong Kong Test of Specific Learning Difficulties in Reading and Writing for Junior Secondary School Students (HKT-JS) because a phonological deficit is rarely found in Hong Kong Chinese adolescents with dyslexia (Chung et al., 2018). Importantly, within a large sample of Chinese children with dyslexia in Mainland China, Siok and Tan (2022) concluded that although phonological skills are related to Chinese reading ability, poor phonological skills are neither a necessary nor sufficient condition for Chinese dyslexia.

Given the unique orthographic structure of Chinese, orthographic processing is consistently recognized as a primary focus of Chinese literacy acquisition (Ho et al., 2003). In Chinese, orthographic knowledge relates to the children's knowledge and awareness of the conventional rules in structuring Chinese characters (Chung & Ho, 2010). Orthographic knowledge is usually measured via tasks of lexical decision and radical position. More recently, tasks of delayed copying have been increasingly in used by researchers to capture orthographic processing because it involves an integration of skills related to orthographic knowledge (e.g., Mo et al., 2018; Ye et al., 2021). Due to the productive nature of the task, as compared to various identification tasks (i.e., lexical decision), delayed copying is arguably a more reliable and robust measure in tapping children's orthographic knowledge in Chinese (e.g., Cheah et al., 2023; Lo et al., 2018). In a recent study, Ye et al. (2022) found that when cognitive-linguistic skills of rapid naming, phonological and morphological awareness were statistically controlled, delayed copying significantly predicted both reading and spelling at Timepoint 1 while the character decision task only predicted spelling but not reading abilities. Moreover, the task of delayed copying uniquely explains both Chinese character and word reading even when other cognitive-linguistic skills are included in the same regression model (Pan et al., 2021). Across Chinese societies, Chinese literacy development is typically fostered primarily via a drill-and-practice format of Chinese character copying exercises of correct writing orders, because such copying practices help promote better orthographic and literacy skills (e.g., McBride-Chang et al., 2011; Tan et al., 2005). Thus, the task of delayed copying involves familiar processes for Chinese children. The orthographic deficit has been identified as one of the most dominant cognitive-linguistic deficits in Chinese dyslexia across societies (e.g., Ho et al., 2004; Meng et al., 2007). Importantly, orthographic knowledge has been suggested to play a greater importance in Chinese literacy learning as children's reading experiences increase. For example, Li et al. (2012) found that orthographic knowledge only emerged as a unique predictor of Chinese reading ability for children in primary school but not in kindergarten. In the present study, we settled on a delayed copying task to measure orthographic knowledge because it involves many of the processes related to orthographic skill, including the

automatization of complex orthographic rules and the identification and positioning of semantic and phonetic radicals.

Morphological awareness is also an important construct in Chinese literacy acquisition. As Chinese consistently make use of a great number of homophones and homographs, distinguishing them with good morphological awareness skills is vital for Chinese literacy development (Liu & McBride-Chang, 2010). Furthermore, compounding morphology is understood as an exceptionally productive method to create new words in Chinese (Packard, 2000). In Chinese, both morphological skills tapping homophone awareness and lexical compounding are crucial for literacy acquisition (e.g., Tong et al., 2009). Morphological awareness has been identified as a consistent correlate of both Chinese literacy acquisition and Chinese dyslexia status (e.g., McBride-Chang, Cho, et al., 2005; Shu et al., 2006; Song et al., 2020; Tong et al., 2017).

In line with the multiple deficit hypothesis (e.g., Ho et al., 2004) and along with the findings reviewed, we included measures of cognitive-linguistic processing in the four main domains of rapid automatized naming, phonological, orthographic, and morphological skills. However, we assumed that the underlying weighting of deficits across cognitive-linguistic skills would differ across Chinese societies due to the differences in their literacy learning experiences, as reviewed below.

Differing Literacy Experiences across Chinese Societies

Chinese literacy learning experiences vary across Chinese societies. The differing literacy experiences in domains of Chinese scripts, languages/dialects, and instructional practices are likely to have some impact on the literacy development of Chinese children across Hong Kong, Beijing, and Taipei (e.g., Cheung & Ng, 2003; McBride et al., 2018).

As mentioned above, Chinese scripts adopted by Chinese societies differ. The traditional Chinese script is used in Hong Kong and Taiwan while the simplified Chinese script is adopted in Mainland China. These two scripts vary in script complexity, with traditional Chinese characters containing around 22.5% more strokes than the simplified characters (Gao & Kao, 2002). When the visual complexity of scripts was compared across 131 written languages, the traditional Chinese was demonstrated to be the most complex, followed by the simplified script (Chang et al., 2018). Some differences in visual skills have emerged across simplified and traditional script users (e.g., McBride-Chang, Chow, et al., 2005; Peng et al., 2010; Tsang et al., 2023; Yang & Wang, 2018), with simplified script users often demonstrating somewhat stronger visual skills. While some (e.g., McBride, 2016) have argued that simplified characters may be easier to write and more difficult to read than traditional characters, there are very little data to demonstrate this to date.

In addition to the two scripts used by Chinese readers, the languages spoken across and within Chinese societies also represent great diversity. For example, children in Mainland China encompass around 56 ethnic groups with their own spoken languages (Cheung & Ng, 2003), while Minnan and Cantonese are used in Taiwan and Hong Kong, respectively. Nevertheless, children in Mainland China and Taiwan are taught to read and write in Mandarin. On the other hand, Hong Kong children learn to read in Cantonese but write in accordance with the Modern Standard Written Chinese, which is based on Mandarin words and syntactic structure (McBride et al., 2018). The inconsistency and mismatch between spoken Chinese languages and written Chinese bring about a complicated picture in Chinese literacy, potentially adding challenges to literacy acquisition (McBride et al., 2018). Furthermore, the linguistic difference between Mandarin and Cantonese has been suggested to influence the development of Chinese literacy. For example, given that Cantonese has more lexical tones and a greater number of rimes as compared to Mandarin, Cantonese-speaking children were found to have better overall tonal and rime awareness compared to their Mandarin-speaking counterparts in one study (Chen et al., 2004) suggesting that exposure to the phonologically richer language—Cantonese may promote a greater phonological ability in Chinese children in early grades (Chen et al., 2004). Importantly, apart from phonological awareness, tonal awareness is also important both for Chinese literacy development and impairment (Li & Ho, 2011; Wang et al., 2017). However, the extent to which languages used at home and school affect the profile of Chinese dyslexia across Chinese societies is still not yet well understood.

Different Chinese societies also vary in their instructional practices. Formal Chinese literacy instruction in Mainland China and Taiwan are typically introduced at the age of 6 years old when children begin primary school, while children in Hong Kong usually learn to read at an earlier age of around 3.5 years old when they are in preschool. In Mainland China and Taiwan, Chinese literacy acquisition is aided with the aid of phonological coding systems (i.e., Pinyin in the Mainland, Zhuyin-Fuhao in Taiwan) through formal literacy instruction; no such instruction has been used in Hong Kong children traditionally (McBride et al., 2018). Instead, Chinese literacy in Hong Kong typically involves rote memorization, or a look-and-say method; this method tends to strengthen children's reliance on orthographic skills for literacy development (Ho et al., 2003). The usage of a phonological system, on the other hand, helps promote phonological awareness. Comparisons of phonological abilities across

Chinese societies have demonstrated that children from Hong Kong tend to exhibit poorer phonological skills as compared to children from Mainland China and Taiwan (e.g., Cheung et al., 2001; Huang & Hanley, 1995). It is important to note that, despite the fact that the symbols of Zhuyin-Fuhao is mapped onto onsets and rimes while Pinyin letters are represented by individual phonemes (Cheung & Ng, 2003), the influence of both phonological systems is believed to be similar (e.g., Chen & Yuen, 1991).

Researchers focused on Chinese dyslexia have wondered whether these differences in Chinese literacy learning experiences might influence the profiles of Chinese dyslexia across different societies (e.g., McBride et al., 2018). For example, in some studies, phonological deficits have been highlighted as a dominant Chinese dyslexia deficit in Chinese societies where a phonological coding system is adopted (e.g., Song et al., 2020; Wang & Yang, 2015). However, as rote learning is emphasized in Hong Kong, both orthographic and rapid naming deficits but not phonological deficits have been highlighted as dominant in Chinese dyslexia in Hong Kong (Ho et al., 2004). For example, in one early study focused on profiles of Chinese dyslexia deficits across Hong Kong and Mainland China, Luan (2005) found a substantial difference in the Chinese dyslexic profiles of phonological (Hong Kong: 12% vs. Beijing: 28%) and rapid naming (Hong Kong: 52% vs. Beijing: 28%) deficits exhibited by children with dyslexia across the two societies. Together, the findings suggest that differences in Chinese literacy experiences can influence the manifestation of Chinese dyslexia profiles. Primarily driven by the difference in Chinese instructional practices across societies, we hypothesized that the phonological deficit subtype might be more prevalent in Beijing and Taipei, while Hong Kong children might manifest a higher prevalence rate for the orthographic and rapid naming deficit subtypes.

Subtypes of Chinese Dyslexia: Evidence from Hong Kong, Beijing, and Taipei

Previous work examining subtypes of Chinese dyslexia in young children has been performed across Chinese societies, but such research has rarely incorporated all four cognitive-linguistic skills highlighted here, namely, rapid automatized naming, phonological awareness, orthographic processing, and morphological awareness concurrently in subtyping analyses (e.g., Beijing; Song et al., 2020; Hong Kong; Ho et al., 2004; Huo et al., 2022; Taiwan; Wang & Yang, 2015). This lack of inclusion of all four may have obscured the exact nature and subtypes of Chinese dyslexia. For example, all four studies listed above were successful in identifying Chinese dyslexia subtypes involving the specific cognitive-linguistic domain deficits of phonological, orthographic, morphological, or rapid naming deficits when these specific cognitive-linguistic skills were included as a clustering variable. As outlined in the previous section, because clear differences in Chinese literacy experiences across societies might influence the development of Chinese literacy acquisition (e.g., McBride et al., 2018), the extent to which such differences could influence the manifestation of Chinese dyslexia across Chinese societies remains unclear.

Utilizing an existing dataset collected on samples of Chinese dyslexics from Hong Kong, Beijing, and Taipei (see Pan et al., 2024), the present study aimed to examine the potential variance/invariance of subtypes of Chinese dyslexia across Chinese societies. With the adoption of an equivalent Chinese assessment battery, the present study is among the very few, if any, that has examined the subtypes of Chinese dyslexia across three Chinese societies concurrently. In line with the multiple deficit view of Chinese dyslexia (Ho et al., 2004) and based on previous research findings on Chinese dyslexia subtypes of young children (e.g., Ho et al., 2004; Huo et al., 2022; Song et al., 2020; Wang & Yang, 2015), we hypothesized that a total of four subtypes with distinctive deficits in each cognitive-linguistic skills (i.e., phonological deficit, orthographic deficit, morphological deficit, and rapid naming deficit subtype), along with a global deficit subtype, would emerge in the present study.

Participants were children in second and third grade who had been identified as having Chinese dyslexia along with their chronological age-matched typically-developing control counterparts across three Chinese cities of Hong Kong (Dyslexic: $N=32$; Control: $N=44$), Beijing (Dyslexic: $N=35$; Control: $N=25$), Taipei (Dyslexic: $N=24$; Control: $N=39$), respectively. The full details of the study methodology are provided in Appendix S1. The participants across the three societies were administered a roughly equivalent Chinese assessment battery covering Chinese word reading ability, phonological awareness (onset and rime detection), orthographic processing (delayed copying), morphological awareness (compounding morphology), and rapid automatized naming of numbers. Measures were carefully designed with input from researchers across all three cities in an effort to ensure that they were roughly equivalent. For example, the Chinese word reading task contained characters that were the same in both simplified and traditional script. The performances of children of each group from each society on the assessment battery are reported in Table 1. Additionally, the partial correlation analysis with grade statistically controlled showed that Chinese word reading correlated significantly with all cognitive-linguistic skills in the dyslexic group ($rs \geq -.28$, $ps \leq .042$) except with morphological awareness ($r=.18$, $p=.091$). For the control group, only morphological awareness was found to be significantly

TABLE 1
Descriptive Statistics of Sample Characteristics in Three Chinese Societies

	Hong Kong		Beijing		Taipei	
Variable (max)	Dyslexia (*N* = 32)	Control (*N* = 44)	Dyslexia (*N* = 35)	Control (*N* = 25)	Dyslexia (*N* = 24)	Control (*N* = 39)
CWR (70)	39.13 (12.20)	52.07 (7.58)	48.09 (13.06)	54.48 (8.50)	26.96 (17.37)	58.64 (6.57)
CPA (13)	5.63 (2.25)	7.05 (2.76)	8.60 (3.20)	10.08 (2.04)	5.33 (2.08)	9.05 (2.26)
CDC (82)	20.16 (8.48)	27.32 (10.64)	40.43 (11.00)	41.52 (10.93)	40.92 (9.60)	56.46 (10.60)
CMA (46)	19.16 (5.44)	25.09 (6.11)	29.20 (6.43)	31.68 (4.99)	18.54 (8.08)	26.87 (5.13)
CDRAN (−)	25.84 (7.54)	23.30 (6.35)	19.86 (4.70)	18.10 (3.96)	26.07 (7.84)	17.00 (3.69)

Note. Values in the parentheses represent the standard deviations of the task performance.
Abbreviations: CDC, Chinese delayed copying; CDRAN, Chinese rapid digit naming; CMA, Chinese morphological awareness; CPA, Chinese phonological awareness; CWR, Chinese word reading.

TABLE 2
Tabulation of Dyslexia Subtypes against Chinese Societies

Dyslexic subtypes	Mild orthographic deficit	Phonological deficit	Morphological deficit	Global deficit
Hong Kong	*n* = 13 (41%)	*n* = 11 (34%)	*n* = 5 (16%)	*n* = 3 (9%)
Beijing	*n* = 16 (46%)	*n* = 13 (37%)	*n* = 3 (9%)	*n* = 3 (9%)
Taipei	*n* = 6 (25%)	*n* = 6 (25%)	*n* = 8 (33%)	*n* = 4 (17%)
Total (*N*)	*N* = 35 (38%)	*N* = 30 (33%)	*N* = 16 (18%)	*N* = 10 (11%)

correlated to Chinese word reading ($r = .22$, $p = .021$) but not with the other cognitive-linguistic skills ($rs \leq .10$; $ps \geq .057$). The full correlational matrix is reported in Table S1 in the Appendix.

In an effort to identify the subtypes of Chinese dyslexia across three societies, we followed the clustering analysis procedure used by Huo et al. (2022), in which a hierarchical cluster analysis with Ward's method and squared Euclidean distance was employed on the 91 dyslexic children. The standardized *Z*-score of the four cognitive-linguistic skills was entered as the clustering variable. The visual inspection of change in clustering coefficients and dendrogram suggested the consideration of both five- and four-cluster solutions. To validate the cluster solution, a clustering analysis was performed again with the whole sample with the control children included, and with the two subsamples randomly generated from the dyslexic sample, and the newly yielded cluster membership was cross-tabulated with the initial yield from the original dyslexic sample (e.g., Huo et al., 2022). The validation work indicated that the four-cluster solution was preferred as the final solution as it achieved the highest stability across both validation methods (i.e., whole sample re-clustering: 73.6%; subsample re-clustering: 73.9% & 80.0%). The distribution of the four dyslexic subtypes against the three Chinese societies is shown in Table 2. Out of the 91 Chinese dyslexic children, 38% identified in Cluster 1, 33% in Cluster 2, 18% in Cluster 3, and 11% in Cluster 4. Regarding the relationship between literacy experience and dyslexia, we compared two opposing hypotheses. The first is that distribution of dyslexia subtypes is variant across Chinese societies; the second hypothesis is that the distribution of dyslexia subtypes is invariant across Chinese societies. A Bayesian Analysis of Contingency Table was conducted to investigate which hypothesis received more support from our data. The Bayesian approach was preferred here due to its strength over the frequentist approach, particularly in its ability to provide a measure of evidence to support and oppose both the null and alternative hypothesis (for a review, see Nuzzo, 2017; van Doorn et al., 2021). A test of association produced a Bayes factor of 1:4.8, in favor of independence between society and dyslexia subtypes with a moderate amount of evidence (Jeffreys, 1961), suggesting that the distribution of Chinese dyslexia subtypes is relatively similar across the three Chinese societies.

One-way analyses of covariance (ANCOVA) with grade statistically controlled showed significant differences in the word reading and cognitive-linguistic measures across the four subtypes of dyslexia and between these subtypes and the control group, as shown in Tables 3 and 4. The sample size of the control group was restricted to 40 which were randomly selected from 108 controls from three societies ($n = 13$ Hong Kong; $n = 11$ Beijing;

TABLE 3
Group Differences of Cognitive-Linguistics Skills among Dyslexic Subgroups in *Z*-Scores (Covariate: Grade)

Variable	OD ($n = 35$)	PD ($n = 30$)	MD ($n = 16$)	GD ($n = 10$)	ANCOVA	Pairwise comparisons
CWR	−0.212 (0.800)	−0.973 (0.897)	−1.06 (1.359)	−0.894 (0.938)	$F = 4.47^{**}$, $\eta_p^2 = .135$	OD > PD = MD
CPA	0.243 (0.670)	−1.23 (0.504)	−0.302 (0.761)	−0.795 (1.05)	$F = 25.47^{***}$, $\eta_p^2 = .470$	OD > PD = GD; MD > PD
CDC	−0.122 (0.764)	−0.350 (0.966)	−0.386 (0.679)	−1.66 (0.618)	$F = 9.38^{***}$, $\eta_p^2 = .247$	OD = PD = MD > GD
CMA	0.273 (0.664)	−0.444 (0.665)	−1.70 (0.661)	−1.09 (0.964)	$F = 31.72^{***}$, $\eta_p^2 = .525$	OD > PD > MD; OD > GD
CDRAN	0.012 (0.952)	0.268 (0.746)	0.202 (0.299)	2.45 (1.05)	$F = 24.02^{***}$, $\eta_p^2 = .456$	GD > OD = PD = MD

Note. Values in the parentheses represent the standard deviations of the task performance.
Abbreviations: C, control; CDC, Chinese delayed copying; CDRAN, Chinese rapid digit naming; CMA, Chinese morphological awareness; CPA, Chinese phonological awareness; CWR, Chinese word reading; GD, global deficit subtype; MD, morphological deficit subtype; OD, mild orthographic deficit subtype; PD, phonological deficit subtype.
$^{**}p < .01$.
$^{***}p < .001$.

TABLE 4
Group Differences of Cognitive-Linguistics Skills among Dyslexic Subgroups and Control in *Z*-Scores (Covariate: Grade)

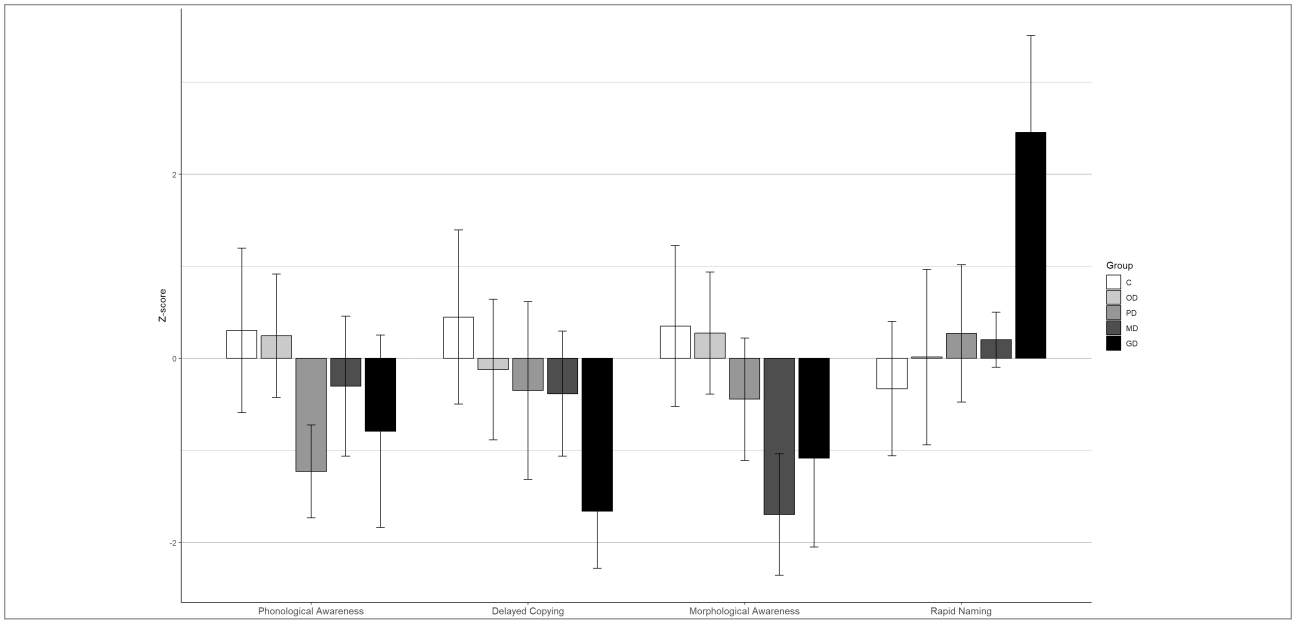
Variable	OD ($n = 35$)	PD ($n = 30$)	MD ($n = 16$)	GD ($n = 10$)	C ($n = 40$)	ANCOVA	Pairwise comparisons
CWR	−0.212 (0.800)	−0.973 (0.897)	−1.06 (1.359)	−0.894 (0.938)	0.50 (0.471)	$F = 17.90^{***}$, $\eta_p^2 = .364$	C > OD > PD = MD; C > GD
CPA	0.243 (0.670)	−1.23 (0.504)	−0.302 (0.761)	−0.795 (1.05)	0.301 (0.893)	$F = 22.46^{***}$, $\eta_p^2 = .418$	C = OD > PD = GD; MD > PD
CDC	−0.122 (0.764)	−0.350 (0.966)	−0.386 (0.679)	−1.66 (0.618)	0.447 (0.945)	$F = 13.28^{***}$, $\eta_p^2 = .298$	C > OD = PD = MD > GD
CMA	0.273 (0.664)	−0.444 (0.665)	−1.70 (0.661)	−1.09 (0.964)	0.350 (0.874)	$F = 16.43^{***}$, $\eta_p^2 = .477$	C=OD > PD = MD = GD
CDRAN	0.012 (0.952)	0.268 (0.746)	0.202 (0.299)	2.45 (1.05)	−0.331 (0.730)	$F = 25.03^{***}$, $\eta_p^2 = .445$	GD > PD > C; GD > OD = MD

Note. Values in the parentheses represent the standard deviations of the task performance.
Abbreviations: C, control; CDC, Chinese delayed copying; CDRAN, Chinese rapid digit naming; CMA, Chinese morphological awareness; CPA, Chinese phonological awareness; CWR, Chinese word reading; GD, global deficit subtype; MD, morphological deficit subtype; OD, mild orthographic deficit subtype; PD, phonological deficit subtype.
$^{***}p < .001$.

$n = 16$ Taipei), to avoid issues of power and type I error rates being affected by the usage of unequal sample sizes (Rusticus & Lovato, 2014). The four cluster groups were all significantly poorer in their word reading and delayed copying abilities relative to the control group (*p*s < .001). Based on the results shown in Tables 3 and 4, Cluster 1 was identified as the *mild orthographic subtype* (OD) as Cluster 1 only exhibited poorer delayed copying abilities relative to the control group while manifesting better cognitive-linguistic skills than the other cluster groups. Cluster 2 exhibited the poorest phonological awareness among all the cluster groups while also showing significantly poorer skills of morphological and rapid naming as compared to the control group; it was therefore classified as the *phonological deficit subtype* (PD). In addition, Cluster 3 was identified as the *morphological deficit subtype* (MD) as it exhibited the poorest morphological abilities among the cluster groups. Additionally, the morphological deficit subtype was found to have significantly better phonological skills than the phonological deficit subtype. Cluster 4 was classified as the *global deficit subtype* (GD), with significantly poorer skills across all domains of cognitive-linguistic skills compared to the control group. Notably, the global deficit subtype manifested significantly poorer delayed copying and rapid naming abilities as compared to the three other cluster groups. The characteristics of cognitive-linguistic performance for the four subtypes of dyslexia we identified are shown in Figure 1.

Our present analysis highlighted the importance of orthographic awareness, phonological processing, and

FIGURE 1
Cognitive-Linguistic Skills Performance across Four Chinese Dyslexic Subgroups against Control



Note. Error bar representing 95% confidence interval. C, control; GD, global deficit subtype; MD, morphological deficit subtype; OD, mild orthographic deficit subtype; PD, phonological deficit subtype

morphological awareness in dyslexia across Chinese societies. Our findings converge with the findings of a meta-analysis in which Chinese societies (i.e., Mainland China and Hong Kong) did not emerge as potential moderators of the deficit profiles of Chinese dyslexia (Peng et al., 2017). Our subtyping analysis also highlights the dominance of an orthographic deficit present in Chinese dyslexia (e.g., Ho et al., 2004). Orthographic deficits were found across all dyslexia subtypes identified, with the global deficit subtype group showing the poorest performance of them all. Interestingly, the mild orthographic subtype group identified in the current analysis did not exhibit other cognitive-linguistic deficits. Given that children with dyslexia have difficulties grasping and automatizing the orthographic rules in Chinese, our findings highlight the role of orthographic processing as one of the most dominant deficits observed in Chinese dyslexia (McBride et al., 2018). Nevertheless, it should be noted, that our measure of orthographic awareness was one of delayed copying, integrating visual-orthographic skills together with writing. This complex task is a relatively new and multi-faceted version of the more traditional orthographic processing tasks used in previous work.

Furthermore, the present work also underscores the importance of morphological awareness in understanding the Chinese dyslexia subtype. To our knowledge, few studies have examined the role of a morphological dyslexia subtype (e.g., Song et al., 2020). Song et al. (2020) found that the morphological deficit emerged as the better predictor of dyslexia status as compared to skills of phonological awareness and rapid naming. Additionally, all four subtypes identified exhibited moderate to severe difficulties in their morphological processing skills (Song et al., 2020). However, while most dyslexia subtypes identified in the present work manifested deficits in morphological skills, only the mild orthographic subtype group exhibited intact skills of morphological processing, possibly suggesting the distinction between the lexical-semantic (i.e., morphological) and non-semantic pathway in Chinese reading (see Yin & Weekes, 2003). Another possible explanation is that the difference in clustering variables across both studies as orthographic awareness was not measured in the previous study, consequently leading to a different clustering solution. Similar to orthographic processing, morphological awareness should be considered in future studies of Chinese dyslexia.

Finally, phonological processing difficulties (i.e., phonological awareness and rapid naming) were found in both the phonological deficit and global deficit subtypes. As previously reviewed, some researchers believe that the dominance of the phonological deficit subtype may be greater in societies in which a phonological coding system is introduced as an aid to reading. However, across societies, phonological deficit subtypes emerged as the second-largest cluster group in the present work. Indeed, previous work on Chinese dyslexia subtypes conducted in societies with a phonological coding system adopted have also highlighted the dominance of deficits in phonological awareness skills (e.g., Song et al., 2020; Wang & Yang, 2015). The relatively high number of phonological deficit subtypes identified in the Hong Kong dyslexic sample may be due to the possible

interrelated relationship between orthographic and phonological processing. Both phonological awareness and rapid naming are conceptualized as part of phonological processing (see Wagner & Torgesen, 1987), and, as noted by Ho et al. (2004), there is no subtype that consists of only a rapid naming deficit alone; rather, RAN difficulties tend to be comorbid with an orthographic deficit. Future studies are required to confirm the present result to further shed light on the relationship between rapid naming, phonological awareness, and orthographic processing.

Nevertheless, the present analysis showcases that while literacy experiences differ across Chinese societies, the cognitive-linguistic composites of dyslexia remain relatively similar, possibly highlighting the cultural invariance of Chinese dyslexia. However, it should be noted that the results of the present study should be interpreted with caution as the notion of invariance of Chinese dyslexia subtypes warrants more careful examination and replication studies with larger sample sizes to ensure the replicability of the present work. Next, as the present study places a strong emphasis on ecological validity, children with dyslexia across each Chinese societies were identified with their own locally devised diagnostic criteria and assessment tools which may have possibly decrease the comparability of the present sample. Future research could attempt to seek to implement a "uniform dyslexia criteria" in identifying Chinese dyslexics across societies to help better draw stronger conclusions regarding the "universality" of Chinese dyslexia. Another potential limitation of the current study is that the present study only administered a single measure to tap into each of the cognitive-linguistic constructs. Of specific note, the task of delayed copying taps into a variety of skills. However, due to the productive nature of the task, we believe that delayed copying is arguably a particularly reliable measure of orthographic processing (e.g., Cheah et al., 2023; Ye & McBride, 2022). Nevertheless, future studies could consider adopting multiple measures in tapping into the cognitive-linguistic constructs to improve the validity and reliability of the findings.

Conclusion and Future Directions

This review and our empirical findings all highlight the importance of a multi-faceted exploration of dyslexia in Chinese, both in a within and cross-cultural Chinese perspective. Assessment of Chinese literacy should include measures of phonological, morphological, and orthographic processing, in addition to rapid automatized naming. These skills all appear to be important for reading Chinese across Chinese societies. However, despite the fact that research on Chinese dyslexia has expanded greatly in the past two decades, the current perspective on Chinese dyslexia requires additional research in different contexts. For example, much of the Chinese dyslexia research performed is confined to Chinese-dominant societies as reviewed. To our knowledge, no study has yet to investigate L1 Chinese literacy acquisition or Chinese dyslexia in Malaysian children whose primary schooling of instruction is in Chinese (e.g., McBride et al., 2022). Future studies should examine the prevalence and nature of Chinese dyslexia in non-Chinese predominant societies, especially those in the Southeast Asia regions where multilingualism and biliteracy are the norm. Similarly, the importance of Chinese dyslexia identification and remediation in Singapore has been increasingly recognized (e.g., Shen et al., 2014; Tan et al., 2018). In addition, in future work, the complicated relationship between Chinese languages and Modern Standard Written Chinese warrants more careful examination, especially under the lens of Chinese dyslexia research. The diglossic context between the Chinese home language and literacy may be complicated and different from other languages (see Cheang & McBride, 2022). However, the mismatches among the grammatical structure, syntax, and vocabulary between the Chinese heritage languages and standard written Chinese may not necessarily bring about a poorer development of Chinese literacy skills. In a recent study conducted in Guangxi, Mainland China that examined the impact of home and school language differences, the researchers found that Chinese heritage language-only speaking children and Chinese heritage-Mandarin bilingual children performed better than Mandarin-only speaking children on their Chinese literacy skills (Luo & Gong, 2022). Similar evidence has emerged previously in Hong Kong, with children who spoke both Cantonese and Mandarin in their home exhibiting the highest literacy attainment (Tse et al., 2007), suggesting a possible influence of Chinese bilingualism on Chinese literacy. Furthermore, when examining the impact of Cantonese or Mandarin as a medium of instruction in Chinese lessons, Tse et al. (2010) found that Hong Kong Cantonese-speaking children whose Chinese was taught in Cantonese had better Chinese reading abilities as compared to those who were taught in Mandarin. Finally, the impact of Chinese keyboarding input methods warrants further investigation on the effect of Chinese dyslexia: Previous research has found that there is a differential impact on Chinese literacy and cognitive-linguistic skills between an orthographic-based (i.e., Cangjie) and pronunciation-based (i.e., Pinyin) input method of choice (Siok & Liu, 2018).

To conclude, we have highlighted and reviewed the characteristics of the Chinese script, cognitive-linguistic correlates, and literacy experiences of Chinese literacy acquisition and Chinese dyslexia. Utilizing an equivalent Chinese assessment battery on children with Chinese dyslexia from three different Chinese societies, the present work highlighted the commonalities in cognitive-linguistic deficit profiles in Chinese dyslexia despite differences in literacy experiences. This work has revealed relative invariance in the concept of Chinese dyslexia despite differences in teaching approaches, as

well as languages and scripts. As understanding of reading development and impairment in Chinese continues to be better understood through the unique lens of Chinese character and word reading models, researchers and practitioners need to find better ways to assess and remediate those with Chinese dyslexia across cultures.

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Conflict of Interest Statement

We have no known conflict of interest to disclose.

Data Availability Statement

Data is available from the corresponding author upon reasonable request.

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Zebedee Rui En Cheah is a PhD Candidate in the Department of Psychology, The Chinese University of Hong Kong, Ma Liu Shui, Hong Kong; email: zebedee@link.cuhk.edu.hk.

Catherine McBride (Corresponding author) is a Distinguish Professor in the Department of Human Development and Family Science, Purdue University, West Lafayette, Indiana, USA; email: mcbridca@purdue.edu.

Xiangzhi Meng is an associate professor in the School of Psychological and Cognitive Sciences, Peking University, Beijing; email: mengxzh@pku.edu.cn.

Jun Ren Lee is an associate professor in the Department of Educational Psychology and Counselling, National Taiwan Normal University, Taipei; email: jrlee@ntnu.edu.tw.

Shuting Huo is now a research assistant professor in the Department of Psychology, The Chinese University of Hong Kong, Ma Liu Shui, Hung Hom, Hong Kong; email: shutinghuo@cuhk.edu.hk.

Supporting Information

Additional supporting information may be found in the online version of this article on the publisher's website:10.1002/rrq.578/suppinfo

Appendix S1.