

**AN INVESTIGATION ON COGNITIVE-LINGUISTIC SKILLS OF ENGLISH-CHINESE BILINGUAL LEARNERS
WITH AND WITHOUT DYSLEXIA IN SINGAPORE**

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ABSTRACT

This thesis investigates dyslexia and the cognitive-linguistics skills, namely phonological awareness, orthographic knowledge, morphological awareness and rapid naming, of bilingual learners in Singapore whose first language is English and second language is Chinese. The two main research aims are to investigate whether the English-Chinese bilingual learners with dyslexia diagnosed only in English are weaker than their typical counterparts in reading and all cognitive-linguistic skills in both languages or either language, and to investigate which cognitive-linguistic skills are strong predictors of reading in each language. Results show that the bilingual learners with dyslexia performed significantly poorer than their typical counterparts in reading and all cognitive-linguistic skills in both languages, although their dyslexia were diagnosed only in English. Results also found all English cognitive-linguistic skills predictive of English word reading, especially the unique predictive roles of morphological awareness and orthographic knowledge after rapid naming and phonological awareness were controlled. However, only rapid naming and morphological awareness were found to be predictive of Chinese word reading. The results suggest that dyslexia may manifest differently in reading and cognitive-linguistic skills of English and Chinese languages in the English-Chinese bilingual learners, based on the two different predictive models with different empirically and theoretically supported orders of cognitive-linguistic skills as predictors for reading development in the two languages. The difference in the unique contributions of the four cognitive-linguistic skills underlying the reading development of both languages may suggest the difference lies in language structure and instruction.

Keywords: dyslexia, bilingualism, English reading, Chinese reading, cognitive-linguistic skills

IMPACT STATEMENT

The key contributions of the thesis research could be put into beneficial use inside and outside of academia. The study has shed some light on how dyslexia may manifest differently in reading and cognitive-linguistic skills of English and Chinese languages based on two different theoretically and empirically supported predictive models, and also has a theoretical contribution to the ongoing debate about the identification and assessment of dyslexia, as the manifestation of reading difficulties and association of cognitive-linguistic skills differ in different languages (e.g., Elliott & Gibbs, 2008; Elliott & Grigorenko, 2014; Landerl et al., 2022; Poole, 2003; Smythe & Everatt, 2002). This is especially so in Singapore's bilingual context, where bilingual learners/students are taught /learn English as a first language and Chinese as a second language, but dyslexia is diagnosed only based on the first language.

Findings from the thesis research support the need for the testing of reading ability and cognitive-linguistic skills to be done separately in English and Chinese for bilingual learners (McBride, 2019; McBride-Chang et al., 2012), in order to better identify and support the struggling readers of either or both languages in Singapore's context. Although the study's sample could not classify poor readers or dyslexic learners in Chinese, the findings that suggested the different patterns of cognitive-linguistic skills as predictors of English and Chinese reading will be shared with the key stakeholders (i.e., MOE and DAS) to reconsider how dyslexia could be better defined and identified for our bilingual students in Singapore and explore better collaboration in the identification process through the learning support programme (i.e., RTI) for both languages. As there is a lack of established assessment tools for Chinese, the non-standardised task measures utilised in this study, especially the Chinese tasks, can be used for the purpose of assessing reading ability and cognitive-linguistic skills in both languages for the student, as they have been assessed to be of good internal consistency reliability. Also, the task measures can be further researched to improve the psychometric properties in future.

The thesis research could be an initial study for possible programmatic research in future, research collaborations could be explored amongst key local establishments, such as MOE and DAS,

and international researchers in the field of dyslexia and bilingualism, to extend the present findings and derive a comprehensive definition and assessment for dyslexia in Singapore's context.

Findings from the thesis research will also be shared with mainstream schoolteachers, educational therapists, parents and other educational professionals by conducting talks and workshops about dyslexia and its manifestation in different languages, the nature of English and Chinese languages and how the underlying cognitive-linguistic skills are associated with learning to read in these languages. Findings from the thesis research will also be disseminated to the wider community of researchers and educational professionals through journal article publication, conference presentations and workshops, so that other bilingual groups locally and internationally can learn and take reference from this study for future research, in investigating dyslexia and the cognitive-linguistic skills in their linguistic contexts.

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DECLARATION

I, Shen Peixin (Priscillia), confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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REFLECTIVE STATEMENT

This reflective statement provides an overview and reflection of my EdD doctoral journey through the taught modules and the Institution Focused Study (IFS) at the National Institute of Education (NIE), and eventually embarking on the thesis at the University College London – Institute of Education (UCL-IOE). It also contains my reflection on how my academic thinking has been influenced and developed, leading up to the development of my ideas for the IFS and thesis.

When I first applied for the EdD (Dual Award) programme, my initial research proposal was to develop a standardised assessment that could monitor the learning progress of Chinese language for children diagnosed with dyslexia in Singapore because second language learning has been largely neglected in the support for children with dyslexia and Chinese language is the ‘mother tongue’ of my ethnicity. I proposed a very ambitious idea to conduct a norming exercise for developed Chinese literacy tests used for informal assessments at my organisation, the Dyslexia Association of Singapore (DAS), with Singapore’s English-Chinese bilingual student population. This idea stemmed from my previous Masters’ thesis which I did an investigation of the difficulties that our Singaporean dyslexic learners face in learning Chinese as a second language (Shen et al., 2014) and Chinese assessment tools suitable for Singapore’s population was unavailable.

Through the EdD Dual Award programme, the taught modules at NIE had helped to reshape and refine my research idea progressively for IFS and thesis. The taught modules were: (1) NEDD800 – Professionalism, Ethics and the Self; (2) NEDD801 – Critical Inquiry in Educational Research and Professional Practice; (3) NEDD802 – Answering Questions with Quantitative Data; (4) NEDD803 – Answering Questions with Qualitative Data; (5) NEDD804 – Conceptualising and Writing the Research Proposal.

Module NEDD800 on professionalism, ethics and the self was an eye-opening learning experience for me, as it allowed me to think critically and debate about what professionalism is and what professional thinking should be. It left me with more sophisticated understanding of my own identity and role as an employee in my organisation as well as my working relationship with colleagues

in relation to my organisation's professionalism. My assignment of this module had explored the topic on how Educational Therapists made sense of our 'profession' as being 'professional' at my organisation. My assignment reflected on the dilemma in my professionalism as a special needs professional, in face of the challenge of "living up" to the "big picture" that DAS has as a well-established organisational dyslexia advocate in Singapore. The module has developed my philosophical knowledge and critical thinking academically, allowing me to question my 'professional' responsibilities in maintaining integrity of my research in view of my dual role as an employee of my organisation and researcher whose study is also of my organisation's interest.

Module NEDD801 on critical inquiry in educational research and professional practice further broadened my knowledge of the philosophical issues that underpin social sciences research. Understanding the ontological, epistemological, axiological and methodological beliefs of various interpretive frameworks has helped me make a more informed choice of the appropriate research paradigm and justify for the research direction for my IFS and thesis. In my assignments, I discussed about my professional practice in supporting my organisation's initiative to contribute to dyslexia research in Singapore and considered the use of post-positivism as the research paradigm for my IFS research proposal.

With better understanding of what professionalism means in my own role as a researcher and employee of my organisation as well as the professional practice in educational research and research paradigms, I was able to have a better grasp of the qualitative and quantitative approaches covered in the subsequent modules. Module NEDD802 on answering questions with quantitative data had deepened my knowledge of quantitative inquiry in educational research. As a positivist in my research beliefs, I found this module particularly enjoyable and was make more informed judgements on the use of parametric and non-parametric analyses for my IFS research.

Module NEDD803 on answering questions with qualitative data had value-added to the refining of my IFS research proposal and allowed me to clarify some of my misconception of qualitative research methods. Being a researcher who was more comfortable with quantitative analysis, this

module had introduced me well into the world of qualitative research with much ease. I was given opportunities to practice taught skills in analysing data, identifying themes and aligning theories to practice through a range of qualitative research methods. Given the nature of data collection in qualitative research, I understood that the rigour and ethics of the research is of utmost importance to ensure a coherent and powerful qualitative study (J. W. Creswell, 2013). I was particularly interested in the Grounded Theory approach (Charmaz, 2014) which has systematic guidelines for gathering and analyzing data to generate theory through rigorous analyses of empirical data. Perhaps the rigorous analytic process of coding and checking data, and integrating theoretical categories makes a quantitative researcher like me more willing to explore the grounds of qualitative inquiry in research.

The final taught module, NEDD804, on conceptualising and writing the research proposal had supported me through the decision-making process and completion of my research proposal for the IFS and thesis. I had decided on the post-positivist paradigm for my proposed research idea for IFS and Thesis, as this paradigm contains logical and empirical elements that are acceptable by quantitative researchers while espousing with rigorous qualitative analyses that supplement quantitative analyses (Creswell, 2013). I proposed the development of a dyslexia screening assessment that detects dyslexic symptoms in Chinese for English-Chinese bilingual learners in Singapore because of the lack of suitable dyslexia assessment tool in Chinese. I thought this interpretative framework worked very well for my research idea, as the research could be conducted in two phases from IFS to thesis stage. The first phase of research that employs the qualitative method that involve case studies of 8 to 11 years old Singaporean dyslexic students of Chinese ethnicity using the Grounded Theory approach (Charmaz, 2014) was proposed to be conducted at IFS stage to develop a theoretical framework for the construction of the dyslexia screening tool. The second phase of research that employs the quantitative method that assess the reliability and validity of the constructed Chinese assessment tool to screen English-Chinese Singaporean bilingual learners who are at risk for dyslexia was proposed to be conducted at the thesis stage.

In my continued discussion with my NIE supervisor and co-supervisor (Dr Li Jen-yi and Dr Victor Chen) after the completion of module NEDD804, the focus of my research proposal had shifted from Chinese language only to both languages for English-Chinese bilingual learners in Singapore. This is based on the theoretical argument that dyslexic difficulties can be manifested in different ways across orthographies of different languages due to an individual's cognitive abilities (Brunswick, 2010; Comeau et al., 1999; Ziegler & Goswami, 2005). Nonetheless, the two phases of research to be conducted at IFS and thesis stage respectively remained unchanged.

During the IFS stage, my NIE supervisor (Dr Li Jen-yi) left her position and was replaced by Dr Beth O'Brien, while Dr Victor Chen remained as my co-supervisor. I had learnt a lot under the guidance of both supervisors in my progress through the IFS, in terms of framing my research questions and qualitative data analysis. As there were no similar studies that investigated on dyslexia in Singapore's bilingual population and no formal definition of dyslexia in Chinese, it had been a challenge in selecting the target participants for the study. The IFS research recruited 10 students with dyslexia and their parents for a series of interviews and simulation activities in English and Chinese, and their work samples (i.e., school worksheets and examination papers) were collected for triangulation of data. Six categories of difficulties emerged through the grounded theory analysis. They are cognitive difficulties, expressive issues, struggles in forming sentences, writing difficulties, reading difficulties, and issues in comprehending. However, because the data collected was subjective data (i.e., perceptions of the students and their parents on the difficulties they face in English and Chinese), I was cautioned against using the data to construct a screening assessment tool. This experience made me reflect a lot on my choice of research methods and the future direction if I wished to continue investigating dyslexia and assessments in Singapore's bilingual context. Moreover, the exploration on dyslexia in Chinese language for English-Chinese bilingual population was considered new and no other similar studies had been conducted before.

After passing the IFS stage, I was fortunate to be able to visit UCL in London and meet my supervisor (Professor Robert Savage) before the Covid-19 pandemic happened. I shared my research

idea about investigating dyslexia in both languages for Singapore's bilingual students with Professor Savage who advised me to consider using standardised tools. However, standardised tools for Chinese are unavailable and if they do, they were developed based on countries where Chinese language is first language and are not suitable for the Singapore's population whose Chinese is second language. Through his network, I was able to access some non-standardised but established Chinese assessments developed by other researchers and adapt for the purpose of my study. I also met Dr Fotini Diamantidaki subsequently as my co-supervisor who also gave me very good advice in literature review and data collection process.

As I embarked on the thesis research, I was still able to integrate my knowledge learnt from the previous four taught modules into real application, like how I did for my IFS study. The summer school RTP classes at UCL also further deepened my philosophical inquiry and critical thinking in research through an international perspective. I considered the moral conflicts in relation to my professionalism as a researcher and an employee of my organisation, as well as the professional responsibilities to maintain research integrity (Resnik & Shamoo, 2011). I was also more aware of my preferred research paradigm and understood the need for a rigorous quantitative study in order to present a more valid research.

One of the biggest challenges I faced was the limited knowledge of what the first step to take on doing research that was probably the first in its kind in investigating the manifestation of dyslexia in both languages of English-Chinese bilingual learners in Singapore, as well as exploring the reliability and validity of assessment tools. I am glad to have Professor Savage as my supervisor and Dr Diamantidaki as my co-supervisor who have rich experience in this area to guide me through my thesis research. In the same year, McBride (2019) published a book about establishing a global perspective on dyslexia, dysgraphia and attention deficit hyperactivity disorder (ADHD) and proposed the key cognitive-linguistic skills that are essential for reading development and understanding dyslexia. I was able to use her model to test my hypotheses in my thesis research and found unique findings that contribute to the field of dyslexia, under the guidance of my supervisors.

It had been a tremendous learning journey under the supervision of Professor Savage and Dr Diamantidaki. The thesis research has not only widened my scope of knowledge about statistics, especially regression model analysis, but also my clarity in writing. One of the feedback from the examiners I received about my IFS study at NIE was the lack of clarity in my definition and argument about dyslexia in bilingualism. With the guidance of my UCL supervisors, I learnt how to be more focused and clear in my arguments in writing. I am very glad that I have embarked on this EdD Dual Award journey which has deepened my knowledge on research and refined my practice as a researcher. Reflecting on the whole process, I have come to the realisation that my initial motivation of exploring and investigating Chinese language learning for our bilingual students with dyslexia has not only been shaped with better and clearer direction, my core belief that dyslexia is a language-based difficulty that may affect the reading development of English and Chinese differently, depending on the pedagogical factors and social factors of the linguistic environment (Paradis et al., 2011; Thomson, 2003; Wen et al., 2017) as well as the individual's cognitive abilities and nature of language (Brunswick, 2010; Comeau et al., 1999; Landerl et al., 2022) has remained unchanged throughout my learning journey in EdD Dual Award programme and it has been affirmed with the findings of my thesis research study.

LIST OF ABBREVIATIONS

Abbreviation	Definition
BERA	British Educational Research Association
CTOPP-2	The 2 nd edition of the Comprehensive Test of Phonological Processing
DAS	Dyslexia Association of Singapore
GPC	Grapheme-Phoneme Correspondences
LSP	Learning Support Programme
MOE	Ministry of Education
MTSP	Mother Tongue Support Programme
RAN	Rapid Automatised Naming
RTI	Response-to-Intervention
WRAT-5	The 5 th edition of Wide Range Achievement Test

An Investigation on Cognitive-Linguistic Skills of English-Chinese Bilingual Learners with and without Dyslexia in Singapore

INTRODUCTION

1. Researcher's Professional Background and Motivation for the Thesis Research

The motivation behind my thesis research is largely due to my profession in the field of dyslexia and educational therapy in Singapore. I started as an educational therapist in 2005 at the Dyslexia Association of Singapore (DAS) providing intervention support in English for students diagnosed with dyslexia. Over the years, I received enquiries from parents and mainstream school teachers of the students whom I was working with about their concerns on the students' learning of Chinese and whether dyslexia affects their Chinese language as well. I also had the opportunity to work closely with allied educators from the Ministry of Singapore (MOE) in mainstream primary and secondary schools. I observed that they also faced difficulties in providing support for Chinese language learning in their work with struggling learners in their schools. At that time, Chinese language (or 'mother tongue' language) was largely neglected in dyslexia intervention and DAS only provided support programme for English.

When I studied the Masters' programme in 2009, I decided to embark on research to investigate the difficulties our students with dyslexia face in learning Chinese language for my thesis. My MA thesis research was a comparison study between children with and without dyslexia using Chinese literacy tests which were adapted from Hong Kong and Taiwan with a contractual agreement with the authors to adapt and utilise only for the purpose of my research. The findings from the research formed a basis for DAS to provide intervention support for our students with dyslexia and training for parents and educators since 2013. However, the impact of the study was not sufficient in conceptualising dyslexia and second language learning in Singapore as the definition and assessment of dyslexia is still focused on the country's first language, English.

I believe that dyslexia is a language-based difficulty that may affect the reading development of English and Chinese differently, depending on the pedagogical factors and social factors of the

linguistic environment (Paradis et al., 2011; Thomson, 2003; Wen et al., 2017) as well as the individual's cognitive abilities and nature of language (Brunswick, 2010; Comeau et al., 1999; Landerl et al., 2022). Researchers in the field of dyslexia and bilingualism, such as McBride (2019), have argued for a global perspective on understanding dyslexia beyond just English language and McBride (2019) proposed set of cognitive constructs that can be used for assessing and training for reading development and understanding dyslexia across languages and scripts. Hence, in this EdD thesis, I hope to embark on a research study that will shed more light on how dyslexia is manifested in the reading development and cognitive-linguistic skills of English-Chinese bilingual learners in Singapore, which may be the first research of its kind as there are no similar studies conducted specifically in Singapore's bilingual context.

2. Bilingualism in Singapore's Context

In Singapore, the Chinese community makes up the majority of the country's population, which makes it the largest Chinese community outside of China (Zheng et al., 2016). Singapore is considered the only Asian country where Chinese is the predominant racial ethnicity, outside of China (王 & 余, 2007). As of the records in the Singapore Department of Statistics (2020), out of about 3.52 million Singapore citizens, the racial ethnicities of the population are 75.9% 'Chinese', 15% 'Malays', 7.5% 'Indians' and 1.6% 'Others' (includes Eurasians and other mixed races that are not classified in one of the three main ethnic groups). However, given Singapore's geographical location as a small island in the middle of Malay-dominated Asian countries, English language has been construed as a neutral medium for all ethnic groups and also for international business, science and technology (Lee, 2012; LePoer & Vreeland, 1991).

Since the country's independence, under the Republic of Singapore Independence Act of 1965, Malay, Chinese, Tamil and English are the four official languages of Singapore. Singapore adopts a bilingual policy in education where students are expected to learn at least two languages in mainstream schools (Dixon, 2005). English is learnt as a first language and the main language for educational instructions, and Chinese or Malay or Tamil is learnt as 'mother tongue' language and

according to the students' ethnic background (Lee, 2012). The term 'mother tongue' refers to the language that is specific to the individual's ethnicity and establishes the heritages, cultural values and identities of the specific ethnic community (Ng, 2014). Singaporean students who are of Chinese ethnicity learn Chinese as their 'mother tongue' language in mainstream schools. For Singaporeans of Chinese ethnicity to learn and communicate in their 'mother tongue' is likely useful for doing business with China, and most importantly, promotes traditional Chinese values (LePoer & Vreeland, 1991)., Singapore adopts the same Chinese reading and writing system as Mainland China, which is the Mandarin Chinese system, in simplified script format alongside 'hanyu pinyin' phonetic symbols. Students of Chinese ethnicity in Singapore learn English as a 'first language' and Chinese as 'mother tongue' language, two different languages that have contrasting sound-print mapping systems (i.e., alphabetic and non-alphabetic).

Learning two languages can be a challenge to some students who do not have a linguistically enriched environment that provides opportunities for them to socialise and use both languages equally in order to develop their cognitive skills and achieve bilingual proficiency (Paradis et al., 2011). Learning to read can also be a challenge for some students who have deficits in certain cognitive processing skills for word recognition and reading in either language (e.g., Goswami, 2000, 2010; McBride-Chang & Liu, 2011; Perfetti, 2011; Ziegler & Goswami, 2005). Students who are diagnosed with dyslexia have difficulties learning to read and the extent of their difficulties can be different in different languages depending on the orthographies (Ziegler et al., 2003).

The aim of this thesis is to understand how the linguistic context of Singapore, in terms of social and pedagogical aspects, differs in its influence on the reading development of bilingual learners in English and Chinese, from the other major Chinese communities where bilingual learners also learn both languages. Specifically, this thesis research focuses on understanding how dyslexia is manifested and how the cognitive-linguistic skills are associated with reading in both languages. As research on dyslexia associated with Chinese language in Singapore is limited, studies reviewed outside of Singapore are from Mainland China, Hong Kong and Taiwan, because Singapore's Chinese community

shares the same anthropology, language and cultural heritage with the three sites of China, despite the differences in the demography and economical statuses (Goh, 2017; Zheng et al., 2016). Therefore, it is important to first understand the bilingualism context of Singapore and the difference from that of Mainland China, Hong Kong and Taiwan.

Part of the different bilingual experiences in Singapore and the three major Chinese communities is the different phonetic and writing systems of Chinese languages used in these places. The chapter will also explain the different types of Chinese languages to form the fundamental understanding of how the language is learnt in different places. The chapter will then discuss the definition and identification of dyslexia in Singapore's context, with reference to those adopted internationally, and the ongoing debate on the assessment of dyslexia, which forms the rationale for the thesis' research inquiry on dyslexia and cognitive-linguistic skills of Singapore's bilingual learners in English and Chinese languages.

Singapore is also called a multiethnic or multilingual society (Bokhorst-Heng & Caleon, 2009; Hornberger & Vaish, 2009; Lim, 2009; Ng, 2014) because of the presence of the four main ethnic groups and official languages. Singaporean students are considered simultaneous bilinguals who are exposed to and learn two languages from or shortly after birth (Paradis et al., 2011). They are exposed to the four official languages which are spoken or heard in their interactions with others. The linguistic context in Singapore may be construed as one of 'additive bilingualism', wherein the learning of 'mother tongue' occurs as an additional language rather than as an ethnic native language (Ng, 2014). Others construe the context as one of 'subtractive bilingualism' wherein the increased use of English language diminishes the use of ethnic native language especially for the Indian ethnic community (Mani & Gopinathan, 1983; Vaish, 2007). According to the Singapore Department of Statistics (2015), the use of English language at home has increased across all the ethnic groups by 4.6% while the use of 'mother tongue' at home has decreased by an average of 1.15%. However, Dixon (2011) argued that Singaporeans are simultaneous bilinguals nonetheless, because most families speak one or a combination of both English and 'mother tongue' languages that is native to

their ethnicity at home. Singaporean students can start school as young as 3 years of age and they are given opportunities to learn both English and their 'mother tongue' once they start school (Ministry of Education, 2020). Following the definition by Paradis et al. (2011), Singaporean students are still considered simultaneous bilinguals and those who are of Chinese ethnicity are in fact learning two majority languages – English and Chinese.

Simultaneous bilingual or not, learners require an appropriate linguistic context to acquire both languages well. It has been reported recently that many Singaporean students struggle with the learning of and succeeding academically in 'mother tongue' in school due to lack of exposure and familiarity with the language (Low, 2021; Yong, 2019). Paradis et al. (2011) stated that bilingual learners undergo dual language development process in two forms – the language-culture connection and the language-cognition connection. Firstly, the language-culture connection is a process that links language learning with a cultural group identity and shapes the way children must live in and mediate between the two cultures. Dual language development depends on how a language is valued by the society and role models such as the parents and teachers, which in turn affects the attitudes towards the language and how the language is dealt with (Curdt-Christiansen & Sun, 2016). In Singapore's linguistic environment, language use and practices are laden with values in daily communications whereby English has instrumental functions while Chinese has cultural functions (Curdt-Christiansen, 2013, 2016; Curdt-Christiansen & Silver, 2013). Hence, many bilingual learners lack motivation to learn and use Chinese language due to the dominant use and presence of English language in the community (Ng, 2014). Secondly, the language-cognition connection is a process that considers both cognitive pre-requisites and consequences of dual language learning. Cummins (2000) theorised that literacy skills and knowledge of the first language can be transferred to the second language through a common underlying proficiency. In a local study by Dixon (2011), a multilevel regression analyses of predictor variables relating to language exposure, socioeconomic status and curriculum emphasis on language skills, found that 'mother tongue' home language and vocabulary predict English vocabulary in Singaporean pre-schoolers. In addition, the Aptitude Theory for second language learning posits

that specific cognitive connectivity such as visual and oral input processing and working memory is required for both implicit and explicit learning of the second language, and it is also dependent on the varying language contexts of the individuals (Thomson, 2003; Wen et al., 2017). This brings the discussion to the following section on how reading is developed through the language-culture and language-cognitive connection processes in the bilingual educational setting of Singapore, such as approaches in English and Chinese language learning and dyslexia support, before discussing the bilingual educational settings of Mainland China, Hong Kong and Taiwan.

3. Bilingual Educational Setting in Singapore

There are two types of mainstream primary schools for students with no or mild learning difficulties in Singapore. The Government and Government-aided primary schools follow the national mainstream education syllabus by the MOE, maintain the same educational standards and charge the same school fees (MOE, 2022). The only difference is that Government-aided schools were set up by various community organisations for their respective communities, such as ethnic clans and religious groups. International schools do not follow the national mainstream education syllabus and are typically attended by students who are not Singapore citizens or are permanent residents. For the purpose of the thesis, the research's main interest is in the bilingual learners who are local students studying in the Government and Government-aid primary schools.

Singapore's bilingual education programme teaches the English and Chinese languages largely based on two monolingual models (Curdt-Christiansen & Sun, 2016). Both English and Chinese languages are taught as means of making meaning and purpose of communication, that involves cognitive and affective engagement, and to create awareness of multilingual context and culture (MOE, 2010, 2011, 2015a). According to Bokhorst-Heng and Caleon (2009), about 40% of curriculum time in a mainstream primary school is used for English and Chinese language learning. In a mainstream primary school, students receive about 5-7 hours of instruction for Chinese language as their 'mother tongue' subject per week, depending on their school level and language ability (MOE, 2015a) whereas in secondary school, they receive only about 2-4.25 hours of instruction for Chinese

language subject per week, depending on their school level and language ability (MOE, 2011). Apart from the time spent on English language learning, English language is used in all other subjects and during most of the time in school. This means that Chinese language learning takes up a proportional range of as low as 7.3% and as high as 25.5% of instruction time, based on an average of about 27.5 curriculum hours of a typical school day in mainstream school (Craw, 2018). Based on the Chinese language learning hours in the primary school and secondary school curriculum, the amount of Chinese language use and exposure is considerably less than English language.

The MOE emphasises the teaching of both English and Chinese languages through a wholistic approach that focuses on speaking, listening, reading and writing (MOE, 2010, 2015a). According to the 2010 English Language Primary syllabus (MOE, 2010), the teaching of English Language adopted both first and second language teaching methods into a blended mix of systematic and explicit as well as contextualised and holistic approach in developing language skills, grammar and vocabulary. Phonemic awareness, phonics and early literacy skills are briefly covered at the start of Primary 1 to build the foundation for language skills, while systematic and explicit instruction of grammar is covered at lower and middle primary levels. Overall, the general emphasis in the English language subject is grammar, vocabulary, comprehension and written expression, which suggests a top-down approach in processing whole word and information using context (Andrews & Bond, 2009) for reading development of students from Primary 2 onwards.

For learning of Chinese language as a subject, students follow the 2015 Chinese language syllabus in which the core part of the syllabus are covered at all primary levels and the advanced part of the syllabus are covered based on the students' individual abilities (MOE, 2015a). The overall emphasis is similar to English language subject, except that 'hanyu pinyin' is taught at lower primary levels to focus on pronunciation of Chinese words and gradually whole Chinese character recognition gains greater focus from Primary 2 onwards to secondary school levels (MOE, 2011, 2015b). For both English and Chinese languages, the language skills such as grammar, vocabulary, comprehension and written expression are examinable in test paper format during the national examinations for primary

schools, including reading fluency as an oral examination (Singapore Examinations and Assessment Board, 2022).

The above discussion on the teaching of English and Chinese languages in mainstream primary schools provides an understanding on how students learn to read in these languages in Singapore, because pedagogical factors and social factors of the linguistic environment can influence the students' success in acquiring their first and second languages (Paradis et al., 2011). How English and Chinese are taught to students influences the cognitive functions of learning to read, as bottom-up (i.e., part to whole word) and top-down (i.e., whole word) approaches for learning are associated with implicit and explicit cognitive skills acquisition respectively (Sun & Zhang, 2004). Studies have found differences in the cognitive skills involved in top-down and bottom-up processing, where lexical retrieval and autonomy are more associated with top-down processing than bottom-up processing, and the results are similar for both alphabetic (English) (Andrews & Bond, 2009) and non-alphabetic (Chinese) languages (Li & Logan, 2008; Wang & Maurer, 2020). Hence, it is also the main research interest of this thesis to investigate how the cognitive-linguistic skills of the bilingual learners in Singapore differ in their reading development of English and Chinese from the bilingual learners in Mainland China, Hong Kong and Taiwan in relation to the differences in the bilingual education settings.

According to Paradis et al. (2011), students should be fully supported in their dual language learning development in a sustainable and enriched bilingual educational experience, but if some students face cognitive challenges, their language-cognitive and language-culture connections in acquiring first and second languages can be impeded. For example, the student-teacher ratio in a Singapore mainstream classroom is between 10 to 30 students per teacher in a primary school (Tan, 2021), so a teacher may not be able to provide more individualised attention to every student in a bigger class size which may compromise the language learning experience of a student who has cognitive disabilities or a learning difficulty such as dyslexia.

In view of the students who may struggle with dual language development, efforts from the government have been put in place such as providing greater support by introducing the Learning Support Programme (LSP) for English to Primary 1 and 2 students and Mother Tongue Support Programme (MTSP) for Chinese to Primary 3 and 4 students. The LSP focuses on building English language skills for Primary 1 and 2 students who are identified as needing additional help in learning English (MOE, 2021c). The programme also serves as a form of progress monitoring to ascertain the students' response to intervention in acquiring early literacy skills in English, such as phonological awareness, the alphabetic principle and phonics, reading accuracy and fluency (MOE, 2018). If the students' difficulties in learning English persist at Primary 3 and 4, further assessment of language and cognitive ability may be conducted by an educational or clinical psychologist to assess for dyslexia (MOE, 2018). If the students are diagnosed with dyslexia, they are further supported by the mainstream school through the School-based Dyslexia Remediation (SDR) Programme (MOE, 2021c). The MTSP is recently introduced for Primary 3 and 4 students who find the learning of Chinese challenging (MOE, 2021c). The MTSP currently only provides support for Primary 3 and 4 students who are identified as requiring more help in building their foundation of Chinese oracy and literacy skills (MOE, 2021a). Unlike the LSP, the MTSP is not part of the Response-to-Intervention (RTI) approach in identifying students with dyslexia. The current focus on supporting students with dyslexia is in English because it is the first and main official language in Singapore. More on definition and identification of dyslexia in Singapore is discussed in section 2 of this chapter.

Before moving on to the bilingual educational contexts of Mainland China, Hong Kong and Taiwan, it is important to note that there are differences in the Chinese language used in these three Chinese communities and Singapore, and it is part of the bilingual experiences in which the language is learnt. Therefore, the different types of Chinese languages will be discussed first and then followed by the bilingual educational settings between these major Chinese communities.

4. Chinese Languages in Singapore, Mainland China, Hong Kong and Taiwan

There are differences in the phonetic and writing systems of Chinese language among China, Taiwan and Hong Kong (Cheng-Lai, 2010). In both Mainland China and Taiwan, the daily use of Chinese language is pronounced in 普通话 'Putonghua' (or Mandarin), while in Hong Kong, the daily use of Chinese language is pronounced in 广东话 'Cantonese' (a dialect specific to a Chinese ethnicity). 'Putonghua' is termed as a common or standard language used by all Chinese under the People's Republic of China after the political movement to unify all ethnic groups of Chinese since the reign of the 'Qin' Dynasty (B.C. 221-206) and greatly reinforced by the National Language Unification Commission in 1932 (Lee, 2008). Whereas, 'Cantonese' is one of the dialects spoken by an ethnic group of Chinese who mainly occupy the province of Guangdong and Hong Kong, and has been a common language used by people of Hong Kong but the use of 'Putonghua' has grown since its handover in 1997 (Lai & Byram, 2003). It is important to highlight the differences between the types of Chinese language used in the literature taken from Mainland China, Hong Kong, and Taiwan, because the research that will be discussed in the 'Literature Review' chapter refer to different groups of bilingual learners who are learning Mandarin Chinese and Cantonese Chinese which are represented in different phonetic and writing systems. This means that there are also bilingual experience differences in terms of Chinese learning between the bilingual populations which are understudied in the research on cognitive-linguistic skills and dyslexia in Chinese. For clarity, the terms 'Mandarin Chinese' and 'Cantonese Chinese' will be used in discussions that involve 'Putonghua' and 'Cantonese' as spoken languages respectively.

Mandarin Chinese is a four-tone system that is commonly spoken in Singapore, Mainland China and Taiwan, while Cantonese Chinese is a nine-tone system that is commonly spoken in Hong Kong (Chu & Taft, 2011). In addition, the pronunciation of Chinese language is taught in Mainland China with an alphabetic morpho-syllabic system called 'hanyu pinyin' and taught in Taiwan with a quasi-syllabic system called 'zhuyin fuhao', whereas it is taught in Hong Kong without any auxiliary

phonetic system (Wang & Tsai, 2011). Table 1 shows a sample of the ‘hanyu pinyin’ and ‘zhuyin fuhao’ with the same corresponding sound.

Table 1

Sample of ‘hanyu pinyin’ and ‘zhuyin fuhao’ with the same corresponding sound

Hanyu Pinyin	Zhuyin Fuhao	Corresponding sound
b	ㄅ	/bə/
m	ㄇ	/mə/
l	ㄌ	/lə/
wu	ㄨ	/wu/
a	ㄚ	/a/
ao	ㄠ	/ao/
ang	ㄤ	/ang/

For writing, the Chinese language is taught in traditional script in both Taiwan and Hong Kong whereas it is taught in simplified script in Mainland China and Singapore. The traditional and simplified scripts of Chinese characters can differ orthographically and by the number of strokes, which are lines that represent the Chinese character in combinations and patterns (Han, 2012). For example, both the Chinese words ‘大’ and ‘小’ have 3 strokes that are of different kinds. Hence, the written Chinese translation of the term ‘dyslexia’ in traditional script is ‘閱讀障礙’ which has more strokes than ‘閱讀障礙’ in simplified script. To summarise the pronunciation and writing systems of Chinese languages, Table 2 is presented below.

Table 2

Summary of the pronunciation and writing systems of Chinese languages used in Singapore, Mainland China, Hong Kong and Taiwan

Place	Spoken	Pronunciation	Writing System
Singapore	Mandarin Chinese	Hanyu Pinyin	Simplified Script
Mainland China	Mandarin Chinese	Hanyu Pinyin	Simplified Script
Hong Kong	Cantonese Chinese	Not available	Traditional Script
Taiwan	Mandarin Chinese	Zhuyin Fuhao	Traditional Script

Now that the different types of Chinese language used in the three major Chinese communities and Singapore have been explained, the bilingual educational settings in these three sites are discussed next.

5. Bilingual Educational Setting in Mainland China, Hong Kong and Taiwan

Schools in Mainland China use Mandarin Chinese as the medium for instruction and English is learnt as a second language, although use of English language is increasingly accorded much importance given the economic benefits and social prestige (Hu, 2005). English language has become a compulsory language subject from Primary Three in Mainland China since 2003 but it is dependent on the various schools' decision on how and when the English lessons are implemented (Qi, 2016). The teaching and learning of English language is task-based, teacher-centred and examination-driven, which mostly result in students' poor motivation in learning the language (Qi, 2016; Wang & Gao, 2008). Through primary and secondary school, there is a greater emphasis on reading and understanding of English texts than on writing (Hu & Baumann, 2014) and using English largely for China's economic purpose (Wang & Gao, 2008). As such, it may stand in contrast to Singapore's use of English. The English language curriculum in Mainland China aims to promote students' language use ability through listening, speaking, reading and writing, but without the use of phonics instruction

(Wang & Lam, 2009), indicating that a whole language approach is adopted. Students are given relatively fewer curriculum hours of learning English as compared to Singapore, with only three 40-minute lessons per week which takes up about 20% of total curriculum hours (Qi, 2016). As for identifying and assessing students with dyslexia, there is limited knowledge of any formal assessment and educational support in schools due to the lack of uniform assessment tools and methods adopted in different parts of Mainland China (Lin et al., 2020).

Hong Kong's education system adopted the biliterate trilingual policy since 1997, which means students are taught in two written languages of Modern Standard Chinese and English, and three spoken languages of Cantonese Chinese, 'Putonghua' or Mandarin Chinese, and English (Poon, 2004). There is a mix of language use in education due to the existence of Chinese-medium schools and English-medium schools (Ng et al., 2017). The compulsory Chinese ('Putonghua' or Mandarin Chinese) medium instruction has been implemented in Chinese-medium schools, while English-medium schools continue to use English as the medium for instruction (Poon, 2004). Mandarin Chinese is a compulsory language subject learnt in all primary and secondary schools, but Cantonese Chinese is used as the medium of instruction for teaching content subjects in Chinese-medium primary and secondary schools, and English is taught as a second language (Wang & Kirkpatrick, 2015). Spoken Cantonese Chinese and traditional script are still widely used by locals in Hong Kong whereas English and Mandarin Chinese are mainly taught in schools only (Ng et al., 2017). In a survey by Wang and Kirkpatrick (2015), schools have varied implementation of the biliterate trilingual policy in teaching the three languages because of the lack of government's guidelines, and hence students from different schools can have varied levels of language proficiency. According to Hong Kong's local curriculum documents on English Language Education, teaching and learning of English language adopts an integrated whole language and phonics approach from primary to secondary school, in which students are introduced phonics skills to apply in reading and spelling of words and taught strategies to pronounce and spell unfamiliar words (The Education Bureau, 2017). This differs greatly from Singapore's English language curriculum. However, it is unknown how the Chinese language

(Cantonese and/or Mandarin Chinese and their respective written forms) are taught in the local curriculum.

Like Singapore, the assessment and support for children with dyslexia is available in Hong Kong. The schools also adopt a response-to-intervention approach to identify and support students who are suspected with learning difficulties (The Education Bureau, 2015). Students are identified with the normed Hong Kong Behaviour Checklist of Specific Learning Difficulties in Reading and Writing at Primary 1 (Chan et al., 2012) and then provided with the tiered intervention model in Chinese language by the schools (The Education Bureau, 2015). Formal diagnosis of dyslexia can be done through the use of Hong Kong population normed assessments which are conducted in Cantonese Chinese, namely The Hong Kong Test of Specific Learning Difficulties in Reading and Writing for Primary School Students (Third Edition) [HKT-P(III)] and The Hong Kong Test of Specific Learning Difficulties in Reading and Writing for Junior Secondary School Students (Second Edition) [HKT-JS(II)] (HK Specific Learning Difficulties Research Team, 2010).

In contrast to Mainland China and Hong Kong, Taiwan became a Mandarin Chinese-speaking population from 1946 after its previous occupation by Japan between 1895 and 1945 (Oladejo, 2006). English is the other compulsory foreign language, besides Mandarin which is an official and compulsory language, to learn in public schools (Oladejo, 2006). Since 2005, students in elementary schools have been expected to learn English from Grade 3 onwards (Chun, 2006). However, the current linguistic situation in Taiwan is mainly 'monolingual' due to some issues arising from elementary schools' limitations in designing their own school-based curriculum to fit the bilingual policy (Chun, 2006), and implementing a new approach in teaching English in English in schools without compromising students' exposure to language and cultural diversity (Graham et al., 2021). Because the elementary schools in Taiwan have their own school-based curriculum and language policy, it is unclear what general approach is adopted in teaching of English and Mandarin Chinese in schools.

Like Singapore and Hong Kong, there are diagnostic assessments and interventions for dyslexia in Taiwan. Dyslexia is typically diagnosed by two senior professors in Special Education, through use of interviews and the child's performance on the locally developed standardised tests that assess Chinese character reading and fluency, reading comprehension and phonological awareness, as well as the translated version of Wechsler Intelligence Scale for Children—3rd Edition (WISC-III), which has been standardized for the Taiwanese population (Lee et al., 2015).

Considering the bilingual educational settings of Mainland China, Hong Kong and Taiwan, their linguistic context should be considered as additive bilingualism, following the definition by Paradis et al. (2011), whereby English language is learned as an additional language after 3 years of age (i.e., in primary school). In terms of the educational, political, and social aspects, Chinese language is learnt as a second language (L2) in Singapore, whereas Chinese language is learnt as first language (L1) in Mainland China, Hong Kong and Taiwan. The term "English-Chinese" is used to indicate these bilingual learners' first language as English and second language as Mandarin Chinese and the term "Chinese-English" is used to indicate the bilingual learners' first language as Chinese (which can be Mandarin or Cantonese) and second language as English. As a bilingual community, Singapore, Hong Kong, and Taiwan adopt a similar method of assessment and support for dyslexia which is based on their first language only. In Singapore, it is English, whereas in Hong Kong and Taiwan, it is Cantonese Chinese and Mandarin Chinese respectively in traditional script. This brings the discussion to the next focus of the thesis which is on the definition and identification of dyslexia.

6. Definition and Identification of Dyslexia in Singapore

This section discusses the definition and identification of dyslexia adopted by established organisations internationally, such as the International Dyslexia Association (IDA), the British Dyslexia Association (BDA) and DAS. As the thesis' research interest is in Singapore's English-Chinese bilingual population, definition and identification of dyslexia adopted in the major Chinese communities is also explored. This section will also discuss the ongoing debate on the definition and assessment of dyslexia, as well as the confusing focus on how dyslexia is currently defined and identified in Singapore. It is

hoped that the thesis research can subsequently shed some light on what the definition and identification of dyslexia should be adopted for a bilingual population like Singapore's.

Dyslexia is a language-based difficulty that affects an individual's ability to read, spell and write. Lyon, Shaywitz, and Shaywitz, (2003, p. 2) defined dyslexia as "a specific learning disability that is neurological in origin" and emphasised the deficit in processing the phonological components of language that caused unexpected poor performance in accurate and/or fluent reading and spelling, rather than cognitive abilities and instruction. Lyon et al. (2003) also recognised reading comprehension as secondary difficulty due to decoding problems associated with dyslexia. The International Dyslexia Association (IDA) (2020a) in the United States also adopted the same definition by its Board of Directors on 12 November 2002. The British Dyslexia Association (BDA) (2020a) in the United Kingdom, on the other hand, adopted the Rose's (2009) definition of dyslexia that difficulties in phonological awareness, verbal memory and verbal processing speed, regardless of intellectual abilities, are the characteristic features that affect accurate and fluent word reading and spelling skills. Rose (2009, p. 10) highlighted that "the severity and persistence of dyslexic difficulties can be gained by examining how the individual responds or has responded to well-founded intervention" and also acknowledged that other difficulties such as aspects of language, motor co-ordination, mental calculation, concentration and personal organisation, co-occur with but are not markers of dyslexia.

In Singapore, the Dyslexia Association of Singapore (DAS) and the MOE have a close working relationship in supporting students with dyslexia, whereby MOE funds and provides students the access to the Main Literacy Programme at the DAS (DAS, 2020b; MOE, 2021d). Both DAS and MOE adopt the definition of dyslexia by the US Department of Education (2006) as a type of developmental specific learning difficulty due to deficits in language learning and cognition that affect accuracy and fluency in word reading and spelling (DAS, 2019; MOE, 2018). In addition, difficulties in phonological awareness, verbal memory and processing speed are acknowledged as characteristic features of dyslexia as well as other difficulties that co-occur with dyslexia as highlighted in the Rose Report (2009). According to both DAS and MOE, an effective and appropriate literacy intervention should support

learners with dyslexia in the five components of language, namely phonemic awareness, phonics, fluency, vocabulary and comprehension, based on the report on the scientific research literature on reading instructions in English by the National Reading Panel (2000).

It could be argued that the definition of dyslexia adopted in Singapore is that it not only uses a definition based on monolingual populations for a bilingual population, it also contradicts with how dyslexia is identified, because there are two recognised approaches for the diagnosis of dyslexia, namely the RTI approach and the comprehensive standardised psycho-educational assessments (MOE, 2018). The RTI approach is used in mainstream primary schools where progress monitoring data is collected systematically, and additional literacy intervention is provided to students who are underachieving in literacy. If a student's literacy difficulties persist after the first two years of intervention (i.e., LSP), further assessments on language and cognitive ability may be conducted to diagnose the student with dyslexia. The comprehensive standardised psycho-educational assessment approach is mainly used in professional organisations outside of mainstream primary schools, such as the DAS, to ascertain students' areas of strengths and weaknesses through cognitive, literacy and phonological assessments, with consideration for students' background and instruction/intervention received. According to Elliott (2020), students who are identified through these two approaches can be very different groups of children with dyslexia.

The confusing diagnosis of dyslexia here is due to the different conceptions of how dyslexia is viewed as a condition clinically assessed by cognitive measures and also as a reading disability that is persistent and treatment-resistant to high-quality intervention (Elliott, 2020; Elliott & Grigorenko, 2014; Gibbs & Elliott, 2020). Students who have undergone the comprehensive standardised psycho-educational assessments for dyslexia may not have received any appropriate and sufficient high-quality intervention prior to warrant their persistent and treatment-resistant difficulties. The RTI model of identification assesses for dyslexia on the bases of an individual's progress over time (Grigorenko et al., 2020), in response to a tailored intervention with tiers of increasing intensity and individualised attention (Gibbs & Elliott, 2020). However, the students with dyslexia identified through

the RTI approach for the first two years in mainstream primary schools may also not have undergone sufficient and stringent progress monitoring through multiple tiers of tailored intervention with increasing intensity. Elliot et al. (2020; 2014; 2020) have argued that the RTI process of ongoing assessments and interventions for at least 3 tiers may take more years to operate effectively and ensure that no struggling learners are missed, citing practices from Lovett et al. (2017) and Moats (2017). Hence, it makes the understanding of dyslexia, whether it is a clinically assessed condition or a treatment-resistant reading disability, quite unclear in Singapore.

Moreover, there has been ongoing debate on the identification of dyslexia (Elliott & Grigorenko, 2014) between the discrepancy model between cognitive ability (i.e. intelligence) and attainment scores in reading and spelling (Thomson, 2003; Tunmer & Greaney, 2010) and the symptomatic model in considering the 'classic' cases of dyslexia and other cases that encompass atypical literacy symptoms of dyslexia and possibly co-occur with other difficulties (Cooke, 2001; Tønnessen, 1997). Both schools of thought contribute to the identification of dyslexia which is generally undertaken with formal psychological assessments, that measure cognitive and literacy abilities, by qualified assessors recognised by the country in which dyslexia is diagnosed. The identification of dyslexia gradually evolved over the years as many researchers (e.g. Elliott & Gibbs, 2008; Poole, 2003; Smythe & Everatt, 2002) debate about how dyslexia should be assessed more comprehensively and defined more broadly. Dyslexia is now explained in the Diagnostic Statistical Manual 5 (DSM-V) by the American Psychiatric Association (2013) as a specific learning disorder in the areas of reading, spelling and writing, and diagnosis can be made by identifying whether individuals are unable to perform academically at a level that is appropriate to their intelligence and age. The difficulties in reading, spelling and writing should be persistent for at least 6 months despite the exposure to and provision of help at home and school. Under the overarching category of Specific Learning Disorder, dyslexia is identified under two literacy-related domains in which an individual is identified to have impairment in – (1) for reading, whereby word reading accuracy, fluency and reading comprehension are impaired, and (2) for written expression, whereby spelling, grammar, punctuation

and organisation are impaired (Elliott & Grigorenko, 2014). According to the American Psychiatric Association (2013), the specific learning disorder is diagnosed through a clinical review of the individual's persistent difficulties in reading, writing, arithmetic or mathematical reasoning skills based on his/her developmental, medical, educational, psychological, and family history, and assessments.

Elliott and Grigorenko (2014) argued about the problematic focus on the diagnosis of dyslexia and oversight of adopting a more pedagogic approach in supporting difficulties related to dyslexia. That is, whether the diagnosis of dyslexia would lead to an effective intervention to cater to remediate difficulties in learning to read for such individuals, and whether there are individuals who are left out due to the lack of socioeconomic capacity to access dyslexia assessment and support services. Gibbs and Elliott (2020) have advocated for the use of RTI approach that engages 'multitiered systems of support' (MTSS) for a more rigorous process of assessment and interventions to take place as soon as the individual's difficulties emerge, so that the "wait-to-fail" situation can be avoided, due to the traditional approach in which individuals with dyslexia may not be identified early enough until they have been exposed to a few years of reading instructions to show persistent difficulties (Reynolds & Shaywitz, 2009). This approach looks within the individual in terms of age-based expectations and failure/success in responding to appropriate instruction (Snowling, 2013). The design of the RTI approach is helpful in identifying individuals who fail to respond to instruction and potentially at risk of dyslexia. It also eliminates that problem of false positives when identification is undertaken too early when the individual is very young or lacks sufficient exposure to appropriate literacy intervention (Compton et al., 2010).

The established organisational advocates for dyslexia in Singapore, UK and US have put in effort to reconcile the different models of identification and remove the use of intelligence testing in the formal assessment process. According to BDA's website (2020b), the assessment of dyslexia in the UK provides a profile of strengths and weaknesses in underlying cognitive abilities of the individual, such as reading, writing and spelling, handwriting and fine motor skills, as well as other underlying learning skills: namely phonological awareness, speed of processing and memory, speech and

language and auditory processing. In addition, other background information is gathered and no intelligence testing is mentioned in the assessment details. According to the IDA's website (2020b), the identification of dyslexia in the US first takes on a symptomatic model through the RTI approach for at-risk students who are assessed to have poor literacy skills stemming from weakness in phonological processing and rapid naming. Subsequently, if a student continues to struggle with literacy and does not respond well to additional high-quality instruction, a formal clinical assessment of the student's cognitive profile will be conducted to determine if the student has dyslexia.

In Singapore, for both comprehensive assessment and RTI approaches, measures of intelligence are not recommended and are only necessary if intellectual disability is suspected (MOE, 2018). However, given that the students are bilingual learners in Singapore, dyslexia is diagnosed through use of formal psychological assessment which is conducted in first language – English (Brookes et al., 2011). That is, only literacy difficulties in English language are screened or assessed for dyslexia in our bilingual learners, without considering if they experience difficulties in their other language (e.g., Chinese). Following the definition adopted by English populations that are primarily monolingual (i.e., the UK and the US) compromises the definition and identification of dyslexia in Singapore's bilingual population, because dyslexia is a language-based difficulty and may manifest itself in either or both languages differently, depending on the individual's cognitive processes and nature of language (Brunswick, 2010; Comeau et al., 1999).

The definition of dyslexia adopted in the major Chinese communities, especially Mainland China and Taiwan, remains unclear, although locally developed standardised intelligence, cognitive and reading assessments have been used to assess for dyslexia (Li & Long, 2019). A definition of dyslexia can be found in Hong Kong's Education Bureau (2021) website which states that students with dyslexia generally have poorer literacy skills and weaker cognitive abilities in relation to reading and writing, such as reading, spelling and dictating words accurately and fluently, and the difficulties are severe and persistent, despite having normal intelligence and formal learning experiences. Frequent omission and addition of strokes when copying Chinese characters is mentioned as one of the

symptoms of dyslexia. The assessment for dyslexia in Hong Kong also uses the same method as Mainland China and Taiwan, which is the intelligence-achievement discrepancy model. It is also noted that, like Singapore, the formal assessment for dyslexia is conducted in their first language.

It is my research interest to investigate the contributing factors to reading development in English and Chinese by assessing the various cognitive-linguistic skills in both languages in relation to dyslexia, so that these cognitive-linguistic constructs can be used for assessing the strengths and weaknesses of at-risk learners for the purpose of tailoring appropriate and effective intervention in future. This aligns with the suggestion of Gibbs and Elliott (2020) in considering the identification of dyslexia with an effective intervention catered to remediate difficulties of dyslexia in mind.

7. Dyslexia and Cognitive-linguistic Skills of English-Chinese Bilingual Learners in Singapore

Although the main focus in Singapore is on supporting bilingual learners with dyslexia in English, there exist a very small number of local studies that took interest in supporting these learners in Chinese (e.g., Lee & Poon, 2014; Shen et al., 2014) and expanding provision for these learners in other areas beyond the main literacy support in English (e.g., Landulfo et al., 2015; Lim & Fong, 2014). The DAS acknowledges the difficulties students with dyslexia face in learning Chinese and offers the Chinese Programme as part of its Specialised Educational Services that focuses on building basic and higher-order literacy skills of Chinese language (DAS, 2020a). However, local students diagnosed with dyslexia only receive subsidies from MOE to attend the main literacy programme in English but not the Chinese programme. The MTSP recently offered by MOE in mainstream primary schools is for students who struggle in Chinese language subject in general but not specifically for those with dyslexia.

McBride (2019) highlighted that the most realistic way of understanding dyslexia is to have a clear profile of the cognitive-linguistic skills that underlie the individual's difficulties in learning to read and write. Many researchers have not only studied bilingual individuals' cognitive abilities based on biological or neurological factors (e.g., Hu et al., 2010; Meng et al., 2016; You et al., 2011), but also the dual language or bilingual environmental factors (e.g., Bialystok & Viswanathan, 2009; Hoff et al.,

2012). There is a considerable amount of research conducted on Chinese-English bilingual learners in Mainland China, Hong Kong and Taiwan (e.g., Chung & Lam, 2020; Ding et al., 2013; McBride-Chang et al., 2013; McBride-Chang & Kail, 2002; Tong & McBride-Chang, 2009), but the differences in the bilingual context between the three sites of China and Singapore have to be considered. It is of my research interest to investigate how dyslexia diagnosed in English impacts on reading and the cognitive-linguistic skills of English-Chinese bilingual learners in both languages in Singapore's context. Relevant literature will be reviewed using Frith's causal model framework that links empirical evidence between four domains, namely the biological, cognitive, behavioural and environmental 'risk' and 'protective' factors to understand the impact of dyslexia within the individual (Frith, 1995, 1999, 2002; Morton & Frith, 1995). Frith's causal model argues that low achieving learners struggle with learning of either language may be due to environmental factors (i.e., home language or second language background, nature of languages or bilingual education) or biological/cognitive factors (i.e., dyslexia or other cognitive-linguistic deficits).

According to Frith (Frith, 1999, 2002), the hypothesised deficits at the cognitive level due to biological origins serve as testable predictions for the biological origin and behavioural signs of dyslexia with written language, and a satisfactory definition of dyslexia can be achieved when the interaction of the biological, cognitive and behavioural factors with the environmental factors is considered together. Moreover, the interactive causal framework was developed with the viewpoint that dyslexia has a universal neurocognitive basis regardless of cultural diversity and the differences in reading performance of dyslexic individuals are due to the difference in orthographies of different languages across countries (Paulesu et al., 2001). Therefore, relevant literature will be reviewed in the next chapter using the structure of Frith's causal model framework (Frith, 1995, 1999, 2002; Morton & Frith, 1995). The research theoretical framework, questions and hypotheses will then be constructed for this thesis.

As there are no similar studies conducted specifically in Singapore's context where first language is English and second language is Chinese, the thesis research will serve as an initial step to

understand the cognitive-linguistic skills, as proposed by McBride (2019), that are important for English-Chinese bilingual learners' reading development in Singapore, and point to a future research direction in understanding how dyslexia can affect reading development in both languages for English-Chinese bilinguals.

LITERATURE REVIEW

1. Introduction

This chapter discusses the literature using the structure of Frith's causal model's four domains in the following sequence: (1) Environmental, (2) Biological, (3) Cognitive, and (4) Behavioural factors. The section on environmental factors is first discussed on the nature of both English and Chinese languages, reading instructions and the dual language theory, so that it sets the foundational understanding about the different language structures of English and Chinese. Subsequently, the section on biological factors discusses fMRI studies that compare the similarities and differences in brain regions involved in reading English and Chinese words. These brain-based evidence are associated with reading developmental stages and reading models of English and Chinese languages, as well as the major theories of dyslexia which are discussed in the section on cognitive factors. Finally, the section on behavioural factors discusses the findings from comparative studies on English and Chinese linguistic skills that reflect the underlying cognitive processes of bilingual learners with and without dyslexia.

2. Frith's Causal Model Framework

2.1 The Environmental Domain

According to the causal model framework (Frith, 1995, 1999, 2002; Morton & Frith, 1995), types of reading instructions and linguistic environment (i.e., cultural attitudes and socio-economic factors) play an important role in influencing reading development. They can alleviate or aggravate an individual's cognitive abilities that stem from biological basis. An individual's difficulties in language acquisition can be manifested in different ways, depending on the individual's cognitive processes and the nature of language that the individual is learning (Brunswick, 2010; Comeau et al., 1999). This section will first explain the nature of both English and Chinese languages, and the literature on effectiveness of reading instructions for both languages, and then discuss the biliteracy context that affect dual language development.

According to Wang and Tsai (2011), there are two major writing traditions for languages – the alphabetic tradition and the logosyllabic tradition. Some researchers (e.g., Katz & Frost, 1992; Sampson, 1994; Unger, 2003) attempted to classify alphabetic and non-alphabetic languages on a continuum of writing systems from alphabetic to logographic in nature to explain the orthographic depth of different languages based on the transparency of the grapheme-phoneme mapping (Katz & Frost, 1992). Figure 1 below is an example of where English and Chinese languages lie in the continuum relative to other languages, according to Katz and Frost (1992), Sampson (1994) and Unger (2003).

Figure 1

Possible orthographic depth of languages on the continuum from alphabetic to logographic



It is important to understand that English and Chinese languages have contrasting sound-print mapping systems, as orthographic transparency and morphological syllabic complexity of languages may have different impact on reading development and dyslexia (Borleffs et al., 2019; Brunswick, 2010; Landerl et al., 2022). English language is alphabetic but less transparent than other alphabetic languages such as Finnish and Spanish, whereas Chinese language as non-alphabetic and more logographic in nature. The Chinese language is based on the logosyllabic tradition in which Chinese characters, or sinograms, presents both semantic and phonetic information simultaneously but not very precisely (Wang & Tsai, 2011). It is claimed to be one of the most phonologically opaque writing systems in the world (Kim & Shin, 2018), because of its lack of graphemes to represent the smallest

unit of sound. Moreover, the Chinese language is a major non-alphabetic language that is spoken in different dialects within the Chinese population that maps to similar scripts but different phonetic representations (Chung & Ho, 2010b). It is also a tonal language that contains single or multiple syllables in a single or multiple morphemic character in a morphographic script (Yin & Weekes, 2004).

2.1.1 Nature of English Language

The English language is an alphabetic language and has 26 letters that map (individually or in combination) up to 44 sounds or phonemes (Linde, 2020). Readers of the English language need to establish an understanding of grapheme-phoneme correspondences (GPC) as they read words and form meaning at the same time. To read or spell a word “cat”, the reader needs to understand and apply the sounds that the consonants and vowels are matched (e.g., /k/-/a/-/t/ for “cat”). Hence, alphabetic instruction with phonemic awareness will be helpful for English word reading development (Foorman et al., 2003). The GPC is important for reading of English words because the language has a complex relationship between 5 vowel letters that map to 14 vowel sounds and the phonetic values change according to their morphology (Wang & Tsai, 2011). Table 3 shows a summary of vowel sounds mapping in English words according to the vowel positions and morphology.

Table 3

Sample of vowel sounds mapping in English words based on vowel positions and morphology

Front	Central	Back	Diphthong	Morphology
in	line	hi	tie	linear
add	chaste		say/said	chastity
elf	shed	she	sheep	shepherd

Readers not only require phonological processing but also orthographic knowledge to learn to read (Goswami et al., 1998). This is because about 86% of English words can be spelled accurately by

letter-sound correspondence and about 14% of English words do not follow the letter-sound regularity (Moats & Tolman, 2013). Some examples of irregular words are “yacht” which is pronounced as “yot” and “have” which does not rhyme with “cave”. In order for readers to process the regular and irregular words in English language, orthographic learning of words is important in reading acquisition (Badian, 2001; Cunningham et al., 2001, 2002; Wang et al., 2013). Lee (2008) adds that the ease of processing phonologically regular words depends on the consistency with which the same letter patterns are pronounced the same in different words as well. Words that contain “-ake” letter pattern, such as “make”, “lake” and “bake”, are more regular and consistent. In contrast, words that contain “-ave” letter pattern, such as “cave”, “wave” and “have”, are considered inconsistent despite there being letter-sound regularity in the words ‘cave’ and ‘wave’. There are also words that contain the ‘-alm’ letter pattern that is irregular but consistent, such as ‘balm’, ‘calm’, ‘palm’, and ‘psalm’. On the other hand, words that contain the ‘-ove’ letter pattern such as ‘move’, ‘prove’, ‘love’ and ‘dove’, are considered irregular and inconsistent, with an exception for a regular but inconsistent variant (e.g., cove).

It has been argued that contextual cues also play an important role in facilitating orthographic knowledge of words and building vocabulary (Wang et al., 2011). The English language also contains many homophones which are words that are pronounced the same but have different meanings. Homophones can be heterographic (e.g., ‘sail’ and ‘sale’) or homographic (e.g. ‘bear’ which can mean to endure or an animal). Homophones constitute about 7.4% (Rodd et al., 2002) or as many as over 3,000 words (Kreuz, 1987) in written English. According to Trott and Bergen (2020), homophones naturally emerge as a consequential feature of any human language that is formed. Therefore, an English language learners not only requires phonological processing skill, but also orthographic and semantic knowledge to read and spell words (Biedermann et al., 2002; White & Abrams, 2004).

Another distinct linguistic characteristic of English language is morphology which plays an important role in word formation (Foorman et al., 2003). Morphemes represent the small units of meaning in English words (Embick, 2015). The morphological features of English words are compound

words, such as “wheelchair” and “rainbow”, and derivational words with prefixes and/or suffixes such as “establish” as the root word, and forms such as “anti-establishment” with a prefix and a suffix. Morphological awareness is an important lexical processing for learning, understanding and production of morphologically complex English words (Marslen-Wilson et al., 1994). It entails decoding and interpreting of morphologically complex words by integrating knowledge of sound, meaning and word formation to process units of meaning called morphemes (Kuo & Anderson, 2006). Different facets of morphological awareness, such as morphological structure awareness and morpheme identification, contribute to vocabulary knowledge by distinguishing different word meanings in homophones, and these skills are distinct from phonological processing of GPCs (McBride-Chang et al., 2005). Morphology also plays an important role in reading comprehension, as it represents a three-way interaction between phonology, semantics and orthography in the lexical representation of English words (Kirby et al., 2012; Kuo & Anderson, 2006; Tong et al., 2011).

2.1.2 Reading Instruction in English

There has been considerable debate for the past decades over two competing approaches to reading instruction in English, which are whole language and systematic phonics, because it has implications on reading development in at-risk students (Hempenstall, 2005, 2005) and whether reading is a natural process or to be nurtured (Elliott & Grigorenko, 2014). Whole language instruction assumes that reading develops through interaction with texts in a top-down approach focusing on vocabulary, grammar, and comprehension (Brooks & Brooks, 2005) and the instruction supplements the limitations that phonics instruction has (Krashen, 2002). Systematic phonics instruction focuses on understanding the relationship between phonemes and graphemes (Brooks & Brooks, 2005) and is especially important for beginning and at-risk readers in becoming more skilful in reading (Wyse & Goswami, 2008). It is claimed that dyslexic children’s difficulty in decoding English words accurately can be alleviated if phonics and phonemic instructions are systematically and explicitly introduced (Defior et al., 2002; Landerl, 2000) and through an integrated training of phonics before sight words (McArthur et al., 2015).

Brooks and Brooks (2005) highlighted that phonics training exercise must be done through contextualized teaching and not be taught in isolation. This claim has been supported by earlier research where intervention for phonological skills integrated with teaching of reading had long-term effectiveness on literacy skills of young struggling readers (Hatcher et al., 1994), and especially with the inclusion of explicit phonemic awareness and letter-sound training to phonic reading instruction (Hatcher et al., 2004). Adams (1994) also proposed that an integration of both phonics and whole language approaches could be used in teaching reading and emphasized the importance of meaning appreciation and orthographic knowledge of words in developing reading skills and fluency. This idea of integration continued to be supported by The National Reading Panel (2000), which concluded the five key areas of research that are important for effective English reading instruction, namely alphabets, fluency, comprehension, teacher education and technology. In the same research, systematic phonics instruction emerged to be the most effective for early reading progress. A teacher survey by Mesmer and Griffith (2005) also suggested that systematic and explicit phonics instruction should be done in combination with other approaches through skilful teaching so as to help students engage better with texts that they decipher.

Research has found that explicit phonics instruction on direct mapping of taught GPCs in text reading integrated within the same reading intervention was effective in improving literacy skills, including reading, spelling and sentence comprehension, of at-risk readers whose first language is English (L1) (Savage, Georgiou, et al., 2018) and whose second language is English (L2) (Yeung & Savage, 2020). An interaction between phonological, orthographic, and morphological processes is likely required to build literacy skills in English. Thus, it has been advocated that a comprehensive approach to English reading intervention should integrate explicit phonics teaching and differentiated instruction to cater to individual learners' needs (Fletcher et al., 2021).

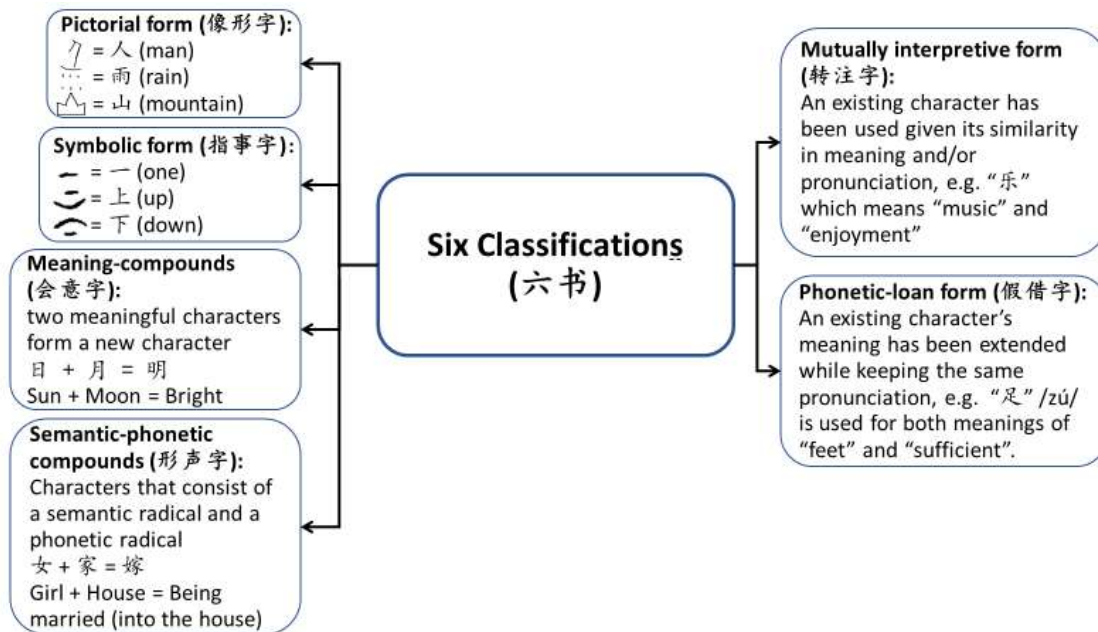
2.1.3 Nature of Chinese Language

As my research interest is in the Chinese language used in Singapore's context, the discussion on the nature of Chinese language refers to the Mandarin Chinese or 'Putonghua' that uses 'hanyu

pinyin' as the phonetic system and simplified script as the writing system. The characters in the Chinese language can be classified into six kinds (Han, 2012; Lee, 2008; McNaughton & Li, 1999) as illustrated Figure 2.

Figure 2

Six classifications of Chinese characters (六书)



The pictorial form of Chinese characters is simply derived from objects, such as “人” which looks like a stick drawing of “man”. There are also Chinese characters in symbolic forms, such as “一、二、三” for “one, two, three”. The other four classification of characters are meaning-compounds such as “日” [sun] + “月” [moon] = “明” [bright], phonetic-loans such as “足” /zú/ which has both meanings of “feet” and “sufficient”, semantic-phonetic-compounds such as “女” [girl] + “家” [house] = “嫁” [being married], and mutually-interpretive forms such as “乐” which means “music” and “enjoyment”.

The semantic-phonetic compounds are most common type of Chinese characters in the language, especially those with semantic radicals and phonetic radicals in a horizontal-type structure

(Bai & Schreuder, 2011). Semantic radicals can be a single character or part of a character that gives meaning to a word. For example, “木” /mù/ means “wood” as a single character and it can be in another character “树” /shù/ which means “tree” and “林” /lín/ which means “forest”, and both words are related to “wood”. Phonetic radicals can also exist as a single character or part of a character that gives phonetic cues. For example, a single character “马” /mǎ/ which means “horse” can exist in other characters like “妈” /mā/ which means “mother” and “码” /mǎ/ which means “yard” that gives similar sounds to its original. However, phonetic radicals may not always provide similar sound cues to all Chinese characters, as there exists phonologically regular, semi-regular and irregular characters (Bai & Schreuder, 2011). Chinese characters that contain the phonetic radical which gives the exact same pronunciation as when it is a single character, is called a regular character. For example, the single character “里” /lǐ/ which means “inside” can exist as a phonetic radical in another character “理” /lǐ/ which means “reason” and gives it the same phonology. When this phonetic radical exists in another character “狸” /lí/ which means “raccoon”, the character is called a semi-regular character because its phonology is different in terms of tone. When the same phonetic radical exists in another character “埋” /mái/ which means “bury”, the character has a totally different phonology and is called an irregular character.

Besides Bai and Schreuder’s (2011) phonological regularity classification, Lee (2008) adds that correct pronunciation of Chinese characters does not only depend on the phonology of its phonetic radical but also the consistency of the pronunciation of other characters that contain the same phonetic radical. More than 85% of the Chinese characters compose of phonetic radicals that specify the pronunciation of the whole character but only 39% of these characters are pronounced the same as their phonetic radicals (Lee, 2008). For example, the phonetic radical “里” /lǐ/ is considered regular and consistent in characters like “理” /lǐ/ and “狸” /lí/, but it is considered less consistent if there are characters like “埋” /mái/ or more that do not follow the same/similar pronunciation. A character that can also be a radical like “卖” /mài/ is considered irregular and inconsistent as the characters that

contain it do not follow the same/similar pronunciation, such as “赎” /shú/ [redemption], “续” /xù/ [continue] and “读” /dú/ [read]. Hence, the phonetic radicals of Chinese characters can be factorially classified as regular or irregular with high or low consistency, showing the limitations in the role of phonology in relation to consistency in Chinese characters, in some regards, similar to the letter patterns in English words (Zhou & Perfetti, 2021).

Using the previous example character “埋”, although the supposed phonetic radical “里” does not provide the same/similar pronunciation for the character, the radicals in this character provide semantic cues instead, whereby “土” (original single character is “土”) means “soil” and “里” means “inside” which makes up the meaning of burying to this character “埋”. The former two characters also have their semantic meanings to their radical, not only phonetic cues. The regular character “理” has “王” (original single character is “王”) which means “royal” and with “里” which means “inside”, it makes up the meaning of “reason/rule” stating that rules are passed down from the royal. On the other hand, the semi-regular character “狸” has “犴” which means “animal” but “里” provides only the phonetic cue to its pronunciation. The semantic radical “犴” is one of the character elements that cannot stand alone as a character but function as a semantic radical and evolves from a pictographic form of a bestial position of an animal.

The Chinese language is also a tonal language, so a change of intonation can change the character altogether and often to a character that is totally unrelated to the original (Liang & van Heuven, 2007). For example, “八”, “拔”, “把”, “爸” are all pronounced as /ba/ but in four different tones respectively, which are “ˉ” (tone 1: level), “ˊ” (tone 2: rising), “ˇ” (tone 3: dipping) and “ˋ” (tone 4: falling), and an additional neutral tone that requires no symbol. Therefore, phonological awareness is also required in acquiring Chinese language (Cheng-Lai, 2010), except for Cantonese Chinese in Hong Kong that does not have any phonetic system and is learnt holistically despite it has 9 tones (Wang & Yang, 2014).

Another salient feature of Chinese language is homophones which refer to Chinese characters that share similar or same pronunciation but have different meanings. They can be distinguished through visual cues provided by the semantic radical of the character (McDougall et al., 2010). For example, “中”, “钟” and “终” share the same pronunciation of /zhōng/ but their meanings are “middle”, “clock” and “end” respectively. The Chinese language also consists of compound words which can contain homophonic or non-homophonic characters (Zhou et al., 1999). Morphological awareness has a unique association with homophone awareness and lexical compounding knowledge of words (Liu et al., 2013). For example, a character (e.g., “大” /dà/ [big]) can be formed with another character to expand vocabulary (e.g., “大象” /dà xiàng/ [big elephant] and “伟大” /wěi dà/ [great or mighty]). Furthermore, many Chinese characters can be combined to form new words. For example, “木” and “马” can be combined to form “木马” which means “wooden horse” as a compound word, and root word “吃” [eat] with a past tense suffix “了” form “吃了” which means “eaten” as a derivational word. Hence, orthographic knowledge, phonological processing and morphological awareness are important for Chinese character recognition (Li et al., 2012b).

In view of the above, the Chinese language is therefore linguistically more opaque than the English language, despite both having deep orthographies (Kim, 2010; McDougall et al., 2010). The orthographic structure of Chinese characters can be quite complex as learning the language would require a learner to have or develop morphological awareness to understand that characters with the same pronunciation may have different meanings and the meanings may change when the characters combine, homograph awareness to understand that the same character may have different meaning (e.g., “乐” can mean “happy” and “music”), and radical awareness to understand the semantic and phonetic roles of the radicals in the Chinese writing system (Cheng-Lai, 2010).

2.1.4 Reading Instruction in Chinese

The Chinese language can be represented in two different systems, namely the ‘hanyu pinyin’ phonetic system which can be written in roman letters to represent pronunciation, and the strokes writing system to represent the orthographic form of Chinese characters. Several studies have taken

interest in finding out whether ‘strokes’ or ‘pinyin’ methods of instruction is effective for learning and reading of Chinese (e.g., Chung, 2002, 2007; Giovanni, 1994; Lee & Poon, 2014; Lin et al., 2010; Liu, 2005; Lü, 2017; Zhang & Liu, 2005).

The teaching of ‘hanyu pinyin’ in the Mandarin Chinese curriculum in Mainland China was implemented since 1958 (魏, 2006) and there had been several Chinese research studies conducted on the effectiveness of the ‘pinyin’ method (Liu, 2005; Zhang & Liu, 2005). The ‘pinyin’ method of instruction allows children to use the ‘hanyu pinyin’ annotations at their beginning stages of learning to speak, listen, read, and write Chinese characters which are taught and presented in meaningful texts (魏, 2006). Liu (2005) has critically reviewed the Chinese literature, which is largely unavailable in the West, on the use of ‘pinyin’ method to teach reading and writing of Chinese in Grades 1 to 5 students in Mainland China. The review found that the students’ word recognition skills significantly improved, especially when early Chinese literacy skills acquisition were considered the most difficult at the lower grade levels. Another benefit of learning ‘hanyu pinyin’ is that it facilitates the use of technology to read and write Chinese words efficiently as teachers and learners can maximise the learning process and improve motivation to learn (Zhang & Liu, 2005).

In a more recent study, Lin et al. (2010) experimented with the teaching of ‘pinyin’ spelling with 296 pre-schoolers in Mainland China and found improvements in their Chinese word reading and phonological awareness 12 months later. However, the limitations to this finding were that the study was conducted as part of another longitudinal study in which the sample had been originally drawn and other possible extraneous variables, such as developmental maturity, was not evaluated. Subsequently, Lü (2017) replicated Lin et al.’s (2010) study with 37 Grade 2 children in the US taking L2 Chinese in an immersion programme and found consistent results where ‘pinyin’ skill is a strong predictor of Chinese word reading and Chinese phonological skills. Two studies by Chung (2002, 2007) further supported the effectiveness of the ‘pinyin’ method with English translations in L2 Chinese learning of Year 7 students in Australia, and recommended teaching of Chinese characters in a sequence of presenting the Chinese character first, then its ‘pinyin’ and then the English translation.

Although research is limited, the 'pinyin' method may seem to be effective for bilingual learners and useful for building reading skills, learning of accurate pronunciation, promoting phonological skills and application in technological devices and dictionaries.

On the other hand, the 'strokes' method of instruction was researched on for its effectiveness in an earlier study by Giovanni (1994) with readers and non-readers of Chinese. It was found that learning of strokes is an important skill for building orthographic knowledge of Chinese characters and is unique to readers of Chinese only. This study seems to suggest that learning of strokes serve as a mental retrieval cue for Chinese readers to access lexical representation of Chinese characters for reading. Yim-Ng et al.'s (2000) study with Hong Kong adult learners have also suggested the beneficial effect of finger-tracing on recognition of Chinese characters as the kinaesthetic-tactile movements that are embedded in the act of writing through the fingertip mediate the sequence and visuo-spatial information. This study's findings implied the importance of visual and kinaesthetic skills in processing spatial layout of the strokes and recognising parts of characters in Chinese language acquisition. A more recent case study with Singaporean children also suggested that the 'stroke' method may be more effective in building Chinese reading skills than the 'pinyin' method (Lee & Poon, 2014). However, empirical research on the effectiveness of 'strokes' method is as limited as the literature on 'pinyin' method of instruction.

Chinese literacy acquisition is considered a difficult learning process, given the logographic representation of morphologically complex Chinese characters that consist of both phonetic and semantic components, and phonological representation of 'hanyu pinyin' in roman letters (Han, 2012; Huang, 2017; Lee, 2008; McNaughton & Li, 1999; Sampson, 1994; Unger, 2003). Ingulsrud and Allen (2003) highlighted three linguistic areas that are interrelated in teaching of Chinese literacy in China: (1) the standard norms of the writing system, which is the learning of strokes, stroke order, radicals and brush calligraphy in a very precise manner, (2) the standard spoken language, which is the 'hanyu pinyin', phonological awareness through syllables and rhymes with tone diacritics, and vocabulary

building, and (3) acquisition of literacy for the purpose of identity and communication. This suggests that learning of Chinese characters require an integration of both 'strokes' and 'pinyin' methods.

Zhang (2011) also suggested an effective compensation strategy, which is found unique to Singaporean students with Chinese vocabulary problems, is to use English equivalents (i.e. “猫” = “cat”), ‘hanyu pinyin’ (i.e. “猫” = /māo/) and dictionaries (i.e. use of strokes, orthographical and radical positional knowledge to search for unfamiliar characters), under scaffolded instruction from competent educators. In another research, Zhang et al. (2019) designed a computerised model that integrates the stroke, structure and pinyin features of Chinese characters for learning Chinese word embeddings, and found effectiveness in the model capturing the morphological and phonetic information of the Chinese characters. Hence, Zhang et al. (2019) proposed that the natural learning process for human follows that of the computerised model, which is to first learn the pronunciation of characters, then further understand their structures and the meanings by studying how to write them. Therefore, this suggests that reading instruction for Chinese may be more effective if embedded with both 'pinyin' and 'strokes' methods.

2.1.5 Effects of Bilingualism and Biliteracy Context

The difference among writing systems and the orthographies of languages has an impact on reading development (Perfetti & Liu, 2005). A more transparent language allows a reader to implement a reliable grapheme-phoneme conversion, whereas a less transparent language makes a reader rely on an orthographic whole-word reading approach. Social and cultural factors, such as socioeconomic status and instructional differences, may also affect reading development (Aro & Wimmer, 2003). Methods of reading instruction vary in different countries (Aro & Wimmer, 2003) and are likely related to the level of transparency of the language orthography (Goswami et al., 1998). Whether the effects of dual language development are due to biological or environmental causes remains open and debatable (Hammer et al., 2014; Hoff & Core, 2013; Yang, 2017).

There are several studies (e.g., Bialystok & Viswanathan, 2009; Hoff et al., 2012; Yang, 2017) that support the effects of bilingualism on cognitive-linguistic abilities and dual language development,

such as enhanced metalinguistic development and executive function (Bialystok, 2007, 2009, 2011). Bialystok and Viswanathan (2009) studied socio-economic status matched groups of monolinguals and bilinguals in Canada and bilinguals in India to investigate the differences in enhanced executive function between these groups. Language exposure to English and another language (i.e., Cantonese, Croatian, French, Hebrew, Hindi, Kannada, Mandarin, Marati, Punjabi, Russian, Tagalog, Telugu, Tamil or Urdu) were also matched between the bilingual groups. Findings showed that the effects of bilingualism on executive function overrides cultural and linguistic differences. Hoff et al. (2012) matched English monolinguals and balanced Spanish-English bilinguals in terms of early exposure and amount of exposure to the languages, age, home language, parental and socio-economic backgrounds. They found that the bilingual learners' rate of development for each language vary according to the amount of exposure. Bilinguals with varying proficiency in their languages may also need certain cognitive-linguistic ability to process and switch between two languages. A study by Yang (2017) on Korean near-monolinguals and Korean-English bilinguals with two different levels of L2 proficiency found that the bilinguals have enhanced working memory than the near-monolinguals. The study suggested that the bilinguals with lower L2 proficiency had even more enhanced working memory is probably due to the need for higher cognitive load to process the weaker second language. Hence, the working memory advantage in the bilinguals in this study was more likely due to the unique use of L2 in the environment rather than the learning of dual languages.

The studies above showed possibilities of a bilingualism effect on cognitive-linguistic skills and language development due to language exposure. It is also believed that social, cultural and linguistic factors in the environment, such as teaching instruction and language use in school and at home, influence language development of learners whether or not they are monolinguals or bilinguals (Hoff, 2006). Cummins (2000) frequently emphasised the key role that bilingual education system plays in biliteracy development and language transfers in second language acquisition can only be resolved by adequate pedagogical conceptualisation of language proficiency and assessment. A significant variable that influence reading development is the classroom environment, as it involves several

elements such as classmates, teacher skills, and curriculum (Elliott & Grigorenko, 2014). In Singapore, the English language is taught as the first language and the medium for educational instruction, whereas the Chinese language is taught as 'mother tongue' or second language with a portion of curriculum hours dedicated to learning of this language subject. Both languages are mainly taught using whole-language approach, even though there is some exposure to a phonics approach in English reading and the 'pinyin' method in Chinese reading. Singapore and the 3 major Chinese communities differ in terms of the individual's amount of exposure to languages through the country's education policy and curriculum, and communicative function within the community, the pedagogical approaches and educational support available for the individual to learn the languages, as well as the linguistic differences between Mandarin Chinese and Cantonese Chinese.

Yang et al. (2013) conducted a study using computational modelling whereby a monolingual model and a bilingual model were compared to study the effects of semantic and phonological processing on literacy acquisition of English and Chinese. They found that the acquisition of reading skills could be driven by differences in the patterns of the writing systems of the languages, rather than differences in cognitive architecture of the learner. This suggests that reading difficulties depends not only on the cognitive functions of the individual but also on the linguistic system of the language, which fits Frith's view. However, if the bilingual learner has dyslexia, the pre-existing biological and cognitive deficits may have a different impact on their dual language development (Paradis et al., 2011).

2.2 The Biological Domain

The biological level of Frith's causal model considers the genetic contribution and neuro-anatomical causes of dyslexia (Frith, 1995, 1999, 2002; Morton & Frith, 1995). Genetic and neurobiological factors are generally the focus of research in understanding the nature of dyslexia, but there have been no firm conclusion on any specific genetic correlates of dyslexia (McBride, 2019). Instead, multiple interactions between neurological basis and environmental influences, such as interventions, have a stronger causal relationship with dyslexia, including children with genetic risks

of dyslexia (Gabrieli, 2009). Neuroimaging methods revealed brain regions that are consistently involved in single word reading in English and reflect how structural brain differences relate to the psychological bases of dyslexia such as deficits in phonological awareness, Rapid Automatised Naming (RAN), reading fluency and perceptual processes (Norton et al., 2015). Friederici (2011) noted that most neuroanatomy models of language processing were based on Western languages such as English, German and Dutch, and only a few were based on Asian languages like Chinese and Japanese.

Paulesu et al. (2000) first presented behavioural and anatomical evidence of a common brain activation in the inferior frontal and premotor cortex, superior, middle and inferior temporal gyri and fusiform gyrus on the left, and superior temporal gyrus on the right during explicit and implicit reading in both English and Italian which are alphabetic languages of different orthographies. Italian orthography is more consistent than English orthography, and so Italian readers showed greater activation in the planum temporal brain region whereas English readers showed greater activation in the left posterior inferior temporal region and in the anterior most part of the inferior frontal gyrus in this study. Paulesu et al.'s (2000) study demonstrated that while there is a common brain system active during reading alphabetic languages, different brain regions can be weighted differently depending on culture-specific orthography. Subsequently, in Paulesu et al.'s (2001) study on English, Italian and French dyslexic individuals, they found reduced activation in the left middle, inferior, and superior temporal cortex and in the middle occipital gyrus are commonly observed in all dyslexic individuals during word reading despite the differences between deep and shallow orthographies in their respective languages. These studies suggest an association between the specific brain region in the left hemisphere and phonological processing on spoken and written languages, and phonological processing deficit is a neurological problem of dyslexia that causes literacy difficulties across all languages.

Shaywitz et al.'s (1998) study undertook a comparison between dyslexic and non-impaired readers on their brain region activations when reading in English. The fMRI results showed that dyslexic readers experienced less activation in the left posterior regions of Wernicke's area than non-

impaired readers. In addition, they found an overactivation in the anterior region in dyslexic readers, suggesting a compensatory effort to overcome the neurological deficit in processing phonology. However, there are studies that argued against the universal biological origin of dyslexia for non-alphabetic languages like Chinese (e.g., Siok et al., 2004)

Siok et al. (2004) argued that while alphabetic learners with dyslexia, like English, French and Italian, showed less activation in the posterior temporal lobe (e.g., Paulesu et al., 2001), logographic learners with dyslexia, like Chinese, showed less activation in the left middle frontal gyrus that is associated with processing the Chinese characters in verbal and spatial working memory. They suggested that there is a significant difference in the biological abnormality between different cultures and orthographies. In response to this, Ziegler (2006, p. 342) explained that the existence of some difference in brain area activation between English and Chinese languages is because English is alphabetic that map letters to phonemes but Chinese is logographic that has a complex mapping of “grapho-motor programs to whole-word phonology”. Ziegler (2006) claims that Siok et al.’s (2004) study did show a clear phonological deficit through the Chinese dyslexics’ poor performance in the phonological tasks in Chinese, but the absence of deactivated left temporal parietal cortex showed that this specific brain region responsible for fine-grained phonemic analysis (i.e., converting alphabetic letters to smallest units of sounds) is not relevant to the Chinese language orthography.

Other fMRI studies on Chinese word reading by Kuo et al. (2001), Lee et al. (2007) and Lee et al. (2010) have found certain parts of the cortex that are involved in processing Chinese characters, which is the left-lateralized neuronal networks that process the orthographic, phonological, and semantic attributes of Chinese words. Findings from these studies generally showed that reading of Chinese characters requires an orchestrated activation of certain parts in the left inferior frontal region for phonological processing, the left temporoparietal region for orthography-to-phonology transformation, and the temporooccipital region for visuo-orthographic processing. These brain regions are consistent with the convergence of findings that Perfetti (2011) had gathered from several neuroimaging studies on English reading. The activation of the left middle frontal gyrus, supported by

Lee et al.'s (2007) study, was found to be specifically involved in processing both semantic and phonological components of Chinese characters. Other fMRI studies that show reading of English and Chinese words involve both shared brain regions and some different regions, also supported the unique involvement of the left middle frontal gyrus with Chinese reading (Chee et al., 2000; Tan et al., 2000, 2001). These studies found a common semantic processing region activated when reading both English and Chinese words. However, the visuospatial analysis region, the visual systems region and cerebellum are also activated when processing Chinese words. Evidence from these studies further supported the difference between nature of English and Chinese languages and certain biological neural network activation is dependent on the language orthographies.

The above studies discussed independently investigated the neural basis of reading and developmental dyslexia in English and Chinese populations. Hu et al. (2010) provided the first neuroimaging study that compared both English and Chinese populations in the UK and Mainland China respectively to investigate the difference between normal reading in English and Chinese, and the effect of dyslexia on brain activation. The study replicated patterns of difference in brain activation in normal reading of English and Chinese reported in previous studies (i.e., Chee et al., 2000; Kuo et al., 2001; Lee et al., 2007, 2010; Paulesu et al., 2001; Tan et al., 2000, 2001) and no cultural difference in the effect of dyslexia in both languages with reduced activation in the left angular gyrus and in left middle frontal, posterior temporal and occipitotemporal regions as compared to normal readers in the respective languages. Hu et al.'s (2010) study result contrasted that of Siok et al.'s (2004) study that claimed cultural and orthographic differences in the biological abnormality between dyslexia in English and Chinese. A more comprehensive set of stimuli was used in Hu et al.'s study which consisted of semantic relationship judgement and naming of words and pictures in both English and Chinese, whereas the stimuli used in Siok et al.'s study consisted of only homophone judgement and character decision in Chinese. Moreover, the participants in Hu et al.'s study were adolescents while Siok et al.'s study were primary school students. This shows that there is still a gap in neurological research that directly compares both English and Chinese populations in all constructs of reading development (e.g.,

phonology, orthography and semantics) in relation to dyslexia. Nonetheless, Hu et al. (2010) claimed that the study reconciled the brain activation evidence from previous studies on the common neurological basis of dyslexia regardless of the language's phonology and orthography and suggested that reading development depends on the interaction between cognitive abilities and learning environment.

You et al. (2011) investigated whether first language learnt by bilingual learners influenced the neurological basis of dyslexia due to the differences in orthographies. They conducted an fMRI study in Mainland China and found neural differences between Chinese-English bilingual learners with and without reading impairment in English. Through use of English phonological awareness and orthographic knowledge tasks, the neuroimaging results showed that impaired English readers had reduced activation in brain areas that are responsible for phonological processing and orthographic processing in English as compared to their typical peers. It was also found that they have less activation in the brain area that plays a specific role in integrating phonology and orthography of English language as compared to their typical peers. This study suggests that the biological origin of dyslexia is consistent regardless of whether English language is first or second language of readers, and that learning of a non-alphabetic language as first language does not change the underlying default network for reading development. A later fMRI study by Meng et al. (2016) investigated Chinese-English bilingual learners in Mainland China who have impaired reading in English and those without reading impairment on their differences in brain activation areas when engaging in English tasks for rhyme detection, syllable identification, phoneme deletion, word identification and word attack skills. A comparison of neuroimaging between English impaired readers and typical readers found that the impaired readers generally have intact phonological representation but lack higher order phonological manipulation and orthographic representation for reading in English. The study supported You et al.'s (2011) findings and also supported that there is a common neurological impairment of English reading across L1 and L2 English learners.

Neuroimaging studies seem to have found significant evidence that support the biological origin of dyslexia or reading difficulties. Although certain regions in the neural network may differ depending on the deep or shallow orthographies of different languages, there is still a common neural mechanism that underlie reading development across all languages which is associated with the deficit in phonological processing. Perfetti (2011) stated that dyslexia could be caused by deficits in the linguistic-graphological components and not limited to only phonological components across different languages. As such, the brain processes Chinese characters along both semantic and phonetic dimensions simultaneously whereas it processes English words along phonetic dimension only (Wang & Tsai, 2011). However, orthographic processing is found to have a stronger relation to the acquisition of Chinese language than English language due to the nature of sound-print structure (Chen et al., 1995; Li et al., 2012). Delays in orthographic processing can be linked to difficulties in English word recognition, English letter recognition and reversals, as well as Chinese stroke patterns (Chen et al., 1996), although it is less widely recognised as a symptom of dyslexia as compared to phonological processing deficit in English language. The subsequent section discusses the cognitive processes that stem from the biological basis of reading development and dyslexia.

2.3 The Cognitive Domain

At the cognitive level of Frith's causal model, neuro-cognitive causes and cognitive theories linked to biological and environmental factors are considered (Frith, 1995, 1999, 2002; Morton & Frith, 1995). This section first discusses the reading developmental stages and reading models of English and Chinese languages, in which there are similarities and differences in the cognitive processes involved in each language due the nature of alphabetic and non-alphabetic orthographies. The section then discusses the subtypes of developmental dyslexia and major theories of dyslexia with reference to literature research on monolingual and bilingual samples of English and Chinese languages.

2.3.1 Reading Development Stages in English and Chinese

Reading development stages start and moves progressively from age of 6 months to over 18 years (Adams, 1994). Frith's (1986) model of reading development in English was proposed over four

decades ago but remain as a classic theoretical framework for many empirical research on developing reading abilities (Kuerten et al., 2020). According to Frith's model, children develop reading through three key stages, and they are (1) logographic stage, (2) alphabetic stage, and (3) orthographic stage. The logographic stage is the beginning phase of reading in which the child recognises a word by its graphic features (Frith, 1986) that does not involve phonological processing but only visual processing (Kuerten et al., 2020). The alphabetic stage is the phase in which the child progresses from visual recognition to understanding letter-sound correspondences (Frith, 1986), and this progression involves development of GPC skills through formal phonics instruction (Kuerten et al., 2020). The orthographic stage is when the child can recognise a word instantly by interpreting its morphemic parts (Frith, 1986) and this phase involves development of orthographic knowledge and GPC skills that promote automatic word recognition and retrieval of meaning from lexical memory (Kuerten et al., 2020). Frith (1986) explained that the above stages of reading development in English are non-gradual, as children's reading performance may fluctuate as they crystallise their strategies to read phonologically regular and irregular words. Successful reading performance is dependent on the interaction between the lexical and non-lexical processing routes based on Coltheart's Dual Route Theory (2001) (see Section 2.3.2).

Early research on reading development in Western languages (e.g., Adams, 1994; Ellis & Large, 1988; Høien & Lundberg, 1988) have investigated how children progress through these stages and slow progression through these stages point the possibility of reading disability as well as differences in cultural, linguistic, and educational settings. Stuart and Coltheart (1988) claimed otherwise in their longitudinal study, stating that children may not follow the same sequence of reading developmental stages, and highlighting that phonological awareness has a reciprocal causal relationship with reading development and plays an important role at the very beginning stage of reading. This claim contradicts Frith's developmental stages that start with logographic stage. However, it is noted in Stuart and Coltheart's study that reported individual differences, so the effect reported is most evident for

children who were already phonologically skilled before they began to read. It leaves open the possibility that children who were not phonologically skilled might start with a logographic stage.

Developmental stages models of Chinese reading have proposed (1) visual stage, (2) phonetic stage, and (3) orthographic (Chen, 2004). These accounts are explicitly informed by research on English reading developmental stages of (1) logographic, (2) alphabetic, and (3) orthographic (Kim & Shin, 2018). A study by Chen (2004) involved more than 300 children from preschool to Grade 6 in Mainland China to examine their reading strategies at different age groups. Pre-schoolers begin to read their first few words by recognising the distinctive features of the characters at visual stage and start to develop some understanding that the characters consist of phonetic components at the phonetic stage and are able to decipher the pronunciation by analysing the phonetic components between different characters by the time they are at Grade 2. At Grade 4 to 6, children progress to the orthographic stage when they can apply structural knowledge to analyse and differentiate similar-looking or similar-sounding characters when reading. This study is aligned with Siok and Fletcher's (2001) study that suggested the children in Mainland China learn to read Chinese progress from logographic to orthographic-phonological phase from Grade 1 to 5.

Kim (2010) and Kim and Shin (2018) subsequently conducted research to investigate if adult learners progress through the same reading developmental stages in Chinese as second and foreign language respectively. Both research studies found that although adult learners progressed through the same stages as L1 Chinese children in reading acquisition, they tend to skip or pass through the visual stage quickly and started from phonetic stage to orthographic stage instead. This suggests the difference in cognitive maturity between children and adults in reading and the possibility that orthographic knowledge plays a bigger role alongside with phonetic strategy than visual strategy in reading Chinese characters.

On the other hand, a study by Ho et al. (2003) was conducted to examine the development of orthographic knowledge and found a strong relationship with reading and spelling among Chinese kindergarten and primary school children in Hong Kong. Ho et al. (2003) explained that there was a

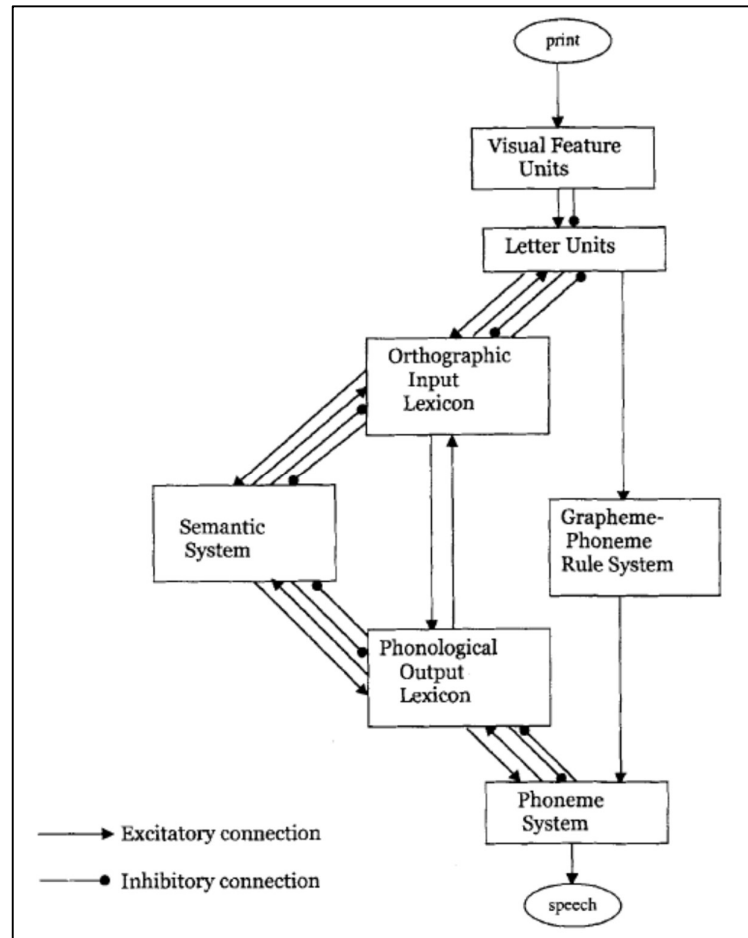
set of progressive stages in the development of orthographic knowledge for reading and writing of Chinese characters. They are: (1) character configuration knowledge, in which children develop rudimentary orthographic skill that differentiates writing from drawing of Chinese characters, (2) structural knowledge, in which children develop understanding of Chinese characters being compounded with two or more separate components called radicals, (3) radical information and positional knowledge, in which children gain understanding of the meanings of semantic radicals and their legal positions within the Chinese characters, (4) functional knowledge, in which children develop the ability to associate phonetic and semantic radicals with sounds and meanings respectively, (5) amalgamation stage, in which children combine knowledge of forms, functions and positions of phonetic and semantic radicals when reading/writing Chinese characters, and (6) when children gain complete orthographic knowledge by being able to read and write correct Chinese characters consistently and apply logical understanding of semantic and phonetic radicals, even in pseudo-characters. This suggests that orthographic knowledge may play a bigger role in Chinese reading development of children in Hong Kong, given that the language is learnt in traditional script and without any auxiliary phonetic system.

2.3.2 Reading Models of English and Chinese

Coltheart's Dual Route theory was developed by Coltheart (1978; cited in Castles & Coltheart, 1993) to explain that reading involves two separate lexical and sublexical procedures, and the different types of reading difficulties in dyslexia. The model also contributed to subsequent research in understanding causes of dyslexia (e.g., Castles et al., 1999; Castles & Coltheart, 1993; Olson, 2002).

Figure 3

The dual-route cascaded model (DRC) of visual word recognition and reading aloud (Coltheart et al., 2001, p. 214)



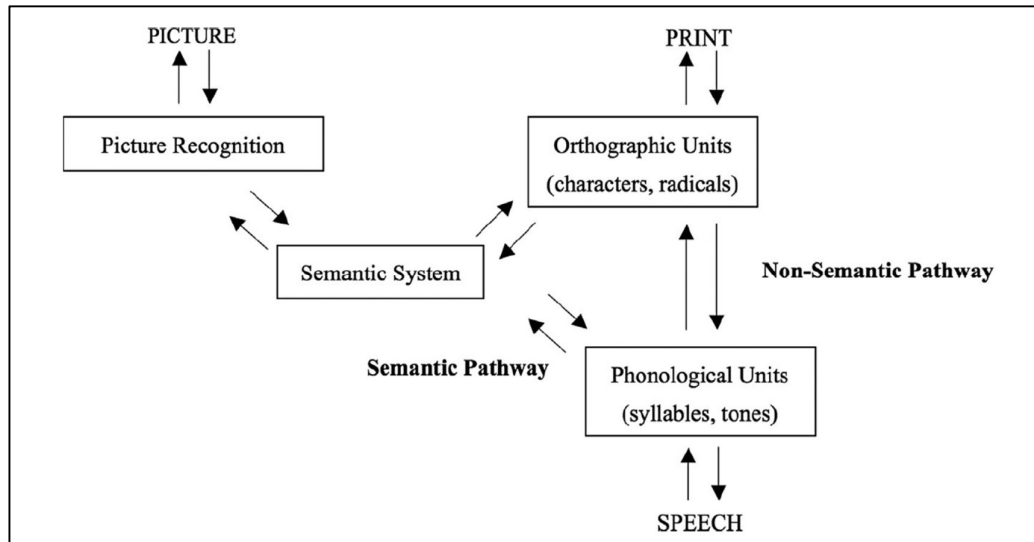
The Dual Route theory, the cascaded model as illustrated in Figure 3, argues that successful word reading consists of two routes – the lexical route which further splits into two sub-routes for semantic system processing and non-semantic system processing, and non-lexical (GPC) route (Coltheart et al., 2001). As English consists of both regular and irregular words, the model shows the two distinct routes that a reader will process when reading (Coltheart, 2006). Regular words obey the GPC rules of English (e.g., “maid” or “cave”) and they can be read correctly by both lexical and non-lexical routes. Irregular words can only be read correctly using the lexical route as they violate the GPC rules (e.g., “have” or “cave”). Impairment in any of the routes explains for the different subtypes of dyslexia in English, which are phonological, surface and deep dyslexia (see Section 2.3.3).

Coltheart et al. (2001) acknowledge the limitations in applying the DRC model on reading in other languages that are structurally different from English, such as Chinese, Japanese and Korean. Similarly, Su et al. (2010) claim that Coltheart's Dual Route model is insufficient in explaining reading procedures involved in Mandarin Chinese, because the non-lexical (GPC) pathway is not relevant to the logographic nature of the language and the irregular words in non-alphabetic script cannot be processed the same way as irregular words in alphabetic script. Ho et al. (2007), in their research on subtypes of dyslexia in Hong Kong children using the dual route model, also suggested that there may be only a single lexical route from print to speech for reading of Chinese words.

Harm and Seidenberg (1999) provided insights to phonology, reading development and dyslexia using a connectionist model that was based on the frameworks by Seidenberg and McClelland (1990) and Plaut et al. (1996). According to the connectionist model, reading development in English involves the synergistic activation of well-specified and inter-connected phonological, orthographic, and semantic representations of the language. Harm and Seidenberg (2004) further found mutual dependence of orthography-to-phonology-semantics and orthography-to-semantics activations when learning to read. This shows that the meaning of words is typically acquired over time when an individual is exposed to word reading frequently. Hence, phonology, orthography and semantics are the three constituencies of word identification that are simultaneously connected and parallelly activated to allow an individual to generalise the regularities of orthography-to-phonology and orthography-to-semantics mapping when learning to read across different writing systems (Siegelman et al., 2020).

Figure 4

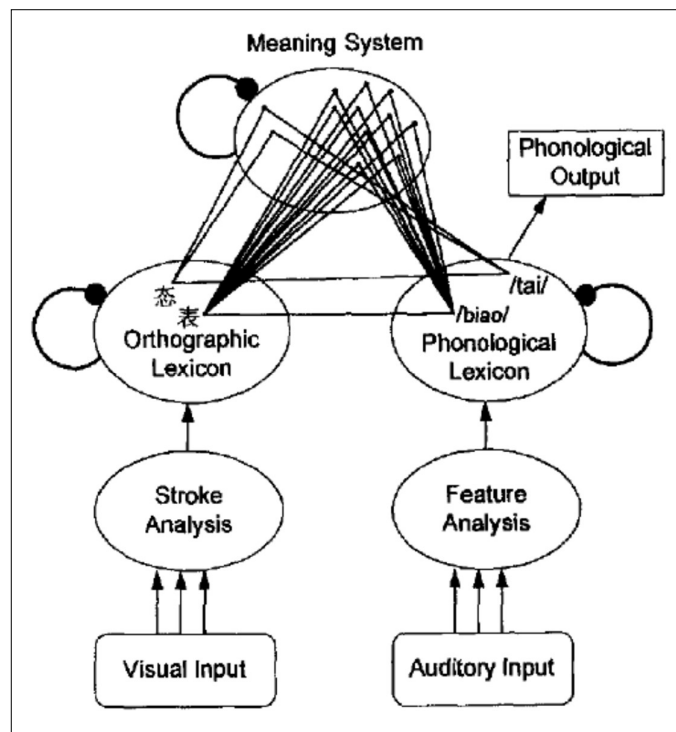
The triangle model by Yin and Weekes (2003)



Yin and Weekes (2003) presented a triangle model, illustrated in Figure 4, for understanding reading and writing in Chinese, based on cognitive neuropsychological evidence with a focus on Chinese-speaking aphasic patients in Mainland China. The triangle model assumes that bi-directional feedforward and feedback connections are activated between orthographic and phonological units, and semantic system when processing a Chinese character. Yin and Weekes (2003) used this model to illustrate how the orthographic representation of a Chinese character will activate the connections between the phonological units and the semantic system but the activation may be inhibited by additional input from the orthographic units to select the correct phonological output when an individual reads a Chinese character. Hence, a reader may misread a character that is orthographically similar but pronounced differently (e.g., “暗” /àn/ [dark] as “音” /yīn/). A similar approach as Coltheart et al.’s (2001) was adopted in this model in an attempt to explain for different subtypes of dyslexia in Chinese (see Section 2.3.3). However, it is important to note that Yin and Weekes (2003) had explained that the triangle model was not a computational model and required hypothesis testing to better understand the cognitive processes involved in reading Chinese.

Figure 5

Schematic model (interactive lexical constituency model) of Chinese single-character identification
(Perfetti & Tan, 1998, p. 112)



In Figure 5, the new Lexical Constituency Model of reading in Chinese (Perfetti et al., 2005) is a connectionist model that has been utilised to explain the parallel activations between the complex representations of orthographic, phonological and semantic (lexical and morphemic) constituents of Chinese characters in producing speech from print. Perfetti et al. (2005) described the interactive lexical constituency model with a key assumption that the Chinese character identification process requires rapid retrieval of phonological form or implicit pronunciation, when the orthographic-phonological relationship is readily available with a given visual input. The same multiple activation process applies when a reader sees an unfamiliar character. The model does not link orthography to phonology via the direct non-semantic pathway and the indirect pathway via the semantics to explain for subtypes of dyslexia in Chinese. Unlike Coltheart's Dual Route model, the reader cannot process an unfamiliar character using the non-lexical pathway and must recognise the radicals within the

character for semantic and phonetic cues. Chinese reading is a complex process (highly interactive between the three units) in which the reader requires the ability to integrate phonological, orthographic, and semantic processes to recognise Chinese characters. In another connectionist model, Yang et al. (2009) specified a sub-lexical language-general reading mechanism that process print-to-sound mapping over orthographic representations that vary in sizes (i.e., from strokes to radical components) within a Chinese character and it is claimed that the same mechanism can be applied across writing systems (i.e., alphabetic and non-alphabetic languages).

Zhou and Perfetti (2021) proposed a global mapping congruence to demonstrate the interactive framework of word identification that is independent of any writing system (i.e., English and Chinese). As discussed in the nature of English and Chinese languages (Sections 2.1.1 and 2.1.3), the indices of orthography-to-phonology regularities for English and Chinese are conceptually similar despite the difference in psycholinguistic grain sizes, and the indices of consistency in the phonological representations for English and Chinese are parallel in nature (Lee, 2008). While regularity arises from the DRC model (Zhou & Perfetti, 2021), it refers to the degree of how the pronunciation of a character is similar to its phonetic radical (Lee, 2008). Consistency arises from the connectionist model (Zhou & Perfetti, 2021) and it refers to the frequency in which the pronunciation of the character is similar to those of other characters that contain the same phonetic radical (Lee, 2008). Although phonological regularity in Chinese as a logographic/morphosyllabic language does not equate to that in English as an alphabetic language, a global orthography-to-phonology mapping congruence is suggested to be a more writing system independent framework as a reading model across languages.

2.3.3 Subtypes of Developmental Dyslexia in English and Chinese

Castles and Coltheart (1993) first described two varieties of developmental dyslexia by using the dual-route theory - phonological and surface dyslexia. Phonological dyslexia is characterised by the selective deficit in the non-lexical procedure which causes the misreading of non-words like “chustery” as a real word such as “chemistry” or “chesty”, despite an intact lexical procedure that allows irregular words such as “yacht” to be read correctly as /yot/ instead of /y-a-ch-t/ phonetically.

Surface dyslexia, on the other hand, is characterised by the selective deficit in the lexical procedure which causes regularisation errors when irregular words such as “one” is read phonetically as “own”, despite an intact non-lexical procedure that allows regular words to be read accurately. Coltheart (2000) attributed reading errors of deep dyslexic readers to extensive reliance on right-hemispheric processing of orthographic and semantic components of words. Deep dyslexic readers may misread “orchestra” as “symphony” (semantic error), “bus” as “brush” (visual error), and “run” as “running” (morphological errors) and reading of non-words is not possible due to severe deficit in the non-lexical procedure. Deep dyslexia is an acquired dyslexia caused by brain damage in the left hemisphere rather than a subtype of developmental dyslexia, as supported by previous studies (e.g., Patterson et al., 1989; Price et al., 1998; Weekes et al., 1997).

In contrast to the dual route theory, Harm and Seidenberg (1999) argue that phonological dyslexia derives from an individual’s impairment in the activation of phonological representations of letter strings that affects reading of non-words, whereas surface dyslexia derives from an individual’s lack of efficient activation of orthography-to-phonology representations efficiently from word reading experience. That is, the connectionist theory differs from the dual-route theory that associates phonological dyslexia with difficulties in reading regular non-words due to impairment in non-lexical route and surface dyslexia with difficulties in reading irregular words due to impairment in lexical route. The connectionist theory explains the individual’s developmental differences in the sensitivity to the consistencies in orthography-to-phonology mapping and orthography-to-semantic mapping across different writing systems with different phonological grain sizes (Siegelman et al., 2020). Based on connectionist principles, readers with dyslexia face challenges in assimilating these complex consistencies through their reading experiences, regardless of the contrasting linguistic differences across languages such as English and Chinese (Harm & Seidenberg, 2004).

As opposed to the dual-route view of Castles and Coltheart (1993), Su et al. (2010) claim that phonological dyslexia is not observed in Chinese readers. This is because the non-lexical (GPC) route does not apply in Chinese reading (Lee, 2008; Yang et al., 2009). This claim is also supported by Ho et

al.'s (2007) study which found no Chinese children with dyslexia belonging to this subtype. The phonological subtype of dyslexia in Chinese may not be evident compared to incidence in English, due to the difference in the nature of the two languages. In addition, a study by Luo (2004) found that phonological dyslexia is more likely a type of acquired dyslexia called 'tonal dyslexia' whereby brain-damaged patients produce an incorrect tone when reading, such as misreading the third tone of the character “马” /mǎ/ [horse] as /mà/ in fourth tone.

Surface dyslexic readers display selective impairment in reading Chinese characters which contain phonetic radicals that are not consistent in their pronunciation and produce phonetic errors such as misreading “暗” /àn/ [dark] as “音” /yīn/ [pitch] due to the similar radical shared. As such, it affects the readers' understanding of word meanings due to the reading errors. Studies by Shu et al. (2005) and Luo et al. (2007) found that poor semantic processing and morphological awareness are more characteristic of developmental surface dyslexia in Chinese than phonological processing. The two studies supported that the phonological regularization of Chinese words in the reading process may be substantially different from alphabetic language like English. Hence, it is more likely for poor readers of Chinese have surface subtype of dyslexia and orthographic-related difficulties which reflects the unique characteristics of the language itself (Ho, 2009).

Su et al. (2010) also included deep dyslexia as one of the subtypes of developmental dyslexia in Chinese which is a severe form of phonological dyslexia coupled with the tendency to make semantic, visual and morphological errors. However, it is claimed that deep dyslexia in alphabetic and non-alphabetic languages, such as English and Chinese, is not comparable. Some Chinese characters can be phonetically similar (e.g., “七” /qī/ [seven] and “漆” /qī/ [paint]), orthographically similar (e.g., “午” /wǔ/ [afternoon] and “牛” /niú/ [cow]) and/or semantically similar (e.g., “看” /kàn/ and “见” /jiàn/ which both mean “see” in different contexts). Poor readers of Chinese may potentially make visual errors by confusing orthographically similar characters, phonetic errors by confusing phonetically similar characters and semantic errors by confusing semantically similar characters. Shu et al.'s (2005) study described children with developmental deep dyslexia often misread abstract

words and produced semantic and visual errors such as “煎” /jiān/ [fry] misread as “煮” /zhǔ/ [cook]. Yin and Weekes (2003), in their triangle model, claimed that selective deficit in the non-semantic pathway may result in deep dyslexia in Chinese while selective deficit in the lexical semantic pathway may lead to surface dyslexia in Chinese.

Interestingly, the subtypes of dyslexia in Chinese may differ based on where the studies were conducted. Wang and Yang (2014) attempted to classify developmental dyslexia in sixth grade readers of Mandarin Chinese in Taiwan by using Coltheart's (2006) dual-route model and Yin and Weekes's (2003) triangle model of Chinese reading. They found inconsistency in classifying dyslexia as phonological, surface and deep in Chinese dyslexic readers in Taiwan, as compared to other studies conducted in Hong Kong (e.g., Ho et al., 2007; Ho et al., 2004; Ho & Siegel, 2012). While Su et al. (2010) claimed that phonological dyslexia is an acquired dyslexia in Chinese readers, Wang and Yang (2014) found otherwise and claimed that phonological developmental dyslexia may be present in readers who learn the Chinese language with its phonetic system, such as 'hanyu pinyin' or 'zhuyin fuhao'. This suggests the possibility of how the Chinese language is learnt may affect the underlying cognitive-linguistic processes in reading.

Besides the use of reading models to explain dyslexia and its subtypes, researchers also investigated the possibility of other multiple deficits responsible for dyslexia. Ziegler et al. (2008) investigated the subtypes of developmental dyslexia in English using the dual-route cascaded model by Coltheart et al. (2001) and found that different dyslexia profiles vary in a complex pattern of phonological, phonemic and letter processing deficits as their causes. Investigations on cognitive profiles of individuals developmental dyslexia in Chinese also found the existence of multiple deficits in some cases (e.g., Chung et al., 2010; Ho et al., 2002). This further suggests investigating dyslexia at individual levels rather than a unitary disorder.

2.3.4 Theories of Dyslexia in English and Chinese

This section will discuss the major theories that explain English developmental dyslexia in relation to respective cognitive deficits at the biological level that are associated with reading

difficulties, and these theories are influential in the field of dyslexia. They are the double deficit theory (Wolf & Bowers, 1999), phonological deficit theory (Snowling, 1998, 2001), morphological deficit theory (Casalis et al., 2004; Elbro & Arnbak, 1996; Joanisse et al., 2000; Siegel, 2008), cerebellar deficit theory (Nicolson et al., 2001; Nicolson & Fawcett, 2011) and magnocellular deficit theory (Stein, 2001; Stein & Walsh, 1997). As there are no specific or major theories of dyslexia for Chinese language, the section will discuss the empirical research (e.g., Chung et al., 2010; Ho et al., 2002, 2004; Ho & Siegel, 2012; McBride-Chang et al., 2012) on the cognitive profiles and multiple-deficit hypotheses investigated in the 3 major Chinese communities alongside with the discussion on the cognitive deficits in the major theories of dyslexia in English.

The phonological theory postulates that dyslexics have specific impairment of phonology that affects their ability in processing speech sounds and associating sound to print (GPC) which, in turn, affect their reading and spelling accuracy in English (Bradley & Bryant, 1978; Hulme & Snowling, 2009). Many researchers in the field of dyslexia (e.g., Bradley & Bryant, 1983; Bruck & Treiman, 1990; Chafouleas et al., 1997; Liberman et al., 1972; Lyon, 1995; Ramus, 2003; Snowling, 1998; Stanovich, 1988a, 1988b, 1996; Wagner et al., 1997) seem to have established a general consensus that phonological processing deficits underlie dyslexic readers' word recognition skills in English. The phonological deficit theory of developmental dyslexia is based on the universal phonological principle by Perfetti et al. (1992) which claims that phonology is engaged at the initial stage of reading and forms the basis of the writing systems of alphabetic languages. In an attempt to understand how dyslexia is manifested across two different alphabetic languages, Ziegler et al. (2003) conducted a comparison study between English monolingual dyslexics and German monolingual dyslexics. They found similarities in their dyslexic-type difficulties, specifically in reading speed, a specific nonword reading, and a phonological decoding. The only difference that the study found was an overall accuracy in word reading which was likely due to the difference in in the transparency of orthographies between the two languages.

How phonology is processed during reading depends on the writing system of the language which is the grain size of orthography. According to Goswami (2010), cross-language studies show many similarities in phonological awareness because of the psycholinguistic grain-size theory. This theory explains that languages vary in their phonological grain size of syllable, onset-rime and phoneme in which orthography is represented (Ziegler & Goswami, 2005). Although the Chinese language is non-alphabetic, some studies (e.g., Goswami et al., 2011; Siok & Fletcher, 2001; Ziegler et al., 2000) have supported the role of phonological awareness in Chinese reading. Goswami et al. (2011) conducted a comparison study between matched samples of children with and without dyslexia, who are learning English, Spanish, and Chinese languages. They suggest that rise time discrimination, which is associated with speech organisation and perception of syllables and provides auditory cue to prosodic structure and phonological awareness, is a universal cross-language sensory deficit in developmental dyslexia in these three languages which are of different phonological transparency and orthographic depths. Similarly, a study by Siok and Fletcher (2001) found that the homophonic syllables in Chinese language that change in tones and at the level of onset and rime also make phonological awareness a critical skill and a predictor of reading and writing in the language. Unlike the English language, phonological awareness in Chinese language is at syllable or onset-rime level but not phonemic level, and was found to be one of the predictors of Chinese reading acquisition in some studies (e.g., Ho & Bryant, 1997; McBride-Chang & Kail, 2002).

Ziegler et al. (2000) conducted two experiments to explore phonological frequency effects in written Chinese characters. They found that Chinese characters with higher phonological frequency are processed faster than those with lower phonological frequency. Chinese characters with higher phonological frequency refer to regular and semi-regular characters which can be pronounced more accurately by identifying the phonetic radicals. Those with lower phonological frequency refer to irregular characters that do not follow phonetic cues. Ziegler et al. (2000), through this study, have shown that phonological processing still plays an important role for word identification even in more opaque language, such as Chinese. Perfetti and Liu (2005) explained that reading Chinese does

activate phonology, just like reading English, but at syllable level – only when the orthographic character is recognised as a unit, the corresponding phonology is activated. Hence, while grain sizes of syllable and onset-rime were found to be similar across languages, grain sizes of phonemes were found to be language-specific (Goswami, 2010), resulting in differences in developmental reading strategies and the manifestation of dyslexia across orthographies (Ziegler & Goswami, 2005).

The view of phonological processing deficit theory as a widely accepted hypothesis of dyslexia in alphabetic systems (Navas et al., 2014) has been strongly contested by researchers (e.g., Landerl et al., 2019; Landerl & Wimmer, 2008; Wimmer et al., 1998) who advocated that both phonological processing and rapid automatized naming (RAN) are longitudinal predictors of reading development in alphabetic systems. Wolf and Bowers (1999, 2000) proposed the double-deficit theory which depicted phonological deficits and naming speed deficits as two independent deficits that result in three subtypes of dyslexia, in which one with phonological deficit only, one with naming-speed deficit only and one with both phonological and naming-speed deficits. The double deficit theory addresses the gap that phonological deficit theory failed to address (Cain et al., 2000; Castles & Friedmann, 2014) and may explain why some readers with dyslexic symptoms have adequate phonological processing and do not respond to phonological-based intervention (Chafouleas et al., 1997; Torgesen et al., 1997). A subsequent study conducted by Wolf et al. (2002), on 144 developmental dyslexic readers of English language in Grades 2 and 3, found that phonological processing contributed more to reading skills that involve decoding or word attack while naming-speed ability contributed more to reading skills that involve word identification. They also found that most of the dyslexic readers fit the double-deficit profile, which is the most severe form of dyslexia, while small percentages of them fit the single-deficit profiles and the remaining smaller percentage that could not be classified. The theory is supported by many other researchers who found the presence of naming speed deficit alongside phonological deficits in English readers with the most severe impairments (e.g., Landerl et al., 2019; Landerl & Wimmer, 2008; Savage et al., 2005; Torgesen et al., 1997; Vukovic & Siegel, 2006; Wimmer et al., 1998). Longitudinal studies on reading development in alphabetic languages (i.e., English, German,

French, Dutch and Greek), by Landerl et al. (2019) and Landerl and Wimmer (2008), have found consensus that both rapid-naming and phonological awareness are longitudinal markers of reading fluency and spelling.

While the double-deficit theory comprehensively addresses the sources of reading dysfunction in readers of English language, the only limitation of the double deficit theory is in addressing linguistic differences across other languages. Research on cognitive profiles of developmental dyslexia in the Chinese language (e.g., Ho et al., 2004; McBride-Chang et al., 2012, 2013) seem to support the presence of a rapid naming deficit alongside phonological and orthographic processing deficits in dyslexic and poor readers. Ho et al. (2004) profiled 147 Hong Kong Chinese primary school students with dyslexia in Cantonese Chinese using a set of literacy and cognitive tasks – the Hong Kong Test of Special Learning Difficulties in Reading and Writing (HKT-SpLD) and the Test of Visual-Perceptual Skills (non-motor) Revised (TVPS). They identified seven subtypes of developmental dyslexia, with rapid naming deficit being the most dominant dyslexic-type difficulty, and it often occurs in combination with other deficits in visual memory, orthographic processing, and orthographic-visual processing. Orthographic deficit was the next most dominant dyslexic-type difficulty as compared to phonological memory which also contributes to Chinese reading difficulty. This suggests that rapid naming and orthographic knowledge are probably more important due to the more complex rules and regularities in the Chinese script than as compared to English.

Researchers have found that morphological deficits are also present alongside phonological skills and are related to reading ability in English dyslexic individuals (Casalis et al., 2004; Joanisse et al., 2000; Siegel, 2008) and Chinese dyslexic individuals (McBride-Chang et al., 2008; Shu et al., 2006). Deacon et al. (2008) have found extensive empirical evidence of morphological deficits in dyslexic and poor readers of English in comparison to their typical same age peers. They have also highlighted the possibility that morphological deficit may originate from the phonological difficulties that the dyslexic individuals already have. Joanisse et al. (2000) investigated the relationship between speech perception, phonology and morphology between dyslexic and typical readers of English, and found

that the dyslexic readers who display phonological difficulties in reading also display morphological difficulties. Li et al. (2012) conducted a study on 184 pre-schoolers and 273 primary school students in Mainland China and also found that morphological awareness and phonological awareness play an important role in both beginning and intermediate stages of Chinese reading acquisition.

Cross-linguistic studies by Ku and Anderson (2003) and Wang et al. (2006) have also shown evidence of the development of morphological awareness in Chinese and English reading acquisition. In Ku and Anderson's (2003) study, 412 Taiwanese Chinese monolingual readers and 256 American English monolingual readers were investigated for their development of morphological awareness at second, fourth and sixth grades. It was found that in both groups of monolingual readers, the more proficient readers developed better morphological awareness with the increasing grade levels given the increasing language experiences, despite the difference between English and Chinese language structures and writing systems. The study also found that morphological awareness was related to vocabulary and reading development. In Wang et al.'s (2006) study that investigated 64 Chinese-English bilingual children in America, findings showed that morphological awareness is important for biliteracy acquisition and there is some similarity between compound morphological structural awareness between English and Chinese languages, whereby two words or characters can be put together to derive an independent meaning. For example, the same morphological understanding can be applied to interpreting the words "raindrop" in English and "雨滴 (rain-droplet)" in Chinese.

Siegel (2008) and Shu et al. (2006), in their studies, have found morphological deficits to be a significant contributor to poor literacy-related skills in dyslexic individuals in English and Chinese language respectively. Siegel (2008) studied over 1,000 Grade 6 children in Canada whose English was their first or second language, and found that a deficit in morphological awareness in the children with dyslexia and a strong association between morphological awareness and word reading and pseudoword reading fluency. Shu et al. (2006) studied over 150 Grade 5 and 6 Chinese children in Mainland China with and without dyslexia, and also found that the dyslexic group has significantly poorer morphological awareness and correlations showed significant association between

morphological awareness with reading, character recognition and comprehension. Shu et al. (2006) proposed morphological awareness as a cognitive construct for dyslexia, and this proposal is supported by McBride (2019) who has also found morphological awareness as the second cognitive-linguistic skill beyond phonological awareness that is essential to learning of any language and script, based on her consolidated findings from previous research on Chinese and English language learners in understanding early predictors and cognitive profiles of dyslexia (e.g., Cho et al., 2011; Liu & McBride-Chang, 2010; McBride et al., 2008; McBride-Chang et al., 2003, 2005, 2008, 2012, 2013; Tong & McBride-Chang, 2009). In some of McBride's studies, it was found that children who were poor readers of either or both English and Chinese not only scored lower in phonological awareness and morphological awareness, but also RAN than their typical peers (McBride-Chang et al., 2012, 2013), suggesting that these cognitive-linguistic skills may be key contributors to reading development.

The cerebellar theory and magnocellular theory, the two remaining theories, are claimed to lack sufficient empirical support for a causal role of sensorimotor processes in dyslexia (Ramus et al., 2006). The cerebellar theory claims that dyslexia is associated with mildly dysfunctional cerebellum that plays a role in motor control, speech articulation, automatisation in learning of grapheme-phoneme correspondences and postural adjustments to maintain balance (Fawcett & Nicolson, 2004; Nicolson et al., 2001; Nicolson & Fawcett, 2011). However, while the cerebellum involves the control of movement, there have been no clinical studies that found patients who acquired alexia solely due to damage in the cerebellum (Beaton, 2004). In addition, while dyslexia and dyspraxia often co-occur, the relation to fine and gross motor difficulties that links dyslexia with cerebellar functions should be viewed more as a correlate rather than a cause of dyslexia, due a lack of neuroanatomical evidence that directly links cerebellar deficits with dyslexia (Bishop, 2002). There are other researchers who have failed to replicate these theories to find any evidence or found inconsistent evidence of cerebellar deficits in dyslexic readers (e.g., Irannejad & Savage, 2012; Ramus, 2003; Savage, 2004; Savage & Frederickson, 2006; Wimmer et al., 1998).

The magnocellular theory attempts to unify Cerebellar Theory, Phonological Theory and other alternative theories, and postulates that the magnocellular dysfunction is a generalised deficit in all modalities of visual, auditory and tactile pathways (Stein & Walsh, 1997), which means, some dyslexic readers may have binocular and visual perceptual instability that affect their orthographic skills in reading and cause the texts that they read to move as well (Stein, 2001). Some researchers, like Iles et al. (2000), found support for this theory in their comparison group study, and found that dyslexic readers who have visual problems related to magnocellular functions also have visual-attentional problems which may contribute to reading problems. The magnocellular system is considered a subdivision of the visual system which involves low level cognitive skills, such as motion and light perception (Beaton, 2004). Evidence from meta-analyses suggests that although children with reading difficulties may have low-level visual problems, empirical evidences point to higher level visual processes that underlie the development of visual pattern memory for word recognition in reading for readers in English (Hulme, 1988; Nazir & Huckauf, 2008). For Chinese reading, there are some researchers who investigated on the relationship between visual perceptual skills (McBride-Chang, Chow, et al., 2005; Siok & Fletcher, 2001; Yang et al., 2013) and grapho-motor skills (Huang, 2017; Lam et al., 2011) with learning of Chinese in two different scripts, indicating that these skills can be predictors of Chinese reading acquisition. However, there are no known studies that associate these visual perceptual skills and grapho-motor skills to deficits in magnocellular or cerebellar functions. The highly complex visual-spatial features of Chinese characters require high level cognitive skills, such as visual memory, which is probably beyond the basic perception functions of the magnocellular visual system. Research has supported that the relationship between low-level visual skills and Chinese reading are possibility mediated by higher level visual perceptual skills (Liu et al., 2021) which are used to form visual-verbal associations to enhance memory of visual representations of characters when reading (Yang et al., 2013).

Based on the literature discussed, the theories of phonological processing deficit, rapid naming deficit, morphological awareness deficit and orthographic processing deficit seem to explain

for developmental dyslexia in both English and Chinese but their prominence in predicting dyslexia and reading development in each language vary, possibly due to the difference in language and script. This brings the discussion to the next section in which cognitive-linguistic skills are explored in bilingual learners English and Chinese languages.

2.4 Behavioural Level

At the behavioural level of Frith's causal model, the literacy difficulties reflect the underlying cognitive deficits (e.g., phonological deficit, rapid naming speed) and consequences of environmental factors (e.g., bilingual context, nature of languages). This section will discuss the comparison studies that investigate on behavioural symptoms of bilingual learners of English and Chinese languages with and without dyslexia in the 3 major Chinese communities. Most of the studies are based on populations in Hong Kong (e.g., Chung & Ho, 2010; Chung & Lam, 2020; Ho & Fong, 2005; McBride-Chang et al., 2012; Tong et al., 2015; Tong & McBride, 2017; Wong et al., 2012; Yuen et al., 2008; Zhou et al., 2014), while there are some studies that based on populations in Mainland China (e.g., Ding et al., 2013; Harrison & Krol, 2007; Meng et al., 2016; You et al., 2011; Zhang et al., 2011). Studies on Mandarin Chinese bilingual population only have samples of poor readers instead of dyslexic samples, because dyslexia is formally diagnosed in Hong Kong, but not in Mainland China. Only one study investigated on poor readers in populations in both Hong Kong and Mainland China (e.g., McBride-Chang et al., 2013). As it is also my research interest to investigate bilingual learners of Chinese and English, these studies will be discussed in more detail in this section to fully understand the findings on reading and cognitive-linguistic skills in both languages.

Ho and Fong (2005) conducted a comparison study in Hong Kong between a total of 50 Cantonese Chinese-English bilingual primary school children with and without a dyslexia diagnosis. The control group was matched by chronological age and intelligence, and both dyslexic and control groups were tested on English vocabulary, English and Chinese word reading, and other cognitive-linguistic skills such as phonological awareness, rapid naming, orthographic skills and verbal memory. They found that the dyslexic group performed significantly worse than control groups in English

reading and vocabulary, Chinese reading and verbal memory and phonological awareness. Further correlational analysis found that the dyslexic group's English phonological awareness correlate with English reading but not Chinese phonological awareness with Chinese reading. The study suggests that phonological awareness may not play a strong role with Chinese reading, even though the dyslexic group has weaker phonological awareness in both English and Chinese than the control group.

Chung and Ho (2010b) conducted a more thorough investigation with a larger sample size of 84 similar aged primary school Cantonese Chinese-English bilinguals in Hong Kong and controlled for chronological age and reading age in their comparison study. They compared amongst three groups (dyslexic group, age-controlled group and reading-controlled group) which was of similar group size as Ho and Fong's (2005) study. It was found that the dyslexic group performed significantly poorer than age-controlled group in all aspects, namely English and Chinese reading, rapid naming, visual-orthographic knowledge, phonological awareness, and morphological awareness. Compared with reading-controlled group, the dyslexic group performed significantly poorer only in rapid naming and visual-orthographic knowledge. Similar to Ho and Fong's (2005) findings, it was also found that phonological difficulties in the dyslexic group were not associated with their Chinese reading problems but were with English reading problems. In addition, Chung and Ho's (2010b) correlational analysis showed two sets of interesting results: (1) Chinese rapid naming, morphological awareness and orthographic knowledge, and English rapid naming are strongly associated with Chinese reading, and (2) English phonological awareness, rapid naming and morphological awareness, and Chinese rapid-naming are strongly associated with English reading. Chung and Ho (2010b) suggested possible crosslinguistic transfer between cognitive-linguistic skills of first and second language reading development, but the authors did not explicitly discuss the crosslinguistic transfer. Nonetheless, the study provided an insight that rapid naming is associated to both English and Chinese reading, while orthographic knowledge is associated with Chinese reading and phonological awareness is associated with English reading, suggesting the difference between these languages and scripts.

It is important to note here that Ho and Fong's (2005) and Chung and Ho's (2010b) findings were based on dyslexic bilingual learners of similar age group and diagnosed using Hong Kong's standardised assessment in Cantonese Chinese. These studies did not specify if the English reading profiles of the dyslexic bilingual learners were similar or varied. In Ho and Fong's (2005) study, there was an interesting case study of a dyslexic group participant who had no reading problems in English and was good at some aspects of English phonological awareness task. The study suggested the possibility that a bilingual with dyslexia diagnosed in one language may not necessarily be poor in reading in both languages.

Tong et al. (2015) explored a different investigation that looked at poor readers (at risk of reading difficulties) in either Cantonese Chinese (L1) or English (L2), or both, to ascertain the risk of cross-language reading difficulties between the two languages, and compare the cognitive-linguistics skills between these groups. A total of 172 Grade 2 students and 165 Grade 5 students were selected from five different schools in Hong Kong, and were grouped into poor Chinese readers, poor English readers, poor readers in both, and control groups, according to their Chinese and English word reading task performances (25th percentile and below for poor readers). In this study, Tong et al. (2015) found that the prevalence of poor English readers among poor Chinese readers was 42% at Grade 2 and 57% at Grade 5, suggesting high risk of cross-language difficulties. For phonological awareness, poor readers of both languages and English only performed significantly weaker than poor readers in Chinese only and control groups across grades. For morphological awareness, poor readers of both languages and English only performed significantly weaker than poor readers in Chinese only and control groups across grades. Interestingly for tone awareness, poor readers of both languages and English only performed significantly weaker than poor readers in Chinese only and controls at Grade 2, but poor readers in English only performed significantly weaker than the other groups at Grade 5. The study seems to suggest that cognitive-linguistic skills like phonological awareness and tone awareness are possibly specific to the language systems.

To investigate if the above significant weaknesses in cognitive-linguistic skills persist in dyslexic individuals long-term, two-year longitudinal studies were also conducted in Hong Kong with Cantonese Chinese-English bilingual pre-schoolers who are at-risk of reading difficulties. Wong et al. (2012) investigated the prevalence of dyslexia diagnosis on 62 pre-schoolers with a diagnosed dyslexic sibling and 52 pre-schoolers who manifested clinical at-risk factors related to literacy. They found pre-schoolers with familial risk, language delay, poor Chinese character recognition and English letter naming to have greater risk of dyslexia after two years. They also found that boys have greater risk of dyslexia than girls. McBride-Chang et al. (2012) supplemented with a more intensive study that annually assessed smaller group size of 40 pre-schoolers who are poor Cantonese Chinese readers, poor English readers, poor readers in both languages and age-controls from age 5 to 9 years on their phonological awareness, morphological awareness and rapid naming speed. Similar to the findings of Tong et al.'s (2015) study, McBride-Chang et al. (2012) found that: (1) poor English readers, poor Chinese readers and poor readers in both languages performed significantly lower than age-controls on phonological awareness across years, (2) poor English readers and poor readers of both languages performed significantly lower than the others on English vocabulary across years, (3) poor Chinese readers and poor readers of both languages performed significantly lower than poor English readers and age-controls on morphological awareness across years, and (4) poor readers in both languages was significantly slower than the others on rapid naming across years. The results suggest the importance of automaticity in reading across orthographies and that morphological awareness is more associated with Chinese reading. Another interesting finding is that despite the pre-schoolers' ages and their mothers' education levels statistically controlled, mothers of poor English readers and poor readers in both languages had lower education levels as compared to those of other groups. The study seems to suggest that parents' educational levels could be both genetically- and environmentally-influenced factors that may influence children's reading development. That is, the poor readers' mothers may be poor readers themselves and their lower educational levels may then contribute to poorer home support in developing the children's reading ability.

The above two longitudinal studies by McBride-Chang et al. (2012) and Wong et al. (2012) investigated poor readers or at-risk pre-schoolers as a formal dyslexia diagnosis could not be done at their age. Zhou et al.'s (2014) longitudinal study investigated Cantonese Chinese-English bilingual pre-schoolers who had a diagnosis of dyslexia at the age of 6 and assessed their reading and cognitive-linguistic skills from the age of 6 to 8 years. The English word reading and vocabulary, Chinese word reading and vocabulary, phonological awareness, morphological awareness, and rapid naming speed were compared between 15 dyslexic pre-schoolers, 15 age-matched controls and 15 reading-matched controls. In this study, it was found that the dyslexic pre-schoolers were significantly weaker in Chinese reading and vocabulary, phonological awareness, morphological awareness and rapid naming but on par in English reading and vocabulary as compared to age-matched controls across ages. By the age of 8 years, age-matched controls significantly outperformed the dyslexic group in all aspects, and the dyslexic pre-schoolers outperformed reading-matched controls in all aspects, due to developmental maturity, except for rapid naming. Similar to McBride-Chang et al. (2012)'s longitudinal study, rapid naming deficit remained as the most persistent and severe deficit in Cantonese Chinese-English bilingual children with dyslexia. Overall findings from McBride-Chang et al. (2012) and Zhou et al. (2014) also suggest that dyslexia-related difficulties in reading and cognitive-linguistic skills are probably more prominent only by the age of 8 years in bilingual individuals.

The studies discussed thus far were investigated on Hong Kong's Cantonese Chinese-English bilingual learners. A longitudinal study by McBride-Chang et al. (2013) explored poor readers of English or Chinese only or both in both Hong Kong and Mainland China. Samples were obtained from 147 children from Hong Kong and 291 children from Mainland China, who started on the longitudinal study since infancy until the age of 8. There were grouped according to their reading performance on English and Chinese word reading tasks (25th percentile and below for poor readers). Across the samples between Hong Kong and Mainland China, it was found that 32% of poor readers in Chinese were also poor readers in English in Hong Kong while 40% of poor readers in Chinese were also poor readers in English in Mainland China. This further supports the notion that bilingual learners can possibly have

difficulties in reading of either languages or both. The study found that poor readers of both languages have significantly weaker phonological awareness, morphological awareness and rapid naming over time, as compared to the poor English readers, poor Chinese readers and age-controls. However, the study did not differentiate Hong Kong and Mainland China samples in their comparison in cognitive-linguistic skills, and hence it is not clear if there is any specific difference between the groups of Cantonese and Mandarin Chinese-English bilinguals. Nonetheless, this study suggested the possibility that cognitive-linguistic difficulties may differ by language orthography because they found that poor English readers and poor Chinese readers were on par in phonological awareness relative to age-controls but poor Chinese readers were weaker in morphological awareness relative to poor English readers, which once again suggests the association of phonological awareness with English and morphological awareness with Chinese.

Though comparatively fewer, studies on Mandarin Chinese-English bilinguals in Mainland China seemed to yield similar findings in reading and cognitive-linguistic difficulties to those studied in Hong Kong. One study by Ding et al. (2013) looked into the reading performance of 102 Mandarin Chinese-English bilingual Grade 4 children in English and Chinese and their rapid naming speed. They found that rapid naming deficits were significant in poor readers in both languages as compared to poor readers in Chinese or English only and reading performance in Chinese as first language was predictive of reading performance in English as second language and vice versa. The study highlighted that the participants in this study were recruited from families with relatively low socioeconomic status, as compared to the previous study by McBride-Chang et al. (2012) in which participants were recruited from a relatively better socioeconomic status, suggesting that rapid naming deficit may be persistent across different language and not influenced by socio-economic status.

The studies discussed thus far have been on pre-schoolers and children in the Chinese-English bilingual populations. The remaining studies to be discussed (i.e., Chung & Lam, 2020; Harrison & Krol, 2007; Tong & McBride, 2017; Zhang et al., 2011) investigated on Chinese-English bilingual learners who are adolescents or adults. Despite the difference in developmental and cognitive maturity,

findings from these studies still provide similar insights on reading and the cognitive-linguistic skills as the previously discussed studies which found deficits in phonological processing, orthographic processing, morphological awareness and rapid naming in adolescents who are poor readers or with dyslexia.

In Mainland China, Harrison and Krol (2007) compared 32 Mandarin Chinese-English bilinguals on their performance in English and Chinese word-level reading and phonological processing tasks, and they found that those who were at-risk of English reading difficulties performed significantly poorer than those who were not in English word reading, pseudoword decoding and repetition, phoneme deletion and detection measures. Interestingly, those who were at-risk of English reading difficulties were also found to perform significantly poorer in Chinese rhyme detection measures than those who were not. The study suggests the association between phonological awareness deficit and English reading difficulties, but this deficit may not necessarily affect Chinese reading, which is similar to the previous studies on younger children.

In Hong Kong, Tong and McBride (2017) investigated whether dyslexia diagnosed in Chinese is associated with English reading development, and compared 11 dyslexic learners and 14 non-dyslexic learners who were Cantonese Chinese-English bilingual adolescents in their development in English reading and English orthographic processing over a period of 4 years. It was found that the adolescents with dyslexia had more difficulties with English orthographic processing but did not differ in English reading performance as compared to their typical peers, suggesting that bilingual learners with dyslexia diagnosed in Chinese may manifest specific difficulties in English orthographic processing. Chung and Lam (2020) compared cognitive-linguistic skills (i.e., morphological awareness, phonological awareness, vocabulary knowledge, rapid naming, word reading and spelling) in both Chinese (L1) and English (L2) between adolescent learners with and without dyslexia. The study found that morphological awareness contributed strongly to word reading and spelling in both languages, while rapid naming contributed strongly only to English word spelling. Although the finding on rapid naming seems quite inconsistent with the previous studies discussed, Chung and Lam (2020) did find

that the bilingual learners with dyslexia performed significantly poorer in reading and cognitive-linguistic skills in both languages than those without dyslexia, which is consistent with the previous studies (e.g., McBride-Chang et al., 2012, 2013).

While these studies from Hong Kong and Mainland China are available and still considered closest to Singapore's context, there are social and pedagogical differences in the use and learning of both languages. There are also some cultural differences between Hong Kong and Mainland China because of the use of Cantonese and Mandarin Chinese. Nonetheless, these studies have provided valuable insights for the purpose of this thesis on how dyslexia is manifested in bilingual learners' reading of both languages and the underlying cognitive-linguistic difficulties, namely processing speed (e.g., Chung & Ho, 2010b; Ding et al., 2013; McBride-Chang et al., 2012, 2013; Zhou et al., 2014), visual orthographic knowledge and word recognition (e.g., Chung & Ho, 2010b; Tong & McBride, 2017), phonological awareness and tone awareness (e.g., Chung & Lam, 2020; Harrison & Krol, 2007; McBride-Chang et al., 2013; Zhou et al., 2014), and morphological awareness and vocabulary (e.g., Chung & Lam, 2020; McBride-Chang et al., 2013; Tong et al., 2015; Zhou et al., 2014). Longitudinal studies have suggested that dyslexia-related difficulties in reading in both languages and cognitive-linguistic skills (i.e., phonological awareness, morphological awareness, and rapid naming speed) are more prominent only by the age of 8 years in bilingual individuals (McBride-Chang et al., 2013; Zhou et al., 2014). These findings are very much aligned to McBride's (2019, p. 34) "the fab four: cognitive constructs for word reading" model which proposed four cognitive-linguistic skills that are essential for learning to read and understanding dyslexia, which point to the direction of the current research.

3. "The Fab Four: Cognitive Constructs" in Understanding Dyslexia and Cognitive-linguistic

Differences in Bilingual Learners of English and Chinese Languages

Morton and Frith (2001) highlighted the essential role of cognition in bridging the gap between brain and behaviour, and that environmental factors (i.e., language orthography, linguistic culture) impacts on cognition and behaviour. This aligns with the notion that language development is based on connections between language and cognition and culture in dual language learners (Paradis et al.,

2011). McBride (2019) has proposed four cognitive-linguistic skills (i.e., phonological awareness, orthographic knowledge, morphological awareness and fluency) as measurable criteria and useful constructs for assessing the degree of or risk of dyslexia, and in training children with dyslexia to learn to read better using the strategies targeting the respective cognitive-linguistics skills that are assessed to be their strengths or weaknesses.

According to McBride (2019), children who have difficulties in identifying stress patterns or lexical tone usage in their native languages tend to have greater risks for dyslexia. In view of the difference in language and script, phonological awareness can be a key predictor for risks of reading problems in English (Badian, 2001; Griffiths & Snowling, 2002; Snowling, 1998) and includes stress patterns in English reading (De Bree et al., 2006; Goswami et al., 2013). Although phonological awareness may seem to be specific to alphabetic languages, syllable-level or onset-rime level awareness can be important to languages that do not involve the alphabetic script, such as Chinese (e.g., Li et al., 2012b; Lin et al., 2010; McBride-Chang et al., 2012; McBride-Chang & Kail, 2002; Shu et al., 2008; Siok & Fletcher, 2001) and may include tonal pronunciation in Chinese reading (Cheung et al., 2009; Li & Ho, 2011; Shu et al., 2008; Zhang et al., 2012).

McBride (2019) explains orthographic knowledge is knowledge of how words are written in a given script that can be consciously or subconsciously built over time in those who are learning to read, and suggests that it facilitates motor memory and recognition of orthographic patterns in words. Orthographic Knowledge plays a role in English reading (Badian, 2001; Cunningham et al., 2001, 2002) and Chinese reading (e.g., Chen et al., 1995; Li et al., 2012; Lin et al., 2016; Tan et al., 2005). It can also be a possible deficit in surface dyslexia in English (Hanley et al., 1992) as well as in Chinese readers with dyslexia (Ho et al., 2002, 2004). McBride (2019) suggests that this cognitive-linguistic skill can be tested across languages by getting individuals to distinguish correctly and incorrectly written words.

Morphological awareness is predictive of vocabulary knowledge and learning to read across languages, and is an important skill for reading and understanding the semantics of language (McBride, 2019). It is also found to be linked to dyslexia in English (e.g., Joanisse et al., 2000; Siegel, 2008) and

in Chinese (e.g., Liu et al., 2013; McBride-Chang et al., 2003; Shu et al., 2006). It has been argued that morphological awareness is related to orthographic knowledge of words because of the need to recognise parts of compound words and morphologically complex words in English (e.g., Marslen-Wilson et al., 1994; McBride-Chang et al., 2005) as well as the compound words and radical components within a character in Chinese (e.g., Cheng-Lai, 2010; Li et al., 2012).

RAN is related to fluency as this skill taps on children's ability to process information and execute tasks quickly and efficiently (McBride, 2019), and has been found to be a prominent predictor of reading development across languages, especially in English and Chinese (e.g., Chung & Ho, 2010a; Chung & Lam, 2020; Ding et al., 2013; Landerl et al., 2019; Landerl & Wimmer, 2008; McBride-Chang et al., 2012, 2013; Savage, 2004; Savage et al., 2005; Torgesen et al., 1997; Wolf, 1999; Wolf et al., 2000, 2002; Wolf & Bowers, 2000). Hence, McBride (2019) suggests rapid naming as one of the constructs to measure fluency as a cognitive-linguistic skill to understand dyslexia.

McBride (2019) has highlighted that each cognitive-linguistic skill, discussed above, can differ in relative importance for reading development and impairment because of the different languages and writing systems. It is the interest of this thesis to use McBride's (2019) model in the research inquiry to investigate the manifestation of dyslexia and the underlying cognitive-linguistic skills for reading development of Singapore's bilingual learners in English and Chinese languages.

4. Theoretical Framework of the Thesis

The thesis research will test McBride's (2019, p. 34) "the fab four: cognitive constructs for word reading" model by investigating English-Chinese bilingual learners' phonological awareness, orthographic knowledge, morphological awareness and fluency (i.e., rapid naming) in relation to dyslexia and reading development in both languages. McBride (2019) has summarised the findings from the existing literature and identified four broad categories of cognitive-linguistics skills that are associated with reading development and dyslexia across languages. As there is no similar research conducted in Singapore's bilingual population, several studies that investigated cognitive-linguistic skills in relation to dyslexia and reading in both languages in Chinese-English bilingual populations in

Mainland China, Hong Kong and Taiwan, were explored (e.g., Chung & Ho, 2010b; Chung & Lam, 2020; Ho & Fong, 2005; McBride-Chang et al., 2008, 2012, 2013; McBride-Chang & Kail, 2002; Tong & McBride, 2017; Tong & McBride-Chang, 2009; Zhou et al., 2014). Given the differences in the bilingual contexts of Singapore, Mainland China and Hong Kong, it is my research interest in this thesis to explore whether the cognitive-linguistics skills of the bilingual learners with and without dyslexia will be similar to the findings of the existing studies on Chinese-English bilingual learners. Moreover, dyslexia is a language-based difficulty that may affect the reading development of English and Chinese differently, depending on the pedagogical factors and social factors of the linguistic environment (Paradis et al., 2011; Thomson, 2003; Wen et al., 2017) as well as the individual's cognitive abilities and nature of language (Brunswick, 2010; Comeau et al., 1999). The investigation of the association of the cognitive-linguistic skills with English and Chinese reading of the bilingual learners may shed some light on the possible influence of environmental linguistic factors in learning to read and the identification of dyslexia in Singapore.

The definition and assessment of dyslexia in Singapore has been based on the country's first language, which is English, even though the learners are bilingual. According to the dual language developmental theory, bilingual learners may vary in proficiency in both languages due to the amount of exposure and use of the languages, and different cognitive demands related to the nature of languages (Hoff et al., 2012; Yang, 2017). Hence, it is imperative to understand how dyslexia impacts on the bilinguals in their reading development in both languages rather than only one. There are two main research interests in the thesis. The first research interest is to investigate whether the English-Chinese bilingual learners with dyslexia diagnosed in English in Singapore are weaker in reading and all four cognitive-linguistic skills in both languages or either language, as compared to their typical counterparts. The second research interest is to investigate which cognitive-linguistic constructs are strong predictors of reading in each language in English-Chinese bilingual learners in Singapore.

As the bilingual learners with dyslexia are diagnosed in Singapore's first language, it is likely that the bilingual learners with dyslexia are weaker in reading and all four cognitive-linguistic skills in

English as compared to their typical counterparts. Based on the dyslexia studies on Chinese-English bilingual learners (e.g., Chung & Ho, 2010b; Chung & Lam, 2020; Ho & Fong, 2005; McBride-Chang et al., 2008, 2012, 2013; McBride-Chang & Kail, 2002; Tong & McBride, 2017; Tong & McBride-Chang, 2009; Zhou et al., 2014), it is likely that the bilingual learners with dyslexia are weaker in all four cognitive-linguistic skills in Chinese if they are poor in Chinese reading as well. However, it is unsure how these cognitive-linguistics skills are associated with English and Chinese reading for English-Chinese bilinguals in Singapore. Therefore, a new model will be developed to predict how each of these cognitive-linguistic skills are associated with English and Chinese reading of Singapore's bilingual learners, by considering the well-established theories and empirical research in the literature.

As English language is first language in Singapore, the order of association of the cognitive-linguistics skills will take reference from theories of dyslexia based on monolinguals of English language as well as the findings from Chinese-English bilingual studies. The predictive model will place phonological awareness and rapid naming first in association in view of the double deficit theory (Wolf, 1999; Wolf & Bowers, 1999, 2000) which states that deficits in both phonological awareness and rapid naming presents the most severe form of dyslexia. Moreover, phonological awareness has been found to be associated with English reading as an alphabetic language (e.g., Bradley & Bryant, 1983; Bruck & Treiman, 1990; Chafouleas et al., 1997; Liberman et al., 1972; Lyon, 1995; Ramus, 2003; Snowling, 1998; Stanovich, 1988a, 1988b, 1996; Wagner et al., 1997) and rapid naming has been found to be a persistent deficit in dyslexic and poor readers in English across ages in the Chinese-bilingual studies (e.g., Chung & Lam, 2020; McBride-Chang et al., 2012, 2013; Zhou et al., 2014). With both phonological awareness and rapid naming considered, the predictive model will place morphological awareness and orthographic knowledge in subsequent steps to explore if these cognitive-linguistic skills also play a role in predicting English reading development. There are studies, though comparatively fewer, that found morphological deficits present in English dyslexic readers and are associated to reading ability (e.g., Casalis et al., 2004; Deacon et al., 2008; Joanisse et al., 2000; Siegel, 2008). However, orthographic deficits in dyslexic or poor readers in English have not been as widely studied and has

not always been found to be a strong predictor of reading (e.g., Badian, 2001; Cunningham et al., 2001, 2002; Tong & McBride, 2017). Nonetheless, orthographic knowledge is considered part of the reading developmental stages in English (Frith, 1986; Kuerten et al., 2020). Hence, the predictive model will explore the order of association of these cognitive-linguistic skills by first considering phonological awareness and rapid naming, and then morphological awareness and orthographic as predictors of English reading development.

As only empirical research on Chinese-English bilinguals in the 3 major Chinese communities are available, the order of association of the cognitive-linguistics skills will take reference from studies based on monolinguals of Chinese language as well as Chinese-English bilinguals, even though Chinese language is considered a second language in Singapore. The predictive model will first place morphological awareness and rapid naming in the order of association because morphological deficits have been found to have strong links with dyslexia in studies conducted on Chinese and bilingual readers, due to the presence of homophones and semantic-phonetic radicals within Chinese characters (e.g., Liu & McBride-Chang, 2010; McBride et al., 2008; McBride-Chang et al., 2003, 2008, 2012, 2013; McBride-Chang et al., 2005; Shu et al., 2006; Tong & McBride-Chang, 2009). Rapid naming was found to be a very strong predictor of reading difficulties, not only in English but also in Chinese, and possibly the most severe deficit in Chinese children with dyslexia (e.g., Chung & Ho, 2010b; Chung & Lam, 2020; Ding et al., 2013; Ho et al., 2002, 2004; McBride-Chang et al., 2012, 2013; Zhou et al., 2014). With both morphological awareness and rapid naming considered, the predictive model will place orthographic knowledge and phonological awareness in subsequent steps to explore if these cognitive-linguistic skills also play a role in predicting Chinese reading development of Singapore's bilingual learners. Given the presence of stroke patterns and radicals in Chinese scripts (Chen et al., 1996; Li et al., 2012), there are some studies that found orthographic knowledge associated with Chinese reading (e.g., Chen et al., 1995; Li et al., 2012; Lin et al., 2016; Tan et al., 2005) as well as presence of orthographic deficit in Chinese readers with dyslexia (Ho et al., 2002, 2004). For phonological awareness, there exists mixed empirical evidence on whether phonological awareness

assessed at syllable or tone awareness level is associated with Chinese reading, as some studies found association (e.g., Chung & Ho, 2010b; Chung & Lam, 2020) while others did not (e.g., Harrison & Krol, 2007; Ho & Fong, 2005). Hence, the predictive model will explore the order of association of these cognitive-linguistic skills by first considering morphological awareness and rapid naming, and then orthographic knowledge and phonological awareness as predictors of Chinese reading development.

Findings from this study may shed some light on the way dyslexia is defined and identified in Singapore and perhaps serve as a reference to other bilingual countries where dyslexia is diagnosed only based on first language. The prediction models generated based on the data from this study will also illuminate whether bilingual learners share the same cognitive-linguistic skills as predictors of English and Chinese reading regardless of first or second languages, and the possible environmental impact on learning to read (i.e., language use and bilingual educational settings).

5. Research Questions

The study hopes to shed some light on the impact of dyslexia on bilingualism by investigating how dyslexia affects the reading development and cognitive-linguistic skills of English-Chinese bilingual learners in Singapore. The study seeks to answer the following research questions:

1. Are there significant differences in reading and the four cognitive-linguistic skills in both languages between English-Chinese bilingual learners with and without a diagnosis of dyslexia in English in Singapore?
2. How are the four cognitive-linguistic skills associated with English and Chinese reading development in English-Chinese bilingual learners in Singapore?

6. Research Hypotheses

For Research Question 1, it is hypothesised that dyslexic learners will perform poorer in reading and all four cognitive-linguistic skills in English than typical learners because their dyslexia diagnoses were based on English. However, the dyslexic learners may have varying proficiency in Chinese in comparison with the typical learners. So, it is also hypothesised that if the dyslexic learners perform poorer in Chinese reading than typical learners, they will perform poorer in all four cognitive-

linguistic skills in Chinese than their typical learners as well. But, if they perform the same as or better in Chinese reading than typical learners, there will be no difference between the learners with and without dyslexia.

Table 4 below provides a summary of the hypothesised performance in cognitive-linguistic skills in English and Chinese for Research Question 1.

Table 4

Summary of the hypothesised performance in cognitive-linguistic skills in English and Chinese for Research Question 1

	English language	Chinese language
Phonological Awareness	Dyslexia group will perform significantly weaker than control group.	Dyslexia group with poor Chinese reading will perform significantly weaker than control group. There will be no significant differences between dyslexic group and control group, if the dyslexia group perform the same as or better in Chinese reading than control group.
Morphological Awareness	Dyslexia group will perform significantly weaker than control group.	Dyslexia group with poor Chinese reading will perform significantly weaker than control group. There will be no significant differences between dyslexic group and control group, if the dyslexia group perform the same as or better in Chinese reading than control group.
Rapid Naming	Dyslexic group will perform significantly weaker than control group.	Dyslexic group with poor Chinese reading will perform significantly weaker than control group.

		There will be no significant differences between dyslexic group and control group, if the dyslexia group perform the same as or better in Chinese reading than control group.
Orthographic Awareness	Dyslexic group will have no significant performance difference with control group.	Dyslexic group with poor Chinese reading will perform significantly weaker than control group. There will be no significant differences between dyslexic group and control group, if the dyslexia group perform the same as or better in Chinese reading than control group.

For Research Question 2, there are two prediction models to test the association of the cognitive-linguistic skills with English and Chinese reading respectively based on the theories and empirical evidence drawn from the literature review. For English reading, it is hypothesised that both Phonological Sensitivity and Rapid Naming will be significant predictors of reading, and Morphological Awareness and Orthographic Knowledge should still be significant predictors of reading after Phonological Sensitivity and Rapid Naming are controlled. For Chinese reading, it is hypothesised that both Morphological Awareness and Rapid Naming will be significant predictors of reading, and then Orthographic Knowledge and Phonological Sensitivity should still be significant predictors of reading after Morphological Awareness and Rapid Naming are controlled.

Table 5 below shows a summary of the hypothesised association of cognitive-linguistic skills with English and Chinese reading for Research Question 2.

Table 5

Summary of the hypothesised association of cognitive-linguistic skills with English and Chinese reading for Research Question 2

	Association of Cognitive-linguistic skills ordered
English Reading	<ol style="list-style-type: none">1) Phonological Sensitivity2) Rapid Naming3) Morphological Awareness4) Orthographic Knowledge
Chinese Reading	<ol style="list-style-type: none">1) Morphological Awareness2) Rapid Naming3) Orthographic Knowledge4) Phonological Awareness

The next chapter on research methodology discusses the research ethics, and how the research instruments were adopted and adapted to measure reading and the cognitive-linguistic skills in English and Chinese. It also discusses sampling and data collection processes of a pilot study and the main study, as well as the quantitative data analysis approach in which the thesis adopted to answer the above research questions and test the hypotheses.

THE PILOT STUDY AND THE MAIN STUDY

In this thesis, the research aims are to investigate the differences in the cognitive-linguistic skills between English-Chinese bilingual learners with and without dyslexia, as well as the cognitive-linguistic skills that are associated with reading development in English and Chinese bilingual learners in Singapore. The present study seeks to understand whether the manifestation of dyslexia is similar or different in a bilingual population (i.e., Singapore) that is linguistic-contextually different from other bilingual populations (i.e., Mainland China, Hong Kong and Taiwan). The present study measures the reading and cognitive-linguistic skills in both languages using established and adapted assessment tasks that are suitable for Singapore's linguistic context.

However, standardised and established tools are less available for task measurements in Chinese as compared to English. Based on the literature review, most studies that investigated Chinese cognitive-linguistic skills utilised test instruments which were locally developed for the Chinese-English bilingual populations (e.g., Chung & Ho, 2010; Chung & Lam, 2020; Ding et al., 2013; Harrison & Krol, 2007; Ho & Fong, 2005; McBride-Chang et al., 2012, 2013; Meng et al., 2016; Tong et al., 2015; Tong & McBride, 2017; Wong et al., 2012; You et al., 2011; Yuen et al., 2008; Zhang et al., 2011; Zhou et al., 2014). Therefore, a pilot study is first conducted to ensure suitability of the non-standardised assessment tasks by examining the content validity before they are utilised in the main study. Standardised and established tools that are available, such as the 5th edition of Wide Range Achievement Test (WRAT-5) and the 2nd edition of the Comprehensive Test of Phonological Processing (CTOPP-2), are utilised in the main study. The non-standardised assessment tasks established from previous research are utilised in this study by obtaining permissions from research authors.

1. Pilot Study

1.1 Introduction

The pilot study adopts a qualitative methodology that describes the task scores and feedback data to examine the content validity of the non-standardised assessment tasks. The purpose of the pilot study was to formatively assess the suitability of the non-standardised assessment tasks and

testing procedures prior to the implementation of the main study (Heiman, 2001). Bearing in mind the cultural and linguistic differences, the non-standardised assessment tasks are adapted according to Singapore's school curriculum, wherever possible, to suit the linguistic context of Singaporean English-Chinese bilingual learners. The pilot study was conducted during the months of April and May in 2021.

Suitability of the research instruments was examined by the scores, verbal feedback and behavioural observations from the participants who were English-Chinese bilinguals, aged between 9 years 0 months and 9 years 11 months. After each assessment task was completed, the participants were asked if they thought the test items were difficult or easy and why. Their verbal feedback and behavioural responses (i.e., anxious, stressed, or relaxed expressions) were noted down in a memo and examined together with the scores they obtained for each assessment task. In addition, feedback on the age- and curriculum appropriateness of the test items were also sought from the researcher's personal contacts of field experts, which consisted of five experienced mainstream school educators and educational therapists. The test items were shared with the field experts and their feedback on the appropriateness of the test items were collected via email. Open-ended questions were asked, such as "Are the test items age- and curriculum appropriate for the study participants aged between 9 years 0 months and 9 years 11 months? Which test items are not, and why?". The feedback from the field experts were also examined together with the participants' scores and feedback for each assessment task. Gathering feedback about the test items allows for an evaluation on whether the test items are measuring what they are intended to measure or need alteration, and if demand characteristics are minimised (Heiman, 2001).

The pilot study sought to answer the following questions:

1. Is the Chinese Single Word Reading task, developed based on Singapore's primary school Chinese language curriculum (MOE, 2015a), a suitable test in terms of age- and curriculum appropriateness for the study participants?
2. Is the Phonological Awareness task in Chinese, adapted from Lin et al. (2016), a suitable test in terms of age- and curriculum appropriateness for the study participants?

3. Is the Orthographic Knowledge task in English, adapted from Cunningham et al. (2001), a suitable test in terms of age- and curriculum appropriateness for the study participants?
4. Is the Orthographic Knowledge task in Chinese, adapted from Lin et al. (2016), a suitable test in terms of age- and curriculum appropriateness for the study participants?
5. Are the Morphological Awareness tasks in English and Chinese, adapted from O'Brien et al. (2021), suitable tests in terms of age- and curriculum appropriateness for the study participants?
6. Is the Rapid Naming task in Chinese, adapted from Li et al. (2012), a suitable test in terms of age- and curriculum appropriateness for the study participants?

1.2 Research Methods

1.2.1 Participants

Five English-Chinese bilingual participants, aged between 9 years 0 months and 9 years 11 months, participated in the pilot study on a voluntary basis. They were 3 boys and 2 girls, and their mean age was 111.2 months ($SD = 3.96$) who were studying in mainstream primary schools and had no reported learning difficulties. This age range is appropriate based on Singapore's primary school curriculum for English and Chinese language subjects, as they will have an adequate amount of exposure to word recognition and reading fluency (MOE, 2010, 2015a). Another reason for selecting this age range is because of the learning support practice in mainstream primary schools which provides early intervention for the struggling learners at Primary 1 and 2 to bridge the gap between them and their typical peers of the same level (MOE, 2021). This learning support practice is also part of the RTI approach which MOE adopted to identify and assess students with dyslexia, and students are typically diagnosed with dyslexia at that age if they continue to struggle with reading after attending LSP (MOE, 2018, 2021). Moreover, in the longitudinal studies by McBride-Chang et al. (2013) and Zhou et al. (2014), difficulties in reading and reading-related skills were found to stabilise after the age of eight years for Chinese-English bilingual readers.

1.2.2 Recruitment Process

Recruitment of participants was done through opportunity sampling within the researcher's personal network. Some parents of children aged between 9 years 0 months and 9 years 11 months were approached through personal contacts and invited to participate in the pilot study. The Participant Information Sheet and Consent Form was shared so that they understood the research that I am undertaking. I also personally explained to the parents via phone call to explain the purpose of the pilot study and that a summary of their children's test performances would be shared with them after the tests were administered.

1.2.3 Research Instruments

There are five sets of research instruments for the main study. The first set of research instruments is the English and Chinese Single Word Reading Tasks to measure the reading performances in both languages of the bilingual learners. The other four sets of research instruments are the cognitive-linguistic assessment tasks in both languages. The cognitive-linguistic skills assessment tasks followed McBride's (2019) proposal in measuring Phonological Awareness, Morphological Awareness, Orthographic Knowledge and Fluency (i.e., Rapid Naming) in both English and Chinese languages. As discussed in the literature, McBride (2019) suggested rapid naming tasks as a cognitive-linguistic skill construct to measure fluency as rapid naming is related to children's fluency in processing information and executing tasks quickly and efficiently. It also has been found to be a prominent predictor of reading development across languages, especially in English and Chinese (e.g., Chung & Ho, 2010a; Chung & Lam, 2020; Ding et al., 2013; Landerl et al., 2019; Landerl & Wimmer, 2008; McBride-Chang et al., 2012, 2013; Savage, 2004; Savage et al., 2005; Torgesen et al., 1997; Wolf, 1999; Wolf et al., 2000, 2002; Wolf & Bowers, 2000). Hence, for clarity, the term "fluency" is replaced with "rapid naming" to reflect the nature of the task measure.

Single Word Reading Tasks. As standardised and established assessment tools are available for English Word Reading (i.e., WRAT-5), only the Chinese Single Word Reading task is examined for its suitability in the pilot study. The Chinese Single Word Reading task is developed based on the

primary school Chinese language character list taken from the curriculum website of Singapore's MOE (MOE, 2020). The primary school Chinese language character list is categorised the Chinese characters for reading and writing at every primary level and by learning units (MOE, 2015b). 96 characters were selected systematically by selecting the 5th character for reading under each learning unit for every primary level (see Appendix 5 for the word list of Chinese Single Word Reading Task). The test items (96 characters) are arranged in rows of 6 characters, from Primary 1 to 6 based on the curriculum. Based on the feedback gathered from mainstream school educators, participants should be able to recognise the characters learnt before up to the day they undertake the test. Hence, the participants' reading performance can be determined if they are below, appropriate at or above the current curriculum level.

The task consists of clear instructions in both English and Chinese that are provided verbally to ensure participants understood the requirements before testing began. Participants are asked to read the words aloud, and accuracy of their responses are scored and reading errors are recorded accordingly. The participants' reading performance are measured based on the raw scores obtained through reading the Chinese language character list by levels. For curriculum-appropriate performance in Chinese, the participants should be able to read the characters up to Primary 3 or 4 level according to the current curriculum level the participant is at during the time of testing. For example, a Primary 3 child should be able to read more than half of the characters at Primary 1 and 2 levels, and up to Primary 3 level, to be considered 'curriculum-appropriate'. Participants who are unable to read the characters in list up to Primary 3 or 4 level according to the current curriculum level the participant is at during the time of testing will be considered below-curriculum performance in Chinese reading.

Phonological Awareness Task. For the Phonological Awareness task in English, there are standardised assessment tools available (i.e., CTOPP-2). So, only the Phonological Awareness task in Chinese was examined for its suitability in the pilot study. A phonological awareness task adapted from Lin et al. (2016) was utilised to measure syllable deletion, onset deletion, rime deletion in Chinese

during the pilot study. The tasks were used in Mainland China with children from kindergarten to Grade 1 age group and was reported to have a reliability coefficient (Cronbach's alpha) of .84. Approval was sought from the authors to utilise their tool in the study for children in Singapore (see email attached under Appendix 6).

The Phonological Awareness task has 20 test items in total. There are 8 items for syllable deletion, in which participants are asked to produce a new set of words after removing the specified syllable (e.g., say “红太阳” /hóng tài yáng/ without “红” /hóng/, and the answer is “太阳” /tài yáng/). There are 6 items for onset deletion, in which participants are asked to produce the remaining sound after removing the specified onset (e.g., say “红” /hóng/ without the beginning sound /h/, and the answer is /óng/). There are 6 items for rime deletion, in which participants are asked to produce the remaining sound after removing the specified rime (e.g., say “红” /hóng/ without the ending sound /óng/, and the answer is /h/). The task is only oral and auditory, and no print is involved. Participants are asked to provide their answers verbally, and accuracy of their responses and errors are scored and recorded accordingly. In view of some participants who may not be fluent in the Chinese language, the Chinese instructions has been translated into English to ensure that the less fluent participants understand the task requirements (see Appendix 7). There are also practice items to ensure consistency in the test procedures and that the participants understand the instructions and requirements before testing.

Orthographic Knowledge Task. There are no standardised assessment tools available for orthographic knowledge in English and Chinese. Hence, established and non-standardised tests developed from previous studies (i.e., Cunningham et al., 2001; Lin et al., 2016) are explored. For Orthographic Knowledge task in English, permission was sought from the author in Cunningham et al.'s (2001) study to utilise and adapt the Orthographic Choice Test (see email attached under Appendix 8). Cunningham et al.'s study was a longitudinal study investigating the development of orthographic knowledge of children from 1st graders to 3rd graders in Canada. Cunningham et al.

adapted the test from the original authors, Olson and colleagues (Olson et al., 1985, 1989), for the purpose of their study and the test was reported to have a split-half reliability coefficient of 0.84.

Same as the Orthographic Choice Test, the Orthographic Knowledge Task in English consists of 23 test items. The participants are presented a pair of words that are pronounced the same but one of them is not spelled correctly (e.g., “book” and “buke”) and are asked to identify which one is correctly spelled (e.g., the answer is “book”). The advantage of using this test is that having pairs of words that are phonetically correct but differentiated with incorrect spelling, and not read aloud to the participants, requires their ability to use their phonological recoding and access their lexical representation to determine which word is correctly written (Cunningham et al., 2001). As the task has no practice item, 3 practice items are created for practice trials to ensure that participants understand the instructions and requirements before testing (Heiman, 2001).

For the Orthographic Knowledge task in Chinese, permission was sought from authors in Lin et al.'s (2016) study to utilise and adapt the task (see email in Appendix 6). The task was used in Mainland China with children from kindergarten to Grade 1. Although the age group used in their study was younger, the difficulty level of the task was observed to be quite high. Lin et al. (2016) adapted the task from the original authors in Li et al.'s (2012) study with kindergarten to Grade 3 children in Mainland China and the task was reported to have internal consistency reliability (Cronbach's alpha) of .96. Hence, the test items were not modified, except for the task instructions, as some of the characters in the test items can be found in Singapore's primary school Chinese syllabus. There were 14 rows of 5 Chinese characters (i.e., a total of 70 characters). The participants are presented a row of 5 characters each time and are asked to identify which characters follow the general radical positions, such as “唱/昌口”. The task has no practice items, and so they were created for practice trials to ensure that participants understand the instructions and requirements before testing (Heiman, 2001). In view of some participants who may not be fluent in Chinese, the Chinese task instructions are also translated into English to ensure that the less fluent participants understand the task requirements.

Morphological Awareness Task. There are no standardised assessment tools for morphological awareness in English and Chinese available. However, there is a set of non-standardised morphological tasks developed locally for Singapore’s population by Dr Beth Ann O’Brien (OER, CRCD) and her research team at the National Institute of Education, which has been piloted and obtained initial data collected from Preschool Nursery Year 2 to Primary 3 children in Singapore (O’Brien et al., 2021). Permission was obtained from O’Brien et al. (2021) to use and adapt their morphological tasks in both English and Chinese for the purpose of this study (see Appendix 10). According to O’Brien et al. (2021), the morphological awareness tasks were adapted from previous research (e.g., Ku & Anderson, 2003; Levesque et al., 2019; Liu & McBride-Chang, 2010; Wei et al., 2014).

Both the tasks in English and Chinese consist of two subtasks. For the first subtask, the Morpheme Discrimination sub-task measures the participants’ ability to understand that a word part may have different meanings in different complex words. Each test item presents three words that share a common part, wherein the common part in one of these words has a different meaning. The requirement of both tasks in English and Chinese is for the participant to select the odd one out, such as “highlight, starlight, sunlight” in the English version and “地球[earth], 篮球[basketball], 足球[football]” in the Chinese version. For the second subtask, the Select Interpretations subtask measures the participants’ ability to use the morphological structural knowledge of compounds and derivatives to choose accurate interpretations of low-frequency derived and compounded words that contained high-frequency base words. For example, in the English version, the word “build” is a high-frequency base word, but the derived word “rebuild” is a low-frequency word. In the Chinese version, the word “跑[run]” is a high-frequency base word, but the derived word “赛跑[race]” is a low-frequency word. In both subtasks in English and Chinese, the participant is asked to select one out of the four alternative responses that best matches the meaning of the word. For example, in the English task, the participant is shown the word “rebuild” and asked to choose the correct response from the four options displayed: (a) a tall building, (b) a man whose job is to build houses, (c) to build again, (d) to build a house with bricks. The same process applies for the Chinese task.

The English task consists of 29 test items for Morpheme Discrimination and 24 test items for Select Interpretations (i.e., a total of 53 test items). The Chinese task consists of 24 test items for Morpheme Discrimination and 24 test items for Select Interpretations (i.e., a total of 48 test items). There are no practice items in the original tasks, except for the second subtask of the original task in Chinese. Nonetheless, the original tasks were carried out as they were in the pilot study and the participants' responses were observed. The original task administration also required the test items to be read aloud to the participants so that their test performance are influenced by their reading abilities. In view of some participants who may not be fluent in Chinese, the Chinese task instructions has been translated into English to ensure that the less fluent participants understand the task requirements.

Rapid Naming Task. McBride (2019) suggested the use of RAN tasks in English and Chinese to capture fluency as one of the cognitive-linguistic skills. She suggested the use of English letters for the English task and simple Chinese characters in numbers (e.g., 一、五、八) for the Chinese task, as the purpose is to measure the speed of processing in the specific language. As standardised assessment tools are available for English Rapid Naming (i.e., the Rapid Letter Naming subtest from CTOPP-2), only the Chinese fluency task was developed and examined for suitability in the pilot study.

The task was developed and guided in its format based on the Rapid Number Naming procedures from Li et al.'s study (2012) but followed McBride's (2019) suggestion to use Chinese characters for numbers (i.e., 一、三、四、五、八). In Li et al.'s study (2012), the five numbers were repeated five times on a single sheet of paper. For this study, the five Chinese number characters were randomly arranged in 7 rows of 5, to align with the Rapid Letter Naming subtest of CTOPP-2 which consists of 36 stimuli with 6 English letters. In view of some participants who may not be fluent in Chinese, the Chinese task instructions are translated into English to ensure that the less fluent participants understand the task requirements. Both tasks also have practice items to ensure that the participants understand the instructions and requirements before testing (Heiman, 2001).

1.2.4 Data Collection and Administration of Research Instruments

The data collection for the pilot study was conducted between April and May in 2021, when the Covid-19 situation was increasingly severe and safe management measures started to tighten to reduce risk of community spread (Government of Singapore, 2021). In view of the dynamic Covid-19 situation and safe management measures, the data collection had to be conducted in two modes (i.e., physically face-to-face or online via zoom) so that participants were allowed to choose either mode of administration. The physical administration of the tasks for the participants was conducted at a convenient time and conducive venue agreed by the parents of the participants, and strictly adhered to the national regulations set out in the Covid-19 Safe Management Measures (Government of Singapore, 2021). For the participants who chose the online mode, a secured private Zoom invitation link was sent to them to log in at specified time for the session. They were asked to ensure that the environment was conducive following a set of instructions: (1) Strong internet connection, (2) Use only laptop with working microphone and speakers/headphones, and (3) A quiet environment with no distractions from noise or presence of a family member at home. This was to ensure that the environment for the online session was as similar as the environment for the physical session.

The online administration of the research instruments was undertaken in a way that is similar to the physical administration as much as possible. All the research instruments were presented on PowerPoint slides and shared on screen. Instructions were provided either verbally or through audio-recording during the physical session and using the speakers via the Zoom app during the online session. The participant sat in front of the screen and provided their answers verbally during the physical session and using the microphone via the Zoom app during the online session. Of the five pilot study participants, two opted for online mode of administration and three opted for physical mode of administration. Administration of the research instruments with the participants in either mode was smooth and uneventful.

As part of the ethical consideration for the community of educational researchers (BERA, 2018) and research integrity (Resnik & Shamoo, 2011), clearance was sought from supervisors and test

developers to administer the research instruments via online mode, because of reasons relating to Covid-19, and under two strict conditions: (1) The scanned copy of the test was strictly used for online administration for this research only and should not be uploaded to any platforms that could be shared openly and permanently, and (2) The original test forms of commercialised test kits were purchased and used to record scores.

1.2.5 Results

The pilot study examined the content validity of the non-standardised and non-establish tasks for the following cognitive-linguistic skills where standardised and established assessment tools were unavailable: (1) Chinese Phonological Awareness, (2) English and Chinese Orthographic Knowledge, (3) English and Chinese Morphological Awareness, and (4) Chinese Fluency. Based on the 5 participants' scores, feedback and observations, as well as opinions and advice sought from field experts (i.e., MOE mainstream school educators and DAS educational therapists), adaptations were made to the tasks accordingly so as ensure suitability of the tasks for English-Chinese bilingual learners in Singapore.

Single Word Reading Tasks. The pilot study participants obtained an average score of 35.6 ($SD = 21.38$), with the highest score of 61 and the lowest score of 8, for the Chinese Single Word Reading task. Two participants obtained above-curriculum reading performance, 2 participants obtained curriculum-appropriate reading performance and 1 participant obtained below-curriculum reading performance. The four participants who obtained above-curriculum and curriculum-appropriate reading performance feedback that they found most of the words familiar and were able to recognise them. The participant who obtained below-curriculum reading performance gave feedback that most words looked familiar as they were taught in school but found them difficult to read. Based on the feedback gathered from mainstream educators and educational therapists, as well as the observations and feedback from the participants, the selected 96 characters were concluded to be suitable for the Chinese Single Word Reading task. Hence, no changes to the task were required for its utilisation in the main study.

Phonological Awareness Task. The pilot study participants were able to follow instructions well and obtained an average score of 17.6 ($SD = 2.51$), with the highest score of 20 and the lowest score of 15, for the Phonological Awareness task in Chinese. The participants fed back that they found some test items easy and some difficult. Feedback from mainstream school educators were that although ‘hanyu pinyin’ was taught in class, students are generally not trained on deletion of syllables, onsets, and rimes auditorily. As phonological awareness is an ability/awareness to recognise and work with sounds of a language and is often untaught for most typical children (Anthony & Francis, 2005), the participants need not be trained in order to know how identify, delete or manipulate sounds during the task. Moreover, the pilot study participants were not observed to be uncomfortable with the demands of the task. Hence, it was decided that no further changes were required for its utilisation in the main study.

Orthographic Knowledge Task. For the Orthographic Knowledge Task in English, the pilot study participants were able to complete the task very quickly and obtained an average score of 21.4 ($SD = .89$), with the highest score of 22 and the lowest score of 20. Feedback gathered from field experts were that the original 23 test items could be too easy for typical children and even for those with dyslexia, especially with mild symptoms. The feedback gathered from field experts also suggested words with spelling rules to be considered as part of the English orthographic knowledge task. Orthographic awareness refers to the understanding of the orthographic rule system that allows correct writing in terms of rules and patterns of written language, and this is a significant deficit in understanding graphotactic or orthographic phonological spelling rules of English in children with dyslexia (Galuschka et al., 2020). Orthographic spelling rules are important features of the language (McBride, 2019), and are harder concepts that need to be explicitly taught to children with dyslexia on how to identify vowels, consonants and parts of words in order to apply the correct spelling rules but they are usually learnt without explicit teaching for typical children (Gillingham & Stillman, 1997). Since the original test items did not incorporate spelling patterns and there were no other similar orthographic tests available, reference was sought from teaching manuals that highlight key spelling

patterns in the scope and sequence of teaching children with dyslexia from basic concepts of letter-sound correspondences to more complex concepts of spelling rules (e.g., Gillingham & Stillman, 1997; Peavler & Rooney, 2019) to create the harder test items. Hence, I decided to further modify the task by adding 17 new test items so that the total number of items will be 40 for this assessment task. This is so that the total number of test items are closer to the Chinese version has comparatively more test items. The 17 new items with spelling patterns, such as “beak/beack” and “prettiest/prettiest”, were added to assess participants’ awareness of the orthographic phonological spelling rules of English (see Appendix 9 for the list of original and new test items). With the new test items included, the Orthographic Knowledge task in English is now considered a new task measure. Reliability coefficient for the original test items and original with new test items will be compared to see if the new task measure has a better internal consistency reliability (see ‘Results’ chapter).

For the Orthographic Knowledge Task in Chinese, the pilot study participants were able to complete the task very quickly and obtained an average score of 51 ($SD = 10.22$), with the highest score of 65 and the lowest score of 41. However, the participants were observed to have lost motivation after the 10th row and the duration to complete the task took longer than expected. The participants also fed back that although the task was relatively easy to complete, the number of test items was wearing them out. Therefore, it was decided that the last 4 rows of the characters were removed to make a total of 50 characters instead and shorten the duration to complete the task.

Morphological Awareness Task. For the Morphological Awareness task in English, the pilot study participants obtained an average score of 36.6 ($SD = 3.78$), with the highest score of 43 and the lowest score of 34. For the Morphological Awareness task in Chinese, the participants obtained an average score of 25.2 ($SD = 14.06$), with the highest score of 37 and the lowest score of 0. The participant, who scored 0, did not complete the task because of anxiety. The parent of the participant explained that he was not confident in Chinese and did not wish to respond to the test items. The participant’s wish to not attempt the task was respected. On both tasks in English and Chinese, the participants generally fed back that some test items were too easy, but some test items were too

difficult as they had not learnt the vocabulary in school. Upon sharing the test items with mainstream educators and educational therapists, their feedback also mentioned that certain words could be challenging for some children, but the level of difficulty for both tasks was considered acceptable overall. It was also observed that the duration to complete the tasks took longer than expected.

In view of the feedback and long duration taken to complete the tasks in the pilot study, some of the test items were removed. The test items that were identified as too easy (i.e., all pilot participants were able to answer correctly and very quickly) were removed. The test items that were identified as too difficult (i.e., none of the pilot participants were able to answer correctly) were removed. In addition, the test items in the Chinese task were also matched with the Chinese language character list from Singapore's primary school Chinese language curriculum (MOE, 2015b), so some test items that contained words outside of the curriculum were removed. The total number of test items were reduced to the same number for both tasks in English and Chinese for the main study. Hence, both tasks in English and Chinese eventually consist of 20 test items for Morpheme Discrimination and 20 test items for Select Interpretations. The total number of correct responses recorded is the raw score for each task.

Administration of the tasks and test items were further adapted to ensure consistency of the setting in which the study was conducted. The original task administration required me to read the test items aloud to the participants so that their test performance were influenced by their reading abilities. However, it was observed that my reading of the test items to the participants was not consistent in terms of speed and intonation during the pilot study which might be an extraneous variable affecting the participants' responses (Heiman, 2001). Hence, for the main study, I decided to audio-record the test items so that participants listen to the reading of the test items from the audio-recording. This is to ensure that the environment and testing experience is consistent for all participants. Additionally, 1 test item from each subtask identified to be too easily understood by the pilot study participants was selected to be a practice item, so that both tasks are consistent with the

other cognitive-linguistic tasks in providing practice trials for the participants to understand the instructions and requirements before testing (Heiman, 2001).

Rapid Naming Task. The pilot study participants obtained an average speed of 18s ($SD = 3.08$), with the fastest speed of 13s and the slowest speed of 21s. The administration of the task was uneventful, and the participants found the task instructions easy to follow. Hence, it was decided that no further changes were required for its utilisation in the main study.

1.2.6 Discussion

For the questions that the pilot study was set out to answer, the adapted tasks were considered suitable in terms of age- and curriculum appropriateness for the study participants. All the tasks adapted from previous studies were reported to have good reliability of .84 and .96 in the respective studies (i.e., Cunningham et al., 2001; Li et al., 2012; Lin et al., 2016), except for the Chinese Single Word Reading and Chinese Rapid Naming tasks which were developed for the purpose of this study, and the English and Chinese Morphological Awareness tasks which were developed locally and still being piloted nationwide (O'Brien et al., 2021). Hence, the adapted tasks can be utilised for the main study. As the Orthographic Knowledge task in English is now considered a new task measure modified with the new test items, the task is assessed for internal consistency reliability in the 'Results of the Main Study' chapter. Internal consistency reliability of all the tasks used in the main study is also assessed and reported in the 'Results of the Main Study' chapter. Table 6 below summarises the variables measured and their respective research instruments used in the main study.

Table 6

Summary of variables and research instruments

Reading and Cognitive-linguistic skills (i.e., variables)	Research Instruments (i.e., task measures)	Subtasks and number of test items	Task duration
English Single Word Reading	Word Reading subtest of the 5 th edition of	55 test items (words)	7 minutes

	Wide Range Achievement Test (WRAT-5)		
English Phonological Awareness	Phonological Awareness subtests of the 2 nd edition of the Comprehensive Test of Phonological Processing (CTOPP-2) – Elision, Blending Words and Phoneme Isolation	3 subtests: 1) Elision (34 items) 2) Blending Words (33 items) 3) Phoneme Isolation (32 items)	15 minutes
English Orthographic Knowledge	Adapted Orthographic Choice Test (Cunningham et al., 2001)	40 test items	5 minutes
English Morphological Awareness	Adapted Morphological Awareness Task (English version) by Dr O'Brien Beth Ann (OER, CRCDC) and colleagues from National Institute of Education (NIE) (O'Brien et al., 2021)	2 subtasks: 1) Morpheme Discrimination (20 items) 2) Select Interpretations (20 items)	10 minutes
English Rapid Naming	Rapid Letter Naming subtest of CTOPP-2	36 letters	3 mins
Chinese Single Word Reading	Chinese Single Word Reading task developed based on the primary school Chinese language character list (MOE, 2015b)	96 test items (words)	10 minutes
Chinese Phonological Awareness	Adapted Phonological Awareness Task (Lin et al., 2016)	3 subtasks: 1) Syllable deletion (8 items) 2) Onset deletion (6 items) 3) Rime deletion (6 items)	10 minutes

Chinese Orthographic Knowledge	Adapted Orthographic Awareness Task (Lin et al., 2016)	50 test items (real and pseudo words)	7 minutes
Chinese Morphological Awareness	Adapted Morphological Awareness Task (Chinese version) by Dr O'Brien Beth Ann (OER, CRCD) and colleagues from National Institute of Education (NIE) (O'Brien et al., 2021)	2 subtasks: 1) Morpheme Discrimination (20 items) 2) Select Interpretations (20 items)	10 minutes
Chinese Rapid Naming	Rapid Number Character Naming based on procedures from Li et al. (2012) and proposal by McBride (2019)	35 number characters	3 minutes

2. Main Study

2.1 Introduction

Following on from the pilot study which helped me to examine the content validity and adapt the non-standardised assessment tasks, the main study utilises the five sets of assessment tasks which include the standardised assessment tasks to measure reading and cognitive-linguistic skills of children with and without dyslexia. The methodological approach for the main study is different from the pilot study, as a scientific deductive method is used in the main study by testing the hypotheses derived from theories through statistical comparisons between groups and correlations between variables (Creswell, 2013; Creswell & Clark, 2018). The quantitative approach is employed for this research because test instruments are utilised to measure various cognitive-linguistic skills performance and the data collected (i.e., test scores) are analysed using statistical procedures to compare between groups and interpret correlations (Creswell & Guetterman, 2018).

The main study was conducted between July and December in 2021. The main study sought to answer the following research questions:

1. Are there significant differences in reading and the four cognitive-linguistic skills in both languages between English-Chinese bilingual learners with and without a diagnosis of dyslexia in English in Singapore?
2. How are the four cognitive-linguistic skills associated with English and Chinese reading development in English-Chinese bilingual learners in Singapore?

Research Question 1 involves a comparison of performance in English and Chinese reading and cognitive-linguistic skills between different groups of English-Chinese bilingual learners. The independent and dependent variables are pre-determined. The independent variable is the grouping of English-Chinese bilingual learners with and without dyslexia diagnosed in English (i.e., dyslexia group and control group). The dependent variables are the task scores of the four key cognitive-linguistic skills, as well as their reading performance in English and Chinese. Research Question 2 involves exploring the existence of an association between measurement scores of the cognitive-linguistic skills and reading in English and Chinese to determine which cognitive-linguistic skills predict reading in the respective languages. For this research question, the independent and dependent variables are predetermined differently. The independent variables are the task scores of the four cognitive-linguistic skills in English and Chinese. The dependent variables are the English and Chinese reading performances. The reading scores and cognitive-linguistic task scores will be analysed according to English and Chinese respectively. How the data will be analysed are discussed in Section 3.5 “Data Analysis Methods”.

2.2 Research Methods

2.2.1 Participants

A total of 70 bilingual English-Chinese learners, aged between 9 years 0 month to 9 years 11 months, were recruited for the study. The participants were Singaporean students recruited from Singapore’s mainstream primary schools and DAS, as well as through opportunity sampling within the researcher’s personal network. All the participants were of Chinese ethnicity, except for one, and still learning both English and Chinese language subjects in school at the time of data collection.

40 participants were recruited for the Dyslexia Group whose mean age was 113.4 months ($SD = 3.53$), with 9 years 0 months being the youngest and 9 years 11 months being the oldest. There were 22 males and 18 females in the group. They were formally diagnosed with dyslexia between 2016 and 2019, based on their psychological report provided by their parents and verified with the DAS. It is noted that these participants were diagnosed either through RTI or comprehensive assessment approach, with standardised tests in English. Of this sub-sample, 7 participants were found to have a co-occurring difficulty (i.e., attentional deficit and hyperactivity, and speech and language difficulty), based on their parents' self-report in the parent questionnaire. As dyslexia can co-exist with other neurodevelopmental disorders, according to systematic reviews on epidemiology of dyslexia (Erbeli et al., 2022; Hettiarachchi, 2021), these 7 participants were included in the Dyslexia Group in the study.

30 participants were recruited for the Control Group whose mean age was 111.7 months ($SD = 3.30$), with 9 years 0 months being the youngest and 9 years 11 months being the oldest. There were 9 males and 21 females in the group. All participants in the group had no reported diagnosis of any learning difficulties based on their parents' self-report in the parent questionnaire. Of this sub-sample, 20 were recruited from the two mainstream schools and 10 were recruited through opportunity sampling within the researcher's personal network. The latter sampling approach was used because only 20 students could be recruited from the two primary schools, and it was hoped to recruit more participants to match with the same number of participants in the Dyslexia Group.

2.2.2 Recruitment Process

After permission was granted by DAS, the Participant Information Sheets and Consent Forms were disseminated to parents of the potential participants with dyslexia. The process was longer for MOE to recruit participants without dyslexia, as an invitation had to be sent to mainstream schools to participate in the study after permission was granted. In view of the Covid-19 situation in Singapore, many schools were unable to accept and only two primary schools accepted the invitation to participate in the study. The two primary schools are Government co-ed primary schools located within the neighbourhoods in the northern part of Singapore.

The recruitment of participants from DAS and the two primary schools was based on consented responses from parents of the potential participants who volunteered to participate in the study. During recruitment, a Parent Questionnaire was disseminated via email to parents who consented to participate in the study to collect information on extraneous variables. The questionnaire was a self-report by the parents on information about the child such as the gender, citizenship, and date of birth, whether the child is learning both English and Chinese in school, most recent English and Chinese language subject results in school, and any reported learning difficulties. The questionnaire also collected information about the parents such as their contact details, birthplace and educational background. In addition, the questionnaire collected other information, such as the type of dwelling, household income, frequency of language use at home, child's first language spoken or learnt at home, as well as child's additional tuition or remediation hours in and outside school for both or either language (see Parent Questionnaire in Appendix 11). This was to understand the demographics of the participants and consider the possible extraneous factors that may influence the study's results when evaluating the findings of the study (Heiman, 2001).

2.2.3 Overview of Participants' Demographic Information

All the participants in both Control and Dyslexia groups were from Government and Government-aided schools, except for one participant from the Dyslexia group. Hence, their educational experiences may have been broadly similar in terms of learning English and Chinese languages in schools. One participant from the Dyslexia group, according to the parent, had been attending a mainstream primary school and only changed to an international school a few months before the time of data collection. Hence, this participant was still included in the study. For home language background, parents of the participants were asked to rate the frequency of English and Chinese language use at home as 'always', 'often', 'sometimes', 'seldom' and 'never'. The majority of the participants in both Control (80%) and Dyslexia (95%) groups also used English language always and most of the time at home, while the frequency of using Chinese language at home was comparably less for both Control (13.3%) and Dyslexia (12.5%) groups. In addition, 22 out of 30 participants (73.3%)

in the Control group and 33 out of 40 participants (82.5%) in the Dyslexia group were reported to speak English as their first spoken language. This is representative of the linguistic context of the general population in Singapore, as discussed in Section 2 of the 'Introduction' chapter. Mother's education levels had been one of the extraneous variables that some studies considered and controlled for (e.g., McBride-Chang et al., 2010, 2012, 2013), as mother-child interactions were believed to mediate children's language and literacy development, based on Vygotsky's zone of proximal development theory (1978; cited in McBride-Chang et al., 2010). It was good to note that majority of the mothers of both Control (96.7%) and Dyslexia (80%) groups obtained 'O' levels, diploma and degree as their highest education and majority of the fathers of both Control (66.7%) and Dyslexia (60%) groups obtained 'O' levels, diploma and degree as their highest education. Hence, the educational background of the parents of both participant groups were largely similar.

2.2.4 Research Instruments

Single Word Reading Task. For English Single Word Reading, the reading list taken from the Word Reading subtest of WRAT-5 is utilised. The Word Reading subtest of WRAT-5 was reported to have excellent internal consistency reliability coefficient of .95 for age group between 9 years 0 months and 9 years 11 months based on the normative sample from the US population (Wilkinson & Robertson, 2017). The Chinese Single Word Reading task developed based on the primary school Chinese language character list taken from the curriculum website of Singapore's MOE (MOE, 2020), and validated through the pilot study, is utilised.

Both tasks have clear instructions in both English and Chinese that are provided verbally to ensure that participants understand the requirements before testing began. Participants are asked to read the words aloud, and accuracy of their responses are scored and reading errors are recorded accordingly. Reading performance in English is measured based on the standard scores of the WRAT-5 according to each participant's chronological age. Reading performance in Chinese is measured based on the raw scores obtained through reading the Chinese language character list by levels, as depicted in Section 3.3.1 "Single Word Reading Task" under the pilot study.

Phonological Awareness Task. For the Phonological Awareness task in English, the CTOPP-2 Phonological Awareness test is utilised. There are 3 subtests that are composites of Phonological Awareness suitable for 7-24-year-olds, namely (1) Elision subtest that measures the ability to remove a specified phonological segment of spoken words to form new words (e.g., say “split” without the /l/), (2) Blending Words subtest that measures the ability to synthesize groups of or individual sounds to form words (e.g., what word do these sounds make? /s/-/ŭ/-/n/), and (3) Phoneme Isolation subtest that measures the ability to isolate the specified individual sounds within the spoken words (e.g., what is the second sound of the word “flat”?). The average internal consistency coefficients of these subtests were reported to exceed the minimal standard of .80, based on a normative sample from the US population (Wagner et al., 2013). For the Phonological Awareness task in Chinese, the adapted Phonological Awareness Task (Lin et al., 2016), which was validated through the pilot study, is utilised. The task consists of subtasks that measure the ability to do syllable deletion (e.g., say “红太阳” /hóng tài yáng/ without “红” /hóng/), onset deletion (e.g., say “红” /hóng/ without the beginning sound /h/), and rime deletion (e.g., say “红” /hóng/ without the ending sound /óng/).

Both the English and Chinese tasks included practice items to ensure consistency in the test administration and that participants understand the instructions and requirements before testing. Both tasks have standardised instructions in English and Chinese provided verbally. No print is involved. Participants are asked to provide their answers verbally and accuracy of their responses are scored accordingly. Phonological Sensitivity in English is measured based on age-standardised scores of the CTOPP-2 based on the US population (i.e., scaled score). Phonological Sensitivity in Chinese is measured based on the raw scores obtained through accuracy of answers.

Orthographic Knowledge Task. The adapted Orthographic Choice Test (Cunningham et al., 2001) for English and the adapted Orthographic Awareness Task (Lin et al., 2016) for Chinese, which were validated through the pilot study, are utilised. Both the English and Chinese tasks have practice items to ensure consistency in the test administration and that participants understand the instructions and requirements before testing. Both tasks have clear instructions in English and Chinese,

provided verbally. Participants are shown a pair of words, such as “beak/beack” for English version and “喙/曷口” for Chinese version and asked to select which word in the pair is correctly written. They provide their answers verbally and accuracy of their responses are scored accordingly. Orthographic Knowledge in English and Chinese are both measured based on the raw scores obtained through accuracy of answers.

Morphological Awareness Task. The adapted morphological tasks in English and Chinese by Dr Beth Ann O’Brien (OER, CRCD) and her research team at the National Institute of Education (O’Brien et al., 2021), which was validated through the pilot study, are utilised. Both the English and Chinese tasks had practice items to ensure consistency in the test administration and that participants understood the instructions and requirements before testing. Both tasks had clear instructions in English and Chinese provided verbally. The test items are read to the participants using an audio-recording to ensure that their performance is not limited by their reading ability. Participants are asked to provide their answers verbally. Morphological Awareness in English and Chinese are measured based on the raw scores obtained through accuracy of answers.

Rapid Naming Task. For the English task, the Rapid Letter Naming subtest from CTOPP-2 is utilised. For the Chinese task, the Rapid Number Naming task developed based on procedures from Li et al. (2012) and proposal by McBride (2019), which was validated through the pilot study, is utilised. Both tasks have clear instructions in both English and Chinese that are provided verbally to ensure that participants understand the requirements before testing began. Participants are asked to name the letters/number characters aloud, and as fast and accurate as they can. Accuracy of their responses and time taken to complete are scored and recorded accordingly. Although rapid naming in English can be measured based on the US-normed scaled score, the time taken will be measured as raw score instead because rapid naming in Chinese is measured based on the time taken as raw score. This is so that the scores of both tasks can be compared during the data analysis.

2.2.5 Data Collection and Administration of Research Instruments

The data collection for the main study was conducted between July and December in 2021, when Singapore underwent a heightened alert phase for Covid-19 safe measures and schools and educational institutions moved to online classes due to increased number of infection cases among primary school students (Channel NewsAsia, 2021; Reuters, 2021; The Straits Times, 2021). The initial data collection plan was to conduct two rounds of data collection, with English and Chinese reading in the first round to explore the natural variations of good and poor readers of Chinese and then the cognitive-linguistics skills tasks in the second round (see Information Sheet in Appendix 2). However, the process was difficult amidst the pandemic, as parents and schools were unable to support long periods of data collection due to the strict and ever-changing safe management measures. Therefore, the English and Chinese reading tasks were conducted together with the cognitive-linguistics skills assessment tasks in the same round of data collection.

Due to the heightened alert phase in Singapore, the data collection had to be conducted in two modes (i.e., physically face-to-face or online via zoom) following the similar process in the pilot study. Participants could choose either mode of administration depending on the Covid-19 situation and whether the DAS or the schools allowed the data collection to be done physically at their premises. The participants recruited from the two primary schools opted for the online mode of administration as the schools were unable to support the physical mode of administration due to the pandemic. For the participants who chose the physical mode, the administration of the tasks strictly adhered to the requirements by the MOE and DAS, as well as the COVID-19 Safe Management Measures (see Appendix 3). For the participants who chose the online mode, a secured private Zoom invitation link was sent to them to log in at specified time for the session, following the same set of instructions to ensure that the environment during the online session was as similar and conducive as the environment for the physical session. Administration of the research instruments in either mode was also ensured to be as similar as possible, same as how it was done during the pilot study. Total duration of test administration was about 1 hour to 1 hour 20 minutes per participant on either mode.

3. Research Ethics

The research ethics of this study are guided by the 4th edition of Ethical Guidelines for Educational Research (British Educational Research Association, 2018) and the Singapore Statement on Research Integrity (Resnik & Shamoo, 2011). As the present research is conducted in Singapore, it is encouraged to ensure the study's research integrity abides the local rules and ethical guidelines of the Singapore Statement on Research Integrity as well. At the same time, formal research ethical approval has been sought from the University College London's (UCL) Research Ethics Committee as part of the Doctor of Educational programme (see ethics application approval in Appendix 1). The research ethics and process were first discussed with the thesis supervisors, in accordance to the professional code of ethics from the British Educational Research Association (BERA) (2018). The supervisors' approvals were sought before the research was registered with the UCL Data Protection Office. As the research is considered conducted outside of the UK and during the Covid-19 pandemic, a risk assessment form was also completed to seek approval on the management and control measures undertaken to mitigate data protection risks as well as Covid-19 risks and hazards. The ethical considerations of a research surround the responsibilities towards the study participants, sponsors, clients, and stakeholders in research, and the community of educational researchers, as well as publication and dissemination of research (BERA, 2018). The following sections detail the ethical considerations made under various aspects of the research process.

3.1 Responsibility towards Participants

The research involves children aged between 9 years 0 months and 9 years 11 months and they are considered vulnerable participants who needed safeguarding and protection. Informed consent is first sought from their parents to participate in the study and subsequently sought from the children prior to the start of data collection. To ensure that expectations of the research is more easily understood by the children, there are two versions of the information sheet and consent form for the parents and children. The Participant Information Sheet clearly explained the expectations of the research, protection of their personal information and the right to withdraw to the parents and

children (see Appendix 2). In the event a child does not wish to consent to participate in the study despite the consent from the parents, the child is given the right to withdraw from the study. All data collected from the withdrawn participant are destroyed immediately. Softcopy data is permanently deleted, and hardcopy data is shredded. No participants withdrew from the study, but there are some missing data due to 2 participants not being able to complete certain tasks because of stress and anxiety. The participants' wish to not complete certain tasks were respected.

Besides the psychological risk mentioned above that need to be identified and addressed (Heiman, 2001), another potential risk that participants will be exposed to is COVID-19 infection when they travel out of their homes to meet the researcher during the data collection period. A Covid-19 Safe Measure Management Advisory has been drawn up and provided to the participants to ensure their health and safety during the study (See Appendix 3). The other potential risk is the safety of the participants in meeting with the researcher outside their school hours. An agreement has been worked out with the parents and school or DAS centre to ensure that the time of assessment is done during the school's or DAS centre's operational hours with security available and parents are informed when the child has arrived at and left the venue.

3.2 Responsibility towards Stakeholders

The MOE and DAS are considered the stakeholders and the gatekeepers in this research as permissions need to be sought from them in order to recruit participants. An approval from the MOE in Singapore is sought before approaching the mainstream primary schools to participate in the study. An application for research approval has been made online (MOE, n.d.) and an official approval was provided via email (see Appendix 4). Similarly, an approval is also sought from the DAS, by a research application made via an online form that is downloadable from the DAS website (DAS, 2020). A detailed recruitment protocol that included a justification for the approach proposed, a flow diagram of the stages of recruitment and a consideration of the measures in place to manage the risks to the participants are presented to the two organisations so that access to the potential participants can be granted.

The sampling method is based on consented responses from parents of the potential participants who volunteer to participate in the study. To ensure an ethical sampling plan, information such as the objectives of the research, the means of data collection, the type of sample to be recruited, and the frequency and period of the data collection, is communicated clearly to both MOE and DAS. After approvals from these two organisations are obtained, informed consent is then sought from the parents of the potential participants and subsequently from the potential participants whose parents have given the consent. As an incentive to garner interests from the parents of potential participants, a summary report of their children's performance is provided to the parents after the tests are administered. The initial research plan stated in the information sheet was to conduct two rounds of data collection, with English and Chinese reading in the first round and then the cognitive-linguistics skills tasks in the second round. However, the recruitment period happened during the peak of Covid-19 pandemic in Singapore when there was a sudden surge of infected cases. The organisations have stated their preference for the data collection with each participant to be conducted in only one seating due to stricter safe management measures.

3.3 Responsibility towards the Community of Educational Researchers

As discussed earlier, standardised and established tools are less available for task measurements in Chinese as compared to English. The non-standardised assessment tasks established from previous research on Chinese-English bilingual populations (e.g., Chung & Ho, 2010; Chung & Lam, 2020; Ding et al., 2013; Harrison & Krol, 2007; Ho & Fong, 2005; McBride-Chang et al., 2012, 2013; Meng et al., 2016; Tong et al., 2015; Tong & McBride, 2017; Wong et al., 2012; You et al., 2011; Yuen et al., 2008; Zhang et al., 2011; Zhou et al., 2014) are adapted and utilised in this study by obtaining permissions from research authors. The non-standardised assessment tasks, that are adapted according to Singapore's school curriculum, are piloted to assess their suitability for the linguistic context of Singaporean English-Chinese bilingual learners. The authors of the assessment tasks will be given credit when the research is published.

3.4 Responsibility towards Dissemination and Use of Findings

Dissemination of findings will be via published journal article, conferences, and poster presentations. The study participants and their parents are invited to attend a sharing session on the findings of the study, as a debrief after the study is completed. They are also allowed to ask questions to clarify about the findings and address any concerns. Taking care of the participants after the study is also an important ethical conduct (Heiman, 2001). To ensure that findings of the study are honestly reported as part of the research integrity (Resnik & Shamoo, 2011), raw data (i.e., hardcopies and softcopies of questionnaire data and test scores) with names anonymised with codes can be requested by supervisors to verify the authenticity of the data.

3.5 Data Storage and Security

For the pilot study, data collected from five children aged between 9 years 0 months and 9 years 11 months old contain the children's names, gender, date of birth, and test scores from the research instruments. Their parents' names and contact details are also collected for the purpose of communication before and after the test administration. For the main study, data collected from 70 children, aged between 9 years 0 months and 9 years 11 months old, and their parents, contain personal data such as names, gender, date of birth, past school results for English and Chinese language subjects, copy of psychological report as proof of diagnoses, and test scores from the research instruments. The parent questionnaires used during the recruitment process collected the parents' names, contact details, birthplace, education background and type of dwelling for the purpose of monitoring possible extraneous variables. As the data are collected in Singapore and from the participants who are residing in Singapore, protection of personal data abides by Singapore's Personal Data Protection Act (Personal Data Protection Commission, 2022).

The data collection involves the use of softcopy questionnaire for parents and hardcopy records for the participants' tasks. The softcopy parent questionnaires are sent via the email addresses of the parents of the participants. The data collected from the Parent Questionnaire and the assessment tasks are collated on an excel sheet using the secured platform which only the researcher

has access to. Together with the excel sheet, the hardcopies of the parent questionnaires and research instruments are scanned and saved securely on the S: Drive or Sharepoint on UCL network and encrypted USB stick. Hardcopies are kept securely under lock and key which only the researcher has access to. All softcopy data are stored with password protection.

Anonymised data are analysed using the Statistical Package for the Social Sciences (SPSS) programme. No information about the participants' and their parents' identification are revealed, in the event when the findings of the study are shared with various stakeholders, namely the MOE, the mainstream schools which participated and supported the research, the DAS, and the participants and their parents. No information about the participants' and their parents' identification are also revealed, in the event when the findings of the study are disseminated to members of the public and field experts via several avenues such as conferences, poster presentations and workshops. All anonymised data are to be kept for 5 years after publication, and after which, softcopy data is to be permanently deleted, and hardcopy data is to be shredded.

All in all, the risks and benefits of the study have been thoroughly considered and carefully weighed. With the potential risks mitigated, the benefit of the study still outweighs them. The study will provide significant findings that bring positive theoretical and practical implications to the current knowledge of dyslexia and bilingualism, as well as the future direction in understanding and supporting bilingual learners with dyslexia. The following sections discuss the processes of the pilot study and the main study in the current research.

RESULTS OF THE MAIN STUDY

1. Preliminary Data Analysis

Results of the main study are reported using descriptive and inferential statistics analysed through SPSS. The English and Chinese Orthographic Knowledge, English and Chinese Morphological Awareness, Chinese Single Word Reading and Chinese Rapid Naming were measured using non-standardised tests that have been validated through the pilot study. Scaled scores are used for analysis for English Single Word Reading and Phonological Awareness tasks, while raw scores are used for analysis for Orthographic Knowledge, Morphological Awareness and Rapid Naming tasks. Raw score is used for English Rapid Naming task for the purpose of scores comparison in the inferential statistical analysis, as raw score is also used for the Rapid naming task in Chinese. Data collected from the task measures in the main study are assessed for normality and reliability before statistical comparison of means and regression are conducted.

Test of internal consistency reliability are conducted using odd/even split-half reliability with a Spearman-Brown coefficient to evaluate the consistency of the results across the different test items within the research instruments used in the present study. The Spearman-Brown prophecy formula is adopted as it provides an estimation of a full-test reliability from the half-test correlation, given the large number of test items and some tests consisted of different sets of constructs (i.e., subtests) in which the test items were arranged in order by level of difficulty (Brown, 2018). As there was only one test administration and the variables are dichotomous in nature, the reliability of the rapid naming tasks cannot be examined, as test re-test reliability are generally used in studies that design and assess reliability of rapid naming tasks (e.g., Howe et al., 2006; Soleymani et al., 2007; Stiver et al., 2021).

Skewness and kurtosis of the task measures will be examined to test for normality of the data. Z-scores for skewness and kurtosis are calculated by dividing their values by their standard errors respectively. A conservative skewness and kurtosis statistical significance level of .01 (i.e., which equates to a z-score that is within ± 2.58) is adopted to determine whether the data is normally distributed (Lund Research Ltd, 2013). Additionally, to determine whether the assumption of

normality has been violated, the Shapiro-Wilk test is also conducted. If the data distribution approximates to a normal distribution, the significance value will be greater than .05 (i.e., $p > .05$). Data that is found not normally distributed will be transformed using three types of conversion methods, namely the “square root” method for moderate skew, “logarithmic” method for strong skew and “inverse” for extreme skew (Lund Research Ltd, 2013), in order to fit the assumptions of General Linear Models and to minimise the risks of Type I and Type II errors in subsequent statistical analyses (Nimon, 2012). The reflected form of the three conversion methods will be used for transforming negatively skewed data. The normally distributed and transformed data will then be used in the inferential statistical analyses to test the research hypotheses.

1.1 Descriptive Statistics on all Task Measures for Dyslexia and Control Groups

The descriptive statistics for English and Chinese task measures are provided separately. For English, the mean scores, standard deviation, and standard error of mean on all English Task Measures between dyslexia and control groups of participants are presented in Table 7.

Table 7

Descriptive Statistics on English Task Measures for Dyslexia and Control Groups

Groups		English Single Word Reading (WRAT-5) ^a	English Phonological Awareness - English (CTOPP-2) ^a	Orthographic Knowledge - English ^b	Morphological Awareness - English ^b	Rapid Naming - English (CTOPP-2) ^b
Control	N	30	30	30	30	30
	Mean	114.23	89.17	37.17	29.93	15.50
	Std. Deviation	12.088	12.052	2.379	3.732	2.980
	Std. Error of Mean	2.207	2.200	.434	.681	.544
	Minimum	92	62	33	22	11

	Maximum	137	116	40	38	24
Dyslexia	N	40	40	40	40	40
	Mean	97.35	82.35	33.68	24.73	20.40
	Std. Deviation	12.046	12.915	3.612	5.325	6.872
	Std. Error of Mean	1.905	2.042	.571	.842	1.087
	Minimum	67	62	24	9	13
	Maximum	120	107	40	34	53
Total	N	70	70	70	70	70
	Mean	104.59	85.27	35.17	26.96	18.30
	Std. Deviation	14.637	12.918	3.575	5.350	6.032
	Std. Error of Mean	1.749	1.544	.427	.639	.721
	Minimum	67	62	24	9	11
	Maximum	137	116	40	38	53

Note. ^a scaled score. ^b raw score.

There were 30 control group participants and 40 dyslexia group participants. The dyslexia group participants performed poorer than the control group participants on all English Task Measures. For English Single Word Reading, the overall mean score is 104.59 ($SD = 14.64$) and the dyslexia group participants ($M = 97.35$, $SD = 12.05$) scored lower than the control group participants ($M = 114.23$, $SD = 12.09$). For English Phonological Awareness, the overall mean score is 85.27 ($SD = 12.92$) and the dyslexia group participants ($M = 82.35$, $SD = 12.92$) scored lower than the control group participants ($M = 89.17$, $SD = 12.05$). For English Orthographic Knowledge, the overall mean score is 35.17 ($SD = 3.58$) and the dyslexia group participants ($M = 33.68$, $SD = 3.61$) scored lower than the control group participant ($M = 37.17$, $SD = 2.38$). For English Morphological Awareness, the overall mean score is

26.96 ($SD = 5.35$) and the dyslexia group participants ($M = 24.73$, $SD = 5.33$) scored lower than the control group participants ($M = 29.93$, $SD = 3.73$). For English Rapid Naming, the overall mean speed (in seconds) is 18.30 ($SD = 6.03$) and the dyslexia group participants ($M = 20.40$, $SD = 6.87$) were also slower than the control group participants ($M = 15.50$, $SD = 2.98$).

Table 8 below shows the mean scores, standard deviation, and standard error of mean on all Chinese Task Measures between dyslexia and control groups of participants.

Table 8

Descriptive Statistics on Chinese Task Measures for Dyslexia and Control Groups

Groups		Chinese Single Word Reading ^a	Phonological Awareness - Chinese ^a	Orthographic Knowledge - Chinese ^a	Morphological Awareness - Chinese ^a	Rapid Naming - Chinese ^a
Control	N	30	30	30	30	30
	Mean	35.03	17.73	41.53	22.50	21.87
	Std. Deviation	19.197	1.818	4.117	5.877	13.791
	Minimum	2	14	31	10	11
	Maximum	85	20	49	35	81
Dyslexia	N	40	40	40	40	39
	Mean	10.33	13.25	37.53	15.02	36.51
	Std. Deviation	9.542	4.186	4.194	5.366	21.865
	Minimum	0	2	27	2	14
	Maximum	42	19	45	34	113
Total	N	70	70	70	70	69
	Mean	20.91	15.17	39.24	18.23	30.14

Std. Deviation	18.921	4.036	4.589	6.684	20.044
Minimum	0	2	27	2	11
Maximum	85	20	49	35	113

Note. ^a raw score.

There was one missing data from the dyslexia group for Chinese Rapid Naming Task, as one of the participants was unable to complete the task due to anxiety. The dyslexia group participants also performed poorer than the control group participants on all Chinese Task Measures. For Chinese Single Word Reading, the overall mean score is 20.91 ($SD = 18.92$) and the dyslexia group participants ($M = 10.33$, $SD = 9.54$) scored lower than the control group participants ($M = 35.03$, $SD = 19.20$). For Chinese Phonological Awareness, the overall mean score is 15.17 ($SD = 4.04$) and the dyslexia group participants ($M = 13.25$, $SD = 4.19$) scored lower than the control group participants ($M = 17.73$, $SD = 1.82$). For Chinese Orthographic Knowledge, the overall mean score is 39.24 ($SD = 4.59$) and the dyslexia group participants ($M = 37.53$, $SD = 4.19$) scored lower than the control group participant ($M = 41.53$, $SD = 4.12$). For Chinese Morphological Awareness, the overall mean score is 18.23 ($SD = 6.68$) and the dyslexia group participants ($M = 15.02$, $SD = 5.37$) scored lower than the control group participants ($M = 22.50$, $SD = 5.88$). For Chinese Rapid Naming, the overall mean speed (in seconds) is 30.14 ($SD = 20.04$) and the dyslexia group participants ($M = 36.51$, $SD = 21.87$) were also slower than the control group participants ($M = 21.87$, $SD = 13.79$).

1.2 Reliability, Skewness and Kurtosis of Research Instruments

1.2.1 Test of Internal Consistency Reliability

The odd/even split-half reliability with a Spearman-Brown coefficient is calculated for all task measures to evaluate the consistency of the results. Table 9 depicts the reliability coefficients of the research instruments. Reliability coefficients for Rapid Naming tasks are excluded as test-retest reliability cannot to be calculated due to the test administration conducted only once for this study.

Reliability coefficient for English Orthographic Knowledge task with original test items is included, as there is an interest to compare the internal consistency between the original and new tasks.

Table 9

Summary of Reliability Coefficients on all Task Measures

Task Measures	Odd/even Split-half Reliability (Spearman-Brown coefficient)
English Single Word Reading (WRAT-5) ^a	.904
Chinese Single Word Reading ^b	.986
Phonological Awareness - English (CTOPP-2) ^a	.951
Phonological Awareness - Chinese ^b	.875
Orthographic Knowledge - English ^{b,c}	.784
Orthographic Knowledge - English ^{b,d}	.806
Orthographic Knowledge - Chinese ^b	.765
Morphological Awareness - English ^b	.780
Morphological Awareness - Chinese ^b	.805

Note. ^a scaled score. ^b raw score. ^c with new test items. ^d with original test items only.

The Chinese Single Word Reading has the highest level of internal consistency among the other task measures, as determined by Spearman-Brown coefficient of .986. The next two task measures with very high internal consistency are English Phonological Awareness and English Single Word Reading, as determined by Spearman-Brown coefficients of .951 and .904 respectively. Both English Phonological Awareness and English Single Word Reading were measured by standardised assessment tools (i.e., CTOPP-2 and WRAT-5), which explains the excellent reliability coefficient. For Chinese Single Word Reading to have higher reliability coefficient than these two task measures shows

English Single Word Reading (WRAT-5) ^a	-.147	.287	-.512	.077	.566	.136	.989	70	.801
Chinese Single Word Reading ^b	1.003	.287	3.494	.417	.566	.737	.866	70	<.001
Phonological Awareness - English (CTOPP-2) ^a	.045	.287	.157	-.632	.566	-1.117	.978	70	.249
Phonological Awareness - Chinese ^b	-1.324	.287	-4.613	1.786	.566	3.155	.882	10	<.001
Orthographic Knowledge - English ^b	-.840	.287	-2.92	.795	.566	1.405	.939	70	.002
Orthographic Knowledge - Chinese ^b	-.241	.287	-.840	-.391	.566	-.691	.976	70	.200
Morphological Awareness - English ^b	-.607	.287	-2.115	.729	.566	1.288	.966	70	.055
Morphological Awareness - Chinese ^b	.274	.287	0.955	-.013	.566	-.0230	.983	70	.482
Rapid Naming - English (CTOPP2) ^b	3.144	.287	10.955	15.67 5	.566	27.69 4	.738	70	<.001
Rapid Naming - Chinese ^b	2.182	.289	7.550	5.212	.570	9.144	.757	69	<.001

Note. ^a scaled score. ^b raw score.

The English Single Word Reading, English Phonological Awareness, Chinese Orthographic Knowledge, and English and Chinese Morphological Awareness task scores were found to be normally

distributed. English Single Word Reading scores were normally distributed with a skewness of $-.147$ ($SE = .287$) and kurtosis of $.077$ ($SE = .566$), and as assessed by Shapiro-Wilk's test ($p > .05$). English Phonological Awareness scores were normally distributed with a skewness of $.045$ ($SE = .287$) and kurtosis of $-.632$ ($SE = .566$), and as assessed by Shapiro-Wilk's test ($p > .05$). Chinese Orthographic Knowledge scores were normally distributed with a skewness of $-.241$ ($SE = .287$) and kurtosis of $-.391$ ($SE = .566$), and as assessed by Shapiro-Wilk's test ($p > .05$). English Morphological Awareness scores were normally distributed with a skewness of $-.607$ ($SE = .287$) and kurtosis of $.720$ ($SE = .566$), and as assessed by Shapiro-Wilk's test ($p > .05$). Chinese Morphological Awareness scores were normally distributed with a skewness of $.274$ ($SE = .287$) and kurtosis of $-.013$ ($SE = .566$), and as assessed by Shapiro-Wilk's test ($p > .05$).

The Chinese Single Word Reading, Chinese Phonological Awareness, English Orthographic Knowledge, and English and Chinese Rapid Naming task scores were not found to be normally distributed, as assessed by Shapiro-Wilk's test ($p < .05$). The data were transformed into variables that showed more modest departures from normality based on the skewness and kurtosis values and fit the conservative statistical significance level of $p < .01$ (i.e., which equates to a z-score that is within ± 2.58). Table 11 provides a summary of the skewness and kurtosis z-scores and Shapiro-Wilk test of all task scores after data transformation.

Table 11

Summary of skewness and kurtosis z-scores and Shapiro-Wilk test of all task scores after data transformation

	Skewness			Kurtosis			Shapiro-Wilk		
	Statistic	Std. Error	Z-Score	Statistic	Std. Error	Z-Score	Statistic	df	Sig.
English Single Word Reading (WRAT-5) ^a	-.147	.287	-.512	.077	.566	.136	.989	70	.801

Chinese Single Word Reading ^c	-.281	.289	-.972	-.937	.570	-1.644	.954	69	.012
Phonological Awareness - English (CTOPP-2) ^a	.045	.287	.157	-.632	.566	-1.117	.978	70	.249
Phonological Awareness - Chinese ^d	-.307	.287	-1.070	-.335	.566	-.592	.966	70	.053
Orthographic Knowledge - English ^e	.035	.287	.122	-.383	.566	-.677	.970	70	.093
Orthographic Knowledge - Chinese ^b	-.241	.287	-.840	-.391	.566	-.691	.976	70	.200
Morphological Awareness - English ^b	-.607	.287	-2.115	.729	.566	1.288	.966	70	.055
Morphological Awareness - Chinese ^b	.274	.287	0.955	-.013	.566	-.0230	.983	70	.482
Rapid Naming - English (CTOPP2) ^f	-.095	.287	-.331	-.097	.566	-.171	.976	70	.205
Rapid Naming - Chinese ^f	.350	.289	1.211	-.551	.570	-.967	.971	69	.108

Note. ^a scaled score. ^b raw score. ^c raw score transformed using “logarithmic” method. ^d raw score transformed using reflected “logarithmic” method. ^e raw score transformed using reflected “square root” method. ^f raw score transformed using “inverse” method.

The Chinese Single Word Reading task scores were transformed close to a normal distribution, with a skewness of -.972 (SE = .289) and kurtosis of -1.644 (SE = .570), although the Shapiro-Wilk’s test was not significant ($p = .012$). However, the skewness and kurtosis values fit the conservative statistical

significance level of .01 (i.e., which equates to a z-score that is within ± 2.58). The Chinese Phonological Awareness task transformed scores were now normally distributed, with a skewness of $-.307$ ($SE = .287$) and kurtosis of $-.335$ ($SE = .566$), and as assessed by Shapiro-Wilk's test ($p > .05$). The English Orthographic Knowledge task transformed scores were also normally distributed, with a skewness of $.035$ ($SE = .287$) and kurtosis of $-.383$ ($SE = .566$), and as assessed by Shapiro-Wilk's test ($p > .05$). The English Rapid Naming task transformed scores were also normally distributed, with a skewness of $-.095$ ($SE = .287$) and kurtosis of $-.097$ ($SE = .566$), and as assessed by Shapiro-Wilk's test ($p > .05$). The Chinese Rapid Naming task transformed scores were also normally distributed, with a skewness of $.350$ ($SE = .289$) and kurtosis of $-.551$ ($SE = .570$), and as assessed by Shapiro-Wilk's test ($p > .05$). The data presented in Table 11 were used for the independent t -test analysis, and correlational and stepwise regression analyses.

2. Main Analysis

2.1 Comparison of Mean Scores between Groups

The first research question asks whether there are significant differences in reading and the four cognitive-linguistic skills in both languages between English-Chinese bilingual learners with and without a diagnosis of dyslexia in English in Singapore. To answer the first research question, scores of each assessment task are compared to find out if there any significant difference in reading and all or any cognitive-linguistic skills between the Dyslexia and Control groups. It is hypothesised that the dyslexia group participants will perform poorer in reading and all four cognitive-linguistic skills in English than control group participants because their dyslexia diagnoses were based on English.

The study explores the natural variations in Chinese reading if there is a balanced number of good and poor readers of Chinese and compare the performance of the cognitive-linguistic skills between them with relation to dyslexia. If a balanced number of good and poor Chinese readers is not obtained, an independent t -test analysis will be employed to compare mean task scores of English and Chinese reading and cognitive-linguistic skills from two independent samples (i.e., dyslexia and control groups) (Heiman, 2011). It is also hypothesised that if the dyslexia group participants perform poorer

in Chinese reading than control group participants, they will perform poorer in all four cognitive-linguistic skills in Chinese as well. But, if they perform the same as or better in Chinese reading than control group participants, there will be no difference between the two groups. Table 12 presents the summary of independent and dependent variables for Research Question 1.

Table 12

Summary of independent and dependent variables for Research Question 1

Dependent Variables	Independent Variables	
	Dyslexia Group	Control Group
Research Question 1.		
Are there significant differences in reading and the four cognitive-linguistic skills in both languages between English-Chinese bilingual learners with and without a diagnosis of dyslexia in English in Singapore?		
English Single Word Reading		
English Phonological Awareness		
English Orthographic Knowledge	Independent samples <i>t</i> -test	
English Morphological Awareness		
English Rapid Naming		
Chinese Single Word Reading		
Chinese Phonological Awareness		
Chinese Orthographic Knowledge	Independent samples <i>t</i> -test	
Chinese Morphological Awareness		
Chinese Rapid Naming		

2.1.1 Comparison of Mean Scores on all Task Measures between Dyslexia and Control Groups

Two-samples independent *t*-tests were conducted to test the hypotheses for the study's first research question on whether there are significant differences in reading and the four cognitive-linguistic skills in both languages between English-Chinese bilingual learners with and without a diagnosis of dyslexia in English in Singapore. The first independent *t*-test is conducted to test the hypothesis that the dyslexia group participants will perform poorer in reading and all four cognitive-linguistic skills in English than control group participants because their dyslexia diagnoses were based on English. The second independent *t*-test is conducted to test the hypothesis that the dyslexia group participants will perform poorer in all four cognitive-linguistic skills in Chinese if they perform poorer in Chinese reading than control group participants. As multiple *t*-tests are conducted for all assessment tasks, including some subtasks, on the same sample will raise the issue of false positive results, the conservative Bonferroni correction method is used by multiplying the raw *p*-values by the number of tests (Jafari & Ansari-Pour, 2019). In this analysis, the *p*-value of .05 is multiplied by the total number of English and Chinese assessment tasks, including the English phonological subtasks, which is 13. Therefore, the *t*-test results are considered significant if the significance level is less than the adjusted *p*-value of .0038.

2.1.2 Comparison of mean scores on English Task Measures between Dyslexia and Control Groups

Table 13 presents the independent *t*-test results for all English task measures between dyslexia and control groups, including the subtasks of phonological awareness.

Table 13

Independent t-test of mean scores on English Task Measures between Dyslexia and Control Groups

<i>t</i>	df	Significance	Mean Differen ce	Std. Error Difference	95% Confidence Interval of the Difference
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			One- Sided <i>p</i>	Two- Sided <i>p</i>			Lower	Upper
English Single Word Reading (WRAT-5) ^a	5.794	68	<.001	<.001	16.883	2.914	11.069	22.698
Phonological Awareness - English (CTOPP-2) ^a	2.248	68	.014	.028	6.817	3.032	.766	12.867
Orthographic Knowledge - English ^c	-4.808	68	<.001	<.001	-.76739	.15962	-1.08591	-.44887
Morphological Awareness - English ^b	4.809	67.738	<.001	<.001	5.208	1.083	3.047	7.370
Rapid Naming - English (CTOPP2) ^d	4.719	68	<.001	<.001	.01397	.00296	.00806	.01988
Elision subtask (CTOPP-2) ^a	3.684	68	<.001	<.001	2.525	.685	1.157	3.893
Blending Words subtask (CTOPP-2) ^a	.028	68	.489	.977	.017	.587	-1.154	1.187
Phoneme Isolation subtask (CTOPP-2) ^a	1.417	68	.081	.161	.742	.523	-.303	1.786

Note. ^a scaled score. ^b raw score. ^c raw score transformed using reflected “square root” method.

^d raw score transformed using “inverse” method.

As assessed by Levene's test for equality of variances, there was homogeneity of variances for English Single Word Reading ($p = .780$), English Phonological Awareness ($p = .339$), English Orthographic Knowledge ($p = .910$) and English Rapid Naming ($p = .794$). However, the homogeneity of variance was violated for English Morphological Awareness ($p = .018$), as assessed by Levene's test for equality of variances. Hence, the result of the Welch t -test (Welch, 1947) generated under “unequal variances assumed” by the SPSS (Lund Research Ltd, 2013), was reported for English Morphological Awareness.

There was a statistically significant difference in English Single Word Reading performance, with dyslexia group participants performing poorer than control group participants, $M = 16.88$, $SE = 2.91$, $t(68) = 5.794$, $p < .001$. This shows that participants with dyslexia were poor readers in English as compared to those without dyslexia, which is one of the main characteristics of dyslexia. For English Phonological Awareness, there was no significant difference in performance, with dyslexia group participants performing poorer than control group participants, $M = 6.82$, $SE = 3.03$, $t(68) = 2.248$, $p = .028$, based on the adjusted p-value of .0038. This is interesting as phonological awareness is one of the main characteristics of dyslexia and it was observed that participants with dyslexia were weaker in processing language sounds in English during the task administration. Hence, there is an interest to further investigate the subskills of phonological awareness which are the 3 subtasks, namely Elision, Blending Words and Phoneme Isolation (i.e., subtests of Phonological Awareness from CTOPP-2). This is to investigate whether there is a strong significant difference between the dyslexia and control groups in any of the subskills of phonological processing.

Levene's test for equality of variances shows that there was homogeneity of variances for Elision ($p = .393$), Blending Words ($p = .520$) and Phoneme Isolation ($p = .211$). For the elision subtask, there was a statistically significant difference in performance, with the dyslexia group participants ($M = 7.88$, $SD = 2.89$) performing poorer than the control group participants ($M = 10.40$, $SD = 2.76$), $M = 2.53$ ($SE = .69$), $t(68) = 3.684$, $p < .001$. For the blending words subtask, there was no statistically significant difference in performance, with the dyslexia group participants ($M = 6.55$, $SD = 2.42$) performing similarly with the control group participants ($M = 6.57$, $SD = 2.45$), $M = .017$ ($SE = .59$). For the phoneme isolation subtask, there was also no statistically significant difference in performance, with the dyslexia group participants ($M = 6.93$, $SD = 2.29$) performing only slightly poorer than the control group participants ($M = 7.67$, $SD = 1.99$), $M = .74$ ($SE = .52$). This shows that participants with dyslexia were weaker in removing a specified phonological segment of spoken words to form new words which requires some form of sound manipulation ability, as compared to those without dyslexia.

However, they did not differ in their ability to blend sounds and isolate phonemes from those without dyslexia.

For English Orthographic Knowledge, there was a statistically significant difference in performance, with dyslexia group participants performing poorer than control group participants, $M = -.77$ ($SE = .16$), $t(68) = -4.808$, $p < .001$. It is noted that the English Orthographic Knowledge scores were transformed using reflected “square root” method for normality, and hence the negative and small values present in the reported mean difference and t-value. The result shows that the participants with dyslexia were weaker in their awareness of the spelling of English words, as compared to those without dyslexia. For English Morphological Awareness, there was a statistically significant difference in performance, with dyslexia group participants performing poorer than control group participants, $M = 5.21$ ($SE = 1.03$), $t(67.769) = 4.809$, $p < .001$. This shows that participants with dyslexia are weaker in interpreting different meanings of word parts in compound words and morphologically complex words that contain affixes. For English Rapid Naming, there was a statistically significant difference in performance, with dyslexia group participants performing poorer than control group participants, $M = .014$ ($SE = .003$), $t(68) = 4.719$, $p < .001$. It is noted that the English Rapid Naming scores were transformed using an “inverse” method for normality, and hence the very small values present in the reported mean difference and standard error difference. The result shows that participants with dyslexia are less fluent in naming English letters quickly and accurately as compared to those without dyslexia.

Overall, there was a statistically significant difference between the mean scores of all English task measures, except for the Phonological Awareness task, between dyslexic and control groups ($p < .0038$). However, the Elision subtask is considered a phonological awareness skill and there was statistically significant difference between the means scores of dyslexic and control groups. Therefore, we can reject the null hypothesis and accept the alternative hypothesis that dyslexic learners performed poorer in reading and all four cognitive-linguistic skills in English.

2.1.3 Comparison of mean scores on Chinese Task Measures between Dyslexia and Control Groups

Table 14 presents the independent *t*-test results for all Chinese task measures between dyslexia and control groups.

Table 14

Independent t-test of mean scores on Chinese Task Measures between Dyslexia and Control Groups

	<i>t</i>	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
			One-Sided <i>p</i>	Two-Sided <i>p</i>			Lower	Upper
Chinese Single Word Reading ^b	6.128	67	<.001	<.001	.56267	.09182	.37941	.74594
Phonological Sensitivity - Chinese ^c	-6.308	68	<.001	<.001	-.38418	.06091	-.50572	-.26264
Orthographic Knowledge - Chinese ^a	3.988	68	<.001	<.001	4.008	1.005	2.003	6.014
Morphological Awareness - Chinese ^a	5.537	68	<.001	<.001	7.475	1.350	4.781	10.169
Rapid Naming - Chinese ^d	5.003	67	<.001	<.001	.02084	.00416	.01252	.02915

Note. ^a raw score. ^b raw score transformed using “logarithmic” method. ^c raw score transformed using reflected “logarithmic” method. ^d raw score transformed using “inverse” method.

As assessed by Levene's test for equality of variances, there was homogeneity of variances for Chinese Single Word Reading ($p = .742$), Chinese Phonological Awareness ($p = .477$), Chinese

Orthographic Knowledge ($p = .926$), Chinese Morphological Awareness ($p = .347$) and Chinese Rapid Naming ($p = .185$).

There was a statistically significant difference in Chinese Single Word Reading performance, with dyslexia group participants performing poorer than control group participants, $M = .56$, $SE = .09$, $t(67) = 6.128$, $p < .001$. It is noted that the Chinese Single Word Reading scores were transformed using a “logarithmic” method for normality, and hence the very small values present in the reported mean difference and standard error difference. The result shows that participants with dyslexia are poor readers in Chinese as compared to those without dyslexia, even though their diagnoses were in English. For Chinese Phonological Awareness, there was a statistically significant difference in performance, with dyslexia group participants performing poorer than control group participants, $M = -.38$, $SE = .06$, $t(68) = -6.308$, $p < .001$. It is noted that the Chinese Phonological Awareness scores were transformed using a reflected “logarithmic” method for normality, and hence the negative and small values present in the reported mean difference and t-value. The result shows that participants with dyslexia were also weaker in processing language sounds in Chinese than those without dyslexia, which is one of the main characteristics of dyslexia, even though their diagnoses were in English.

For Chinese Orthographic Knowledge, there was a statistically significant difference in performance, with dyslexia group participants performing poorer than control group participants, $M = 4.01$ ($SE = 1.01$), $t(68) = 5.537$, $p < .001$. This shows that the participants with dyslexia were weaker in their awareness of general radical positions in Chinese words, as compared to those without dyslexia. For Chinese Morphological Awareness, there was a statistically significant difference in performance, with dyslexia group participants performing poorer than control group participants, $M = 7.48$ ($SE = 1.35$), $t(68) = 5.537$, $p < .001$. This shows that participants with dyslexia are weaker in interpreting different meanings of word parts in compound words and morphologically complex words in Chinese. For Chinese Rapid Naming, there was a statistically significant difference in performance, with dyslexia group participants performing poorer than control group participants, $M = .021$ ($SE = .004$), $t(67) = 5.003$, $p < .001$. It is noted that the Chinese Rapid Naming scores were

transformed using an “inverse” method for normality, and hence the very small values present in the reported mean difference and standard error difference. The result shows that participants with dyslexia are less fluent in naming Chinese number characters quickly and accurately as compared to those without dyslexia.

Overall, there was a statistically significant difference between the mean scores of all Chinese task measures between dyslexic and control groups ($p < .0038$). Therefore, we can reject the null hypothesis and accept the alternative hypothesis that dyslexic learners performed poorer in reading and all four cognitive-linguistic skills in Chinese.

2.2 Correlational and Stepwise Regression Analyses

The second research question asks how the four cognitive-linguistic skills are associated with English and Chinese reading development in English-Chinese bilingual learners in Singapore. To answer the second research question, stepwise regression analysis will be conducted to analyse the significant unique effect of each cognitive-linguistic skills in predicting English and Chinese reading development. Stepwise regression analysis serves as a prediction model in which variables are entered one at a time, in a series of steps, to calculate the percentage of the variance of the dependent variable the most in addition to the other variables previously entered (Thayer, 2002). The order of variables to be entered in the SPSS can be predetermined to explore correlations or based on correlated variables that are found prevalent in literature as well as theories of dyslexia and reading development. There are two prediction models to test the unique effects of the cognitive-linguistic skills in predicting English and Chinese reading respectively.

For English reading, it is hypothesised that both Phonological Awareness and Rapid Naming will be strong predictors of reading, and Morphological Awareness and Orthographic Knowledge should still be strong predictors of reading after Phonological Awareness and Rapid Naming are controlled. The four cognitive-linguistic skills are entered into the regression model in the following order: (1) Phonological Awareness, (2) Rapid Naming, (3) Morphological Awareness, and then (4) Orthographic Knowledge. Phonological Awareness and Rapid Naming are alternately entered at Step

1 and 2, and Morphological Awareness and Orthographic Knowledge are alternately entered at Steps 3 and 4 of regressions, to assess which predictive order of the four cognitive-linguistic skills has a unique effect.

For Chinese reading, it is hypothesised that both Morphological Awareness and Rapid Naming will be strong predictors of reading, and then Orthographic Knowledge and Phonological Awareness should still be strong predictors of reading after Morphological Awareness and Rapid Naming are controlled. The four cognitive-linguistic skills are entered into the regression model in the following order: (1) Morphological Awareness, (2) Rapid Naming, (3) Orthographic Knowledge and then (4) Phonological Awareness. Morphological Awareness and Rapid Naming are alternately entered at Steps 1 and 2, and Orthographic Knowledge and Phonological Awareness are alternately entered at Steps 3 and 4 of regressions, to assess which predictive order of the four cognitive-linguistic skills has a unique effect.

Before the stepwise regression analysis, correlational analyses are conducted to measure any statistically significant relationships between the task scores and reading scores and examine any multicollinearity between the variables. Age, gender and home language (English and Chinese) are also included in the correlational analysis, as they can be extraneous variables that need to be entered in the regression analysis as control variables. The independent variables here are the task scores of the four cognitive-linguistic skills in English and Chinese, while the dependent variables are the English and Chinese reading scores. The reading scores and cognitive-linguistic task scores will be analysed according to English and Chinese respectively. Table 15 presents the summary of independent and dependent variables for Research Question 2.

Table 15

Summary of independent and dependent variables for Research Question 2

Research Question 2.

2. Gender	-.095	-						
3. English language use at home	-.174	.344**	-					
4. English Single Word Reading (WRAT-5) ^a	-.184	.068	.076	-				
5. Phonological Awareness - English (CTOPP-2) ^a	.052	.138	.004	.561**	-			
6. Orthographic Knowledge - English ^c	.025	-.037	-.002	-.762**	-.538**	-		
7. Morphological Awareness - English ^b	-.051	-.018	-.015	.655**	.555**	-.654**	-	
8. Rapid Naming - English (CTOPP2) ^d	-.060	.179	.223	.400**	.255*	-.403**	.333**	-

Note. ^a scaled score. ^b raw score. ^c raw score transformed using reflected "square root" method.

^d raw score transformed using "inverse" method.

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

All the English cognitive-linguistic skills are strongly correlated with English reading, namely phonological awareness ($r = .56, p < .001$), orthographic knowledge ($r = .76, p < .001$), morphological awareness ($r = .65, p < .001$) and rapid naming ($r = .40, p < .001$). It is noted that the English Orthographic Knowledge scores were transformed using a reflected "square root" method, and hence the negative value in the correlation coefficient. All the English cognitive-linguistic task measures have no correlations greater than 0.7, and hence there is no multicollinearity concern. However, age, gender and English home language are not significantly correlated with any of the English task measures. Hence, these variables will not be entered into the regression analysis as control variables.

Table 17*Regression Analyses on English Cognitive-linguistic skills as predictors of English Reading*

Step	Independent Variable	Unstandardised Coefficients		Standardised Coefficients <i>Beta</i>	<i>R</i> ²	<i>R</i> ² Change	<i>F</i> Change	Sig. <i>F</i> Change	Collinearity Statistics	
		<i>B</i>	Std Error						Tolerance	VIF
1	Phonological Awareness - English (CTOPP-2) ^a	.166	.105	.147	.314	.314	31.178	<.001	.638	1.568
2	Rapid Naming - English (CTOPP2) ^d	90.855	84.906	.087	.385	.071	7.699	.007	.829	1.206
1	Rapid Naming - English (CTOPP2) ^d	90.855	84.906	.087	.160	.160	12.968	<.001	.829	1.206
2	Phonological Awareness - English (CTOPP-2) ^a	.166	.105	.147	.385	.225	24.499	<.001	.638	1.568
3	Morphological Awareness - English ^b	.577	.284	.211	.515	.130	17.649	<.001	.510	1.960
4	Orthographic Knowledge - English ^c	-9.824	2.027	-.510	.644	.129	23.493	<.001	.496	2.017
3	Orthographic Knowledge - English ^c	-9.824	2.027	-.510	.621	.236	41.067	<.001	.496	2.017
4	Morphological Awareness - English ^b	.577	.284	.211	.644	.023	4.138	.046	.510	1.960

Note. ^a scaled score. ^b raw score. ^c raw score transformed using reflected “square root” method. ^d raw score transformed using “inverse” method.

The stepwise regression analysis confirms that both Phonological Awareness and Rapid Naming were significant predictors of English Single Word Reading when they were first entered at Steps 1 and 2. At Step 1, English Phonological Awareness led to a statistically significant increase in R^2 of .314, $F(1, 68) = 31.178$, $p < .001$. At Step 2, English Rapid Naming subsequently led to a statistically significant increase in R^2 of .071, $F(1, 67) = 7.699$, $p = .007$. Reversal of the order entry of Steps 1 and 2 revealed that Rapid Naming led to an even higher statistically significant increase in R^2 of .160, $F(1, 68) = 12.968$, $p < .001$, at Step 1 and Phonological Awareness subsequently led to a statistically significant increase in R^2 of .225, $F(1, 67) = 24.499$, $p < .001$, at Step 2. This shows that Rapid Naming and Phonological Awareness are significant predictors for English reading and 38.5% of English reading performance can be explained by both cognitive-linguistic skills.

With Rapid Naming and Phonological Awareness controlled at Step 1 and 2 respectively, English Morphological Awareness was also a significant predictor after it was added at Step 3, which led to a statistically significant increase in R^2 of .130, $F(1, 66) = 17.649$, $p < .001$. English Morphological Awareness was also a significant additional predictor at Step 4, which led to a statistically significant increase in R^2 of .129, $F(1, 65) = 23.493$, $p < .001$. Reversal of the order entry of Steps 3 and 4 revealed that English Orthographic Knowledge and English Morphological Awareness were still significant predictors, but significance of change was lower ($p = .046$) at Step 4. This shows that after controlling for Rapid Naming and Phonological Awareness, Morphological Awareness and Orthographic Knowledge are still significant predictors for English reading and 62.2% of English reading performance is explained by all four cognitive-linguistic skills. Therefore, the predictive model of all four English cognitive-linguistic skills predicting English Single Word Reading was statistically significant, and we can accept the hypothesised predictive model with the four cognitive-linguistic skills in the following order of unique contribution to English reading development: (1) Rapid Naming, (2) Phonological Awareness, (3) Morphological Awareness, and (4) Orthographic Knowledge.

Scatter plots with linear regression lines were generated to depict the relationships between English reading and each English cognitive-linguistic skills (see Appendix 12), where Control group and

Dyslexia group are compared. The present study's predictive model is empirically- and theoretically-derived from literature for English reading development, as there is no similar research conducted in Singapore's bilingual population. To show fullness of the data and as a demonstration of what results the data would give without a theory, I decided to run a stepwise regression analysis that is data-driven in addition to the theory-driven one. Unlike the theory-driven regression analysis where each variable was deliberately entered at each step, all the variables were entered at Step 1 and the SPSS programme added each variable at each step according to its contribution to the model's R^2 . The data-driven regression analysis found Orthographic Knowledge and Morphological Awareness to be the only cognitive-linguistic skills that have significant unique contribution to English reading development, in contrast to the results of the theory-driven regression analysis. As the present study is focused on testing the hypothesis that is based on the theoretical framework, the data-driven regression analysis is included in Appendix 14 for reference.

2.2.2 Stepwise Regression Analyses on Cognitive-linguistic skills as predictors of Chinese Reading

Pearson's correlational analysis was first conducted to explore the intercorrelations for all Chinese task measures and assess for multicollinearity between age, gender, home language and the cognitive-linguistic task measures, before the stepwise regression analyses were conducted. Table 18 reveals the intercorrelations between Chinese reading and Chinese cognitive-linguistic task measures.

Table 18

Intercorrelations between Chinese reading and age, gender, home language and Chinese cognitive-linguistic task measures

Variables	1	2	3	4	5	6	7	8
1. Age	-							
2. Gender	-.095	-						

3. Chinese language use at home	.110	-.117	-					
4. Chinese Single Word Reading ^b	-.082	.134	-.613**	-				
5. Phonological Sensitivity - Chinese ^c	.044	-.110	.320**	-.581**	-			
6. Orthographic Knowledge - Chinese ^a	.024	.016	-.375**	.524**	-.562**	-		
7. Morphological Awareness - Chinese ^a	-.014	.065	-.599**	.771**	-.591**	.522**	-	
8. Rapid Naming - Chinese ^d	-.037	.206	-.635**	.772**	-.448**	.451**	.621**	-

Note. ^a raw score. ^b raw score transformed using “logarithmic” method. ^c raw score transformed using reflected “logarithmic” method. ^d raw score transformed using “inverse” method.
 **. Correlation is significant at the 0.01 level (2-tailed).

For Chinese, all the Chinese cognitive-linguistic skills are strongly correlated with Chinese reading, namely phonological awareness ($r = .58, p < .001$), orthographic knowledge ($r = .52, p < .001$), morphological awareness ($r = .77, p < .001$) and rapid naming ($r = .77, p < .001$). It is noted that the Chinese phonological awareness scores were transformed using a reflected “logarithmic” method, and hence the negative value in the correlation coefficient. All the Chinese cognitive-linguistic task measures have no correlations greater than 0.7, and hence there is no multicollinearity concern. However, age and gender are not significantly correlated with any of the Chinese task measures. Hence, these variables will not be entered into the regression analysis as control variables. Home language in Chinese is significantly correlated with the Chinese task measures ($p < .001$) and the correlations are not greater than 0.7. Hence, Chinese home language will be entered as control variable in the regression analysis for Chinese task measures.

Stepwise regression analyses were then conducted to test the hypotheses for the study's second research question on how the four cognitive-linguistic skills are associated with English and Chinese reading development in English-Chinese bilingual learners in Singapore. The first stepwise regression analysis was conducted to test the hypothesis that both Phonological Sensitivity and Rapid Naming will be strong predictors of reading, and Morphological Awareness and Orthographic Knowledge should still be strong predictors of reading after Phonological Sensitivity and Rapid Naming are controlled. Phonological Sensitivity and Rapid Naming were alternately entered at Step 1 and 2, and Morphological Awareness and Orthographic Knowledge were alternately entered at Steps 3 and 4 of regressions, to assess the unique effects of the cognitive-linguistic skills. The stepwise regression analyses of English Cognitive-linguistic skills as predictors of English Reading are depicted in Table 18.

The stepwise regression analysis was conducted to test the hypothesis that that both Morphological Awareness and Rapid Naming will be strong predictors of reading, and then Orthographic Knowledge and Phonological Awareness should still be strong predictors of reading after Morphological Awareness and Rapid Naming are controlled. As Chinese language use at home was found to have significant correlation with the Chinese task measures, it was first entered at Step 1 as a control variable. Morphological Awareness and Rapid Naming were then alternately entered at Steps 2 and 3, and Orthographic Knowledge and Phonological Awareness were alternately entered at Steps 4 and 5 of regressions, to assess the unique effects of the cognitive-linguistic skills. The stepwise regression analyses of Chinese cognitive-linguistic skills as predictors of Chinese Reading are depicted in Table 19.

Table 19*Regression Analyses on Chinese Cognitive-linguistic skills as predictors of Chinese Reading*

Step	Independent Variable	Unstandardised Coefficients		Standardised Coefficients	R^2	R^2 Change	F Change	Sig. F Change	Collinearity Statistics	
		B	Std Error	$Beta$					Tolerance	VIF
1	Chinese language use at home	-.027	.038	-.063	.372	.372	39.144	<.001	.523	1.913
2	Morphological Awareness - Chinese ^a	.025	.007	.356	.626	.254	44.085	<.001	.423	2.361
3	Rapid Naming - Chinese ^d	10.031	2.141	.425	.733	.107	25.762	<.001	.489	2.045
2	Rapid Naming - Chinese ^d	10.031	2.141	.425	.621	.249	42.607	<.001	.489	2.045
3	Morphological Awareness - Chinese ^a	.025	.007	.356	.733	.112	26.995	<.001	.423	2.361
4	Orthographic Knowledge - Chinese ^a	.008	.008	.081	.744	.010	2.535	.116	.589	1.672
5	Phonological Awareness - Chinese ^c	-.169	.125	-.116	.751	.007	1.841	.180	.551	1.814
4	Phonological Awareness - Chinese ^c	-.169	.125	-.116	.747	.014	3.426	.069	.551	1.814
5	Orthographic Knowledge - Chinese ^a	.008	.008	.081	.751	.004	.984	.325	.589	1.672

Note. ^a raw score. ^b raw score transformed using “logarithmic” method. ^c raw score transformed using reflected “logarithmic” method. ^d raw score transformed using “inverse” method.

The stepwise regression analysis confirms that both Morphological Awareness and Rapid Naming are significant predictors of Chinese Single Word Reading when they were entered at Step 2 and Step 1 respectively, after controlling for Chinese language use at home. Morphological Awareness led to a statistically significant increase in R^2 of .254, $F(1, 66) = 44.085, p < .001$, at Step 2. Rapid Naming led to a statistically significant increase in R^2 of .107, $F(1, 65) = 25.762, p < .001$, at Step 3. Reversal of the order entry of Steps 2 and 3 revealed that Rapid Naming led to a statistically significant increase in R^2 of .249, $F(1, 66) = 42.607, p < .001$, at Step 2, and Morphological Awareness subsequently led to a statistically significant increase in R^2 of .112, $F(1, 65) = 26.995, p < .001$, at Step 3. This shows that both Morphological Awareness and Rapid Naming are significant predictors for Chinese reading, and 36.1% of Chinese reading performance can be explained by both cognitive-linguistic skills, after controlling for Chinese language use at home.

With Morphological Awareness and Rapid Naming controlled at Step 2 and 3 respectively, Chinese Orthographic Knowledge was not a significant predictor after it was added at Step 4, which led to a very small increase in R^2 of .010, $F(1, 64) = 2.535, p = .116$. Chinese Phonological Awareness was also not a significant additional predictor at Step 5, which led to a very small increase in R^2 of .007, $F(1, 63) = 1.951, p = .180$. Reversal of the order entry of Steps 4 and 5 revealed that Orthographic Knowledge and Phonological Awareness were still not significant predictors. However, the significance value of change for Phonological Awareness was higher despite that it was not significant ($p = .069$) at Step 4. This shows that after controlling for Morphological Awareness and Rapid Naming, both Phonological Awareness and Orthographic Knowledge were not significant predictors of reading, even with the order entry of steps alternated. However, it is noteworthy that the change of variance has a small effect size of .014 when Phonological Awareness was entered at Step 4, as compared to when it was entered at Step 5, suggesting a plausible modest influence on reading. The predictive model of only two cognitive-linguistic skills predicting Chinese Single Word Reading was statistically significant, with the following order of unique contribution to Chinese reading development: (1) Morphological

Awareness and (2) Rapid Naming. We therefore reject the hypothesised predictive model for Chinese reading that all four Chinese Cognitive-linguistic skills predict Chinese Single Word Reading.

Scatter plots with linear regression lines were generated to depict the relationships between Chinese reading and each Chinese cognitive-linguistic skills (see Appendix 13), where Control group and Dyslexia group are compared. The present study's predictive model is empirically- and theoretically-derived from literature for Chinese reading development, as there is no similar research conducted in Singapore's bilingual population. To show fullness of the data and as a demonstration of what results the data would give without a theory, I decided to run a stepwise regression analysis that is data-driven in addition to the theory-driven one. Unlike the theory-driven regression analysis where each variable was deliberately entered at each step, the control variable was first entered at Step 1 and the remaining variables were entered at Step 2, and the SPSS programme added each variable at each step according to its contribution to the model's R^2 . The data-driven regression analysis found Morphological Awareness and Rapid Naming to be the only cognitive-linguistic skills that have significant unique contribution to Chinese reading development, similar to the results of the theory-driven regression analysis. As the present study is focused on testing the hypothesis that is based on the theoretical framework, the data-driven regression analysis is included in Appendix 15 for reference.

3. Correlational Analysis of English Phonological Sensitivity Subtask Measures with English Reading

In the earlier independent *t*-test analysis, the subskills of English phonological awareness were further compared between the dyslexia and control groups and there was an interesting finding that a very strong statistically significant difference in performance between both groups was only evident in elision subskill. Therefore, a further correlational analysis was conducted for the three subtasks of phonological awareness task to analyse the association of these three phonological awareness subskills with English reading. Table 20 shows the correlational coefficients between English reading and English phonological awareness subtask measures.

Table 20

Correlational Analysis between English reading and English Phonological Sensitivity subtask measures

Variables	1	2	3	4
1. English Single Word Reading (WRAT-5) ^a	-			
2. Elision subtask (CTOPP-2) ^a	.714**	-		
3. Blending Words subtask (CTOPP-2) ^a	.167	.438**	-	
4. Phoneme Isolation subtask (CTOPP-2) ^a	.380**	.484**	.403**	-

Note. ^a scaled score.

** . Correlation is significant at the 0.01 level (2-tailed).

Two of the three subtests were found to have statistically significant correlation with English reading. There was statistically significant, strong positive correlation between elision and English reading, $r(68) = .71, p < .001$, with elision subskill explaining 50.4% of the variation in reading. There was statistically significant, moderate positive correlation between phoneme isolation and English reading, $r(68) = .38, p < .001$, with phoneme isolation subskill explaining 14.4% of the variation in reading. However, there was no statistically significant correlation between blending words subskill and English reading, $r(68) = .17, p = .168$, with blending words subskill explaining only 2.5% of the variation in reading. This shows an interesting association between higher order phonemic manipulation and isolation skills with English word reading, rather than blending skill, based on the data from this study's sample. This result will be discussed in greater detail in the next chapter.

6. Summary of Results

Preliminary data analysis revealed that the internal consistency of the task measures was of acceptable to very high level, with reliability coefficients between .765 and .986. It was also found that the reliability coefficient of the modified English Orthographic Knowledge task was lower, suggesting that the Orthographic Choice task with original test items seemed to have better internal consistency. Nonetheless, the reliability coefficient of the modified task still indicated an acceptable level of

internal consistency. The task scores were tested for normality and transformed for the purpose of conducting the independent *t*-test analysis, and correlational and stepwise regression analyse to test the hypotheses of the study's research questions.

The hypotheses for Research Question 1 were supported and the null hypothesis was rejected. The dyslexia group participants were found to have performed statistically significantly poorer than the control group participants in reading and all four cognitive-linguistic skills in both languages. The statistical significance was very strong ($p < .001$) in the task measures on cognitive-linguistics in both languages, except for English phonological awareness. A further analysis on the three subtasks of English phonological awareness has found that only Elision, a subskill of phonological processing, to have very strong statistically significant difference between the two groups ($p < .001$). Due to this interesting finding, a correlational analysis was conducted to further analyse the association of these three subskills with English reading. Both Elision and Phoneme Isolation subskills correlated strongly with English reading ($p < .001$).

The hypotheses for Research Question 2 were partially supported. All four English cognitive-linguistic skills predicting English Single Word Reading were statistically significant, with the following order of unique predictive effects on English reading development: (1) Rapid Naming, (2) Phonological Awareness, (3) Morphological Awareness, and then (4) Orthographic Knowledge. However, only two cognitive-linguistic skills predicting Chinese Single Word Reading was statistically significant, which are Rapid Naming and Morphological Awareness. The results of the present study will be discussed in the following chapter.

DISCUSSION

1. Introduction

In this thesis, it is argued that dyslexia is a language-based difficulty that may affect the reading development of English and Chinese differently, depending on the pedagogical factors and social factors of the linguistic environment (Paradis et al., 2011; Thomson, 2003; Wen et al., 2017) as well as the individual's cognitive abilities and nature of language (Brunswick, 2010; Comeau et al., 1999). As the English-Chinese bilinguals with dyslexia are diagnosed using formal psychological assessments only in L1 English in Singapore, the individual differences in L1 English are formally identified but L2 Chinese reading and cognitive-linguistic skills can only be explored. The thesis research adopted McBride's (2019, p. 34) "fab four: cognitive constructs for word reading" model to investigate English-Chinese bilingual learners' phonological awareness, orthographic knowledge, morphological awareness and fluency (i.e., rapid naming) in relation to dyslexia and reading development in both languages.

This chapter will discuss each finding in the following sections respectively with reference to the existing theories and evidence from Chinese-English bilingual studies on dyslexia and reading development and highlight some new insights on the influence of pedagogical factors and nature of language on the cognitive-linguistic skills in predicting reading.

2. Cognitive-linguistic Skills Differences between English-Chinese Bilingual Learners with and without Dyslexia

It is hypothesised that dyslexic learners will perform poorer in reading and all four cognitive-linguistic skills in English than typical learners because their dyslexia diagnoses were based on English. And, if the dyslexic learners perform poorer in Chinese reading than typical learners, they will perform poorer in all four cognitive-linguistic skills in Chinese than their typical learners as well. The present results indicate that English-Chinese bilingual learners with dyslexia do perform poorer in reading and all cognitive-linguistic skills in both languages than those without dyslexia. The present study's findings are generally in line with the previous comparison studies on differences in reading and all four

cognitive-linguistic skills in both languages between Chinese-English bilinguals with and without dyslexia diagnosed in Chinese (e.g., Chung & Ho, 2010b; Chung & Lam, 2020; Ho & Fong, 2005; Tong & McBride, 2017; Wong et al., 2012; Zhou et al., 2014). Findings from the *t*-test analysis also supported McBride's (2019, p. 34) "fab four: cognitive constructs for word reading" model that posits phonological awareness, orthographic knowledge, morphological awareness and fluency (i.e., rapid naming) as essential cognitive-linguistics skills in understanding dyslexia across all languages and scripts.

The statistically significant *t*-test results for English is in line with the major theories of dyslexia in English, specifically the phonological processing deficit theory (Snowling, 1998, 2001), double deficit theory (Wolf & Bowers, 1999) which states that a rapid naming deficit is present alongside a phonological deficit in the most severe cases of dyslexia, and morphological deficit theory (Casalis et al., 2004; Elbro & Arnbak, 1996; Joanisse et al., 2000; Siegel, 2008). Although an orthographic processing deficit is less researched in its relation with dyslexia in English (e.g., Hanley et al., 1992), it has been associated with predicting reading in English for monolinguals (e.g., Badian, 2001; Cunningham et al., 2001, 2002). This cognitive-linguistic skill deficit may be prominent in bilingual learners with dyslexia because of the dual language learning of English and Chinese, as Chinese-English bilingual learners with dyslexia were also found to be poorer in English orthographic knowledge than their typical peers (Chung & Ho, 2010b). It could also be due to the task measure modified with new test items that allowed the variance in this cognitive-linguistic skill to be observed in this present study's sample, which will need further exploration in future research.

The statistically significant *t*-test results for Chinese is also in line with the empirical research on cognitive processing deficits that found links with dyslexia in Chinese, namely phonological awareness at syllable level and onset-rime level (e.g., Li et al., 2012b; Lin et al., 2010; McBride-Chang et al., 2012; McBride-Chang & Kail, 2002; Shu et al., 2008; Siok & Fletcher, 2001), rapid naming (e.g., Chung & Ho, 2010b; Ho et al., 2004; McBride-Chang et al., 2008; Zhou et al., 2014), morphological awareness (e.g., Liu & McBride-Chang, 2010; McBride et al., 2008; McBride-Chang et al., 2003, 2008,

2012, 2013; McBride-Chang et al., 2005; Shu et al., 2006; Tong & McBride-Chang, 2009), and orthographic knowledge (Ho et al., 2002, 2004).

Although the participants with dyslexia in this study were diagnosed in English only, they were found to perform significantly poorer in both English and Chinese reading than those without dyslexia. The result may not be supporting the psycholinguistic theory that dyslexia varies across languages (Goswami, 2010; Ziegler et al., 2003, 2008; Ziegler & Goswami, 2005) because the present study was unable to purposefully sample bilingual learners, with and without dyslexia, who are good and poor readers of either language. Hence, the result cannot be generalised across all bilingual learners with dyslexia that they are poor readers in both languages. In the attempt to explore the natural variations in Chinese reading for this study sample, there were participants in the dyslexia group (2 out of 40) who obtained curriculum-appropriate and above-curriculum level of performance in Chinese reading. There were also participants in the control group (11 out of 30) who obtained below-curriculum level of performance in Chinese reading. It seems that there is a possibility for bilinguals with dyslexia to be better in reading in either language, as highlighted by some dyslexia studies on bilinguals, such as a dyslexic Chinese-English bilingual who had no reading problems in English and was good at some aspects of English phonological awareness (Ho & Fong, 2005) and a dyslexic English-Japanese bilingual who had reading difficulties in English but not in Japanese (Wydell & Butterworth, 1999; Wydell & Kondo, 2003). McBride et al. (2012) also noted anecdotal reports from the teachers in their study that highlighted the possibility of learners with dyslexia diagnosed in L1 may or may not have reading difficulties in L2.

However, it is not possible for the present study to use the cognitive-linguistic task measures to determine whether the 11 participants (37%) in the control group who obtained below-curriculum reading performance in Chinese have dyslexia in Chinese, as formal psychological assessments for dyslexia are conducted in English in Singapore. Also, it is not the purpose of my study to investigate individual cases to determine dyslexia in either language. An analysis using a Mann-Whitney U test was however run to determine if there was a difference in using Chinese as home language between

the 37% and remaining 67% of the control group participants. Ordinal data on the use of Chinese as home language was collected through self-report by the participants' parents on the Parent Questionnaire whether the language use was 'never', 'seldom', 'sometimes', 'often' or 'always'. The median score was statistically different between the two subgroups, $U = 42$, $z = -2.799$, $p = .005$. This shows that home language use may play a part in the participants' reading performance. In the present study's results, it is also found that Chinese home language use correlated significantly with the Chinese reading and cognitive-linguistic tasks and hence was used as a control variable in the regression analysis. However, it is important to note that this is based on self-report data collected from the Parent Questionnaire with uncorroborated reliability and validity. Hence, the uncertainty of the quality of language exposure should be taken into consideration when interpreting the relationship between home language use and reading.

Nonetheless, this present study has found the cognitive-linguistic differences for English-Chinese bilingual learners with dyslexia who were poorer in both English and Chinese reading than their typical peers similar to the findings of the studies on Chinese-English bilinguals who are poor readers of either language or both (e.g., Ding et al., 2013; Harrison & Krol, 2007; McBride-Chang et al., 2012, 2013; Tong et al., 2015) that found Chinese-English bilingual learners who were poor readers on both English and Chinese to be weaker in phonological awareness (McBride-Chang et al., 2013; Tong et al., 2015), morphological awareness (McBride-Chang et al., 2012, 2013; Tong et al., 2015) and rapid naming (Ding et al., 2013; McBride-Chang et al., 2012, 2013) than average readers. These studies also found more differentiated cognitive-linguistic skills differences whereby the bilingual learners who were poor readers of English were found to be poorer in phonological awareness (Harrison & Krol, 2007; McBride-Chang et al., 2012; Tong et al., 2015), and bilingual learners who were poor readers of Chinese were found to be weaker in phonological awareness (McBride-Chang et al., 2012), morphological awareness (McBride-Chang et al., 2012, 2013) than those who are average readers. Although these previous studies did not involve dyslexia, their findings have shown the possibility of

bilingual learners being poor readers of either languages or both and their underlying cognitive skills for their reading difficulties may differ given the orthographic differences between both languages.

One interesting point to note is that the *t*-test results showed high practical effect sizes for all English and Chinese cognitive-linguistic task measures between groups, except for English phonological awareness which showed a medium effect size. This finding is interesting because phonological awareness has been found to be a prominent processing deficit in dyslexia in monolinguals of English (e.g., Bradley & Bryant, 1983; Bruck & Treiman, 1990; Chafouleas et al., 1997; Liberman et al., 1972; Lyon, 1995; Ramus, 2003; Snowling, 1998; Stanovich, 1988a, 1988b, 1996; Wagner et al., 1997) but the bilingual learners in this study's sample showed a less prominent deficit in this cognitive-linguistic skill. A further comparison between the two groups on the phonological awareness subtasks found Elision to be the only subskill of phonological awareness that yielded a high effect size. This seems to suggest that a metalinguistic level of phonological awareness, that is, tasks such as elision that require explicit awareness and manipulation of phonemes, is the key marker of dyslexia in English-Chinese bilingual learners.

The Elision subtask assesses an individual's ability to analyse phonemes within a word, remove a specified phoneme, synthesise, and blend the remaining phonemes to produce a new word, as explained in several studies that investigated phonemic elision as a contributor to English reading and a deficit in this aspect of phonological awareness in dyslexia (e.g., Eckert et al., 2003; Eden & Zeffiro, 1998; Katzir et al., 2006; Kroese et al., 2000; Park & Lombardino, 2013; Robertson et al., 2013). Hence the Elision subtask requires the application of metalinguistic phonological awareness which is the ability to apply explicit phonological knowledge to discriminate, analyse and synthesise, and manipulate sequences of words, syllables and phonemes in spoken language (Bryen & Gerber, 1987; Carroll et al., 2003; Chaney, 1992; Cunningham, 1990; Savage et al., 2006; Tunmer et al., 1988). Metalinguistic phonological awareness is found to be associated with reading development (Chaney, 1992; Cunningham, 1990; Goswami, 2000; Melby-Lervåg et al., 2012; Tunmer et al., 1988) and is often

found to be deficient in children with reading difficulties (Bryen & Gerber, 1987; Goswami, 2000; Melby-Lervåg et al., 2012).

On the other hand, the Blending Words subtask is considered to assess epilinguistic phonological awareness as only implicit form of phonological knowledge is applied to detect similarities or differences of sounds, and procedurally blend and segment sequences of sounds in spoken language (Carroll et al., 2003; Cunningham, 1990; Goswami, 2000; Savage et al., 2006). The test items in Blending Words and Elision subtasks in the CTOPP-2 Phonological Awareness Task were arranged in the order of increasing difficulty from words to syllables, and to phonemes. The present study participants with dyslexia were observed to have more difficulties at the phonemic level than those without dyslexia, which is in line with the literature that monolingual and bilingual learners of English with dyslexia find phonemic awareness tasks challenging due to the neurological basis of dyslexia and nature of the English language (Dulude, 2012).

In view of the *t*-test results that showed the significant difference in elision subskill of phonological awareness between groups, a further analysis on the correlational relationship between the subskills of phonological awareness and English word reading was conducted and found that both Elision and Phonemic Isolation subskills correlated strongly with English word reading. This could be explained by the nature of the elision subtask of CTOPP-2 where isolating phonemes was part of the process of elision. During the Elision subtask, the participants were asked to produce a new word after removing a specified phoneme from the stimulus (e.g., participants have to say a new word after removing /p/ from the word “split”), so they would have to segment the phonemes in the word to identify the target phoneme to remove. Moreover, neuroimaging studies have found specific brain regions within the temporoparietal junction, the insula and the inferior frontal gyrus for processing phonemic elision (e.g., Eckert et al., 2003; Eden & Zeffiro, 1998), which were found to have less activation in dyslexic readers. These studies suggested the test of elision skill at phonemic level as a useful task for measuring phonological processing to identify symptoms of dyslexia in English.

The Elision task has also been utilised in studies to measure behavioural evidence of phonological processing deficit in dyslexia and reading development of native speakers of English (e.g., Katzir et al., 2006; Kroese et al., 2000; Park & Lombardino, 2013; Robertson et al., 2013). These studies utilised the earlier edition of CTOPP which is similar to the CTOPP-2 utilised in this present study, and found that Elision performance strongly associated with English word reading (Katzir et al., 2006; Kroese et al., 2000) and significantly weaker in children with dyslexia as compared to their matched controls (Robertson et al., 2013). In the study by Park and Lambardino (2013) that compared the cognitive-linguistic skills between younger and older children with dyslexia found that Elision and rapid naming were the main difficulties that persisted across time after the children entered school. Findings from these studies support that phonemic elision is associated with English reading and a deficit in this phonological subskill is a key characteristic of dyslexia. Therefore, this result showing that English-Chinese bilinguals with dyslexia performed significantly poorer than English-Chinese bilinguals without dyslexia in elision awareness in their first language and the significant correlation between English reading, and elision and phonemic isolation aligns with the findings of studies on English-speaking populations (e.g., Katzir et al., 2006; Kroese et al., 2000; Park & Lombardino, 2013; Robertson et al., 2013).

Another explanation for the strong correlation between English reading, and elision and phonemic isolation in the present bilingual sample could be the bilingual effect on metalinguistic development. While there is limited research that investigated the effect of bilingualism on metalinguistic development of phonological skills, it has been found that Taiwanese Chinese-English bilingual learners performed better than their English and Chinese monolingual counterparts in Elision and Blending Words subtasks of CTOPP (Marinova-Todd et al., 2010). Other similar studies also found bilingual facilitation effects in Taiwanese Chinese-English bilingual learners on their increased sensitivity in Chinese phonological skills (Kuo & Anderson, 2010) and Japanese-English bilingual learners on their increased phonological awareness in onset awareness of English (Kuo et al., 2016) over their respective monolingual counterparts. These studies have suggested the structural

sensitivity theory which postulates that early exposure to two languages, regardless of writing systems, allows bilingual children to have an advantage in forming language structural sensitivity at an abstract level and developing metalinguistic phonological skills (Kuo & Anderson, 2012). This may possibly explain the significant difference between dyslexia and control group in elision, and correlations of elision and phonemic isolation with reading.

3. Cognitive-linguistic Skills as Predictors of Reading Development in English-Chinese Bilingual

Learners

While the correlational analysis results showed strong statistically significant relationships between all four cognitive-linguistics skills and word reading in both English and Chinese, which further supported McBride's (2019) theory on the association of these cognitive-linguistic skills with reading, the thesis has also taken the investigation further on the association between reading and cognitive-linguistic skills by using regression analyses to test whether there are significant unique effects of other cognitive-linguistic skills in predicting reading when the most empirically and theoretically supported cognitive-linguistic skills (i.e., rapid naming and phonological awareness in English, and rapid naming and morphological awareness in Chinese) are controlled. McBride (2019) has highlighted that each cognitive-linguistic skill can differ in relative importance for reading development and impairment because of the different languages and writing systems. It is hypothesised that all four cognitive-linguistic skills will be significant predictors of English and Chinese languages respectively. For English reading, it is hypothesised that both Phonological Sensitivity and Rapid Naming will be significant predictors of reading, and Morphological Awareness and Orthographic Knowledge should still be significant predictors of reading after Phonological Sensitivity and Rapid Naming are controlled. For Chinese reading, it is hypothesised that both Morphological Awareness and Rapid Naming will be significant predictors of reading, and then Orthographic Knowledge and Phonological Sensitivity should still be significant predictors of reading after Morphological Awareness and Rapid Naming are controlled.

The present results found all four cognitive-linguistic skills to be predictive of reading in English, which fully supported the hypothesised predictive model for English reading. However, only two of the cognitive-linguistics skills, namely Rapid Naming and Morphological Awareness, are found to be predictive of reading in Chinese, which did not fully support the hypothesised predictive model for Chinese reading. The findings are discussed in detail in the following sections.

3.1. All four Cognitive-linguistic Skills as Unique Predictors of English Reading

The present study found significant and unique effect of rapid naming when it was first entered in the regression model, which is consistent with the literature that established rapid naming as a strong predictor of English reading development in bilingual learners (e.g., Chung & Ho, 2010b; Chung & Lam, 2020; Ding et al., 2013; McBride-Chang et al., 2012, 2013). The present study also found phonological awareness a significant predictor, after rapid naming was considered, which shows that phonological processing still has a unique effect on English reading for bilingual learners. This is in line with studies that support phonological processing as a critical cognitive-linguistic skill of English reading development (e.g., Anthony & Francis, 2005; Badian, 2001; Chafouleas et al., 1997; Hatcher et al., 1994, 2004; Joanisse et al., 2000; Navas et al., 2014; Snowling, 1998, 2001; Wagner et al., 1997). The finding of the significant unique effects of both rapid naming and phonological awareness reported here also supports the double deficit theory and studies that found the presence of both deficits in dyslexic individuals (e.g., Landerl et al., 2019; Landerl & Wimmer, 2008; Torgesen et al., 1997; Wolf, 1999; Wolf et al., 2000, 2002; Wolf & Bowers, 1999, 2000).

In addition, the finding that morphological awareness and orthographic knowledge were also significant unique predictors after controlling for rapid naming and phonological awareness suggests that there is more to atypical reading development than the double deficit theory alone. Morphological awareness has been found associated with reading development and dyslexia (e.g., Casalis et al., 2004; Joanisse et al., 2000; Kuo & Anderson, 2006; Siegel, 2008). Two local studies by Sun (2010) and Sun and Curdt-Christiansen (2016) on English-Chinese bilingual learners in Singapore, utilised an earlier version of the current morphological awareness tasks (O'Brien et al., 2021) adapted

and utilised in the present study. Although not specifically focused on dyslexia, these studies that found morphological awareness in English and Chinese a consistent and significant contributor to vocabulary and reading comprehension in the respective languages and can be shared between L1 and L2 languages. Findings from these studies also suggested the possible impact of language structure and instruction on bilingual learners' reading, given that the main emphasis of Singapore's curriculum for language subjects is on grammar, vocabulary, comprehension and written expression (MOE, 2010, 2015). While orthographic deficits in dyslexia in English less researched (e.g., Hanley et al., 1992), orthographic knowledge has been associated with reading developmental stages in English (Cunningham et al., 2001, 2002; Frith, 1986; Kuerten et al., 2020; Landerl, 2000). The present study's result showed that orthographic knowledge is a significant unique contributor to English reading with a very small effect size of .129, after controlling for rapid naming, phonological awareness, and morphological awareness, for the English-Chinese bilingual learners in Singapore.

It is noted here that there are no studies in literature that have found additional effects of morphological awareness and orthographic knowledge on reading in English, after rapid naming and phonological awareness were considered. Hence, the present study's finding is a unique contribution to current theories of dyslexia and reading development in English, based on the English-Chinese bilingual sample and language context in Singapore.

3.2. Morphological Awareness and Rapid Naming as Unique Predictors of Chinese Reading

The regression analysis showed that morphological awareness and rapid naming are robust predictors of Chinese reading, together explaining 36.1% of Chinese reading performance can be explained by both cognitive-linguistic skills, after controlling for Chinese language use at home. This analysis shows that morphological awareness plays a significant and unique role, beyond rapid naming, in reading development in Chinese, which aligns with the literature that established it as a key cognitive-linguistic skill associated with Chinese reading (e.g., Li et al., 2012; Liu et al., 2017; Liu et al., 2013) and deficient in Chinese dyslexic individuals (e.g., Luo et al., 2007; McBride et al., 2008; Shu et al., 2005, 2006). This finding further supported the two local studies by Sun (2010) and Sun and Curdt-

Christiansen (2016) on English-Chinese bilingual learners in Singapore that suggested morphological awareness a consistent and significant contributor to reading ability in both languages. In addition, the highly significant unique effect of rapid naming on Chinese reading further aligns with the current literature that rapid naming is a powerful predictor of reading (e.g., Chung & Ho, 2010b; Chung & Lam, 2020; Ding et al., 2013; Ho et al., 2002, 2004; McBride-Chang et al., 2012, 2013). Moreover, other studies have also found rapid naming a strong predictor for reading across other languages and scripts (e.g., Georgiou et al., 2008, 2011; McBride, 2019; Norton & Wolf, 2012; Savage, McBreen, et al., 2018). The high variance explained by both control variable, Chinese home language use, as well as the two cognitive-linguistic skills, morphological awareness and rapid naming, in this present study suggests that home language use, and deficits in morphological awareness and rapid naming in Chinese should be considered when assessing English-Chinese bilingual learners for dyslexia more holistically, instead of only phonological processing and processing speed in English which is the current focus in Singapore.

Although the remaining two cognitive-linguistic skills are not found to be predictive of Chinese reading in English-Chinese bilingual learners, phonological awareness may have some predictive role in Chinese reading as it explained for a very small but unique effect size of about 1% when it was entered into the regression model after controlling for rapid naming and morphological awareness. However, the change in variance was not significant probably due to the sample size. It is an unexpected result, considering that phonological awareness and orthographic knowledge were found to be significant contributors to reading of Chinese-English bilingual learners from Mainland China and Hong Kong (e.g., Ho et al., 2004; McBride-Chang et al., 2012, 2013; Shu et al., 2008; Siok & Fletcher, 2001). However, it should be noted that the sample in the present study cannot be classified into learners with and without dyslexia in Chinese, so the deficit model of dyslexia cannot be tested similarly as the bilingual studies from the major Chinese communities.

Some studies have suggested that there are differences in the prominence of these two cognitive-linguistic skills in Mainland China and Hong Kong populations, which could be due to cultural and educational differences. Chung and Ho (2010a) cited a study by 輝 (Luan) (2005) that found

significant differences in cognitive-linguistic deficits between dyslexic learners in Mainland China and Hong Kong, where there were more learners with phonological awareness deficit and less learners with less rapid naming deficit in Mainland China than in Hong Kong, suggested the possibility of how 'pinyin' and word recognition skills are learnt differently in both places. Studies that found orthographic and rapid naming as more prominent cognitive deficits of dyslexia were mainly evident in the Hong Kong population (e.g., Chung & Ho, 2010b; Ho et al., 2007; Ho et al., 2002, 2004), which could possibly due to how Chinese word recognition is learnt using traditional script and without auxiliary phonetic system (Wang & Tsai, 2011). Moreover, Siok and Fletcher (2001) also found phonological awareness predicting Chinese word reading of Chinese children in Mainland China, suggesting that it probably due to their learning of the 'hanyu pinyin' alphabetic script. Another comparison study by Leong et al. (2005) found Chinese-English bilingual learners from Mainland China to have stronger phonological awareness in English than those from Hong Kong, also suggesting that the learning of 'hanyu pinyin' may have contributed to this difference. As Singapore's Chinese language curriculum adopts the simplified script and 'hanyu pinyin' phonetic system of Chinese which is similar to Mainland China, this possibly explains why phonological awareness may play a modest predictive role but is surprisingly not found to be significant in this present study.

As compared to English, Chinese orthography is considered rather deep. Hence, phonological awareness may play a much minor role in reading and rapid naming has a stronger association given the significant contribution of visual processes within rapid naming to reading in Chinese (Norton & Wolf, 2012). It is interesting to note the present study also found rapid naming a strong predictor for English reading. This is supported by a study by Georgiou et al. (2008) which studied typically developing English, Greek and Chinese readers and found that the association between rapid naming and reading were similar across languages. A further study by Georgiou et al. (2016) that studied typically developing English, Finnish and Chinese readers found the same strong effect of rapid naming on reading across languages. Both studies suggested that certain components of rapid naming process may be more associated with the orthographic and phonological differences between the languages,

such as articulation, pause time and serial processing. However, it is unclear of the specific mechanisms underlying rapid naming in English and Chinese, given the lack of literature that compares rapid naming between English and Chinese, although Norton and Wolf (2012) claim that the differences across languages and orthographies are small.

The present study finding that orthographic knowledge plays no observable unique predictive role in Chinese reading could probably be explained by the literature that orthographic knowledge is found to be more associated with writing and copying rather than reading of Chinese words (e.g., Ho et al., 2003; Lam et al., 2011; McBride-Chang et al., 2011; Mo et al., 2018; Wang et al., 2013; Wang et al., 2014). While some studies did find orthographic knowledge associated with reading in Mainland China (e.g., Li et al., 2012; Tan et al., 2005), it could possibly be due to Chinese language being the first language to these bilingual learners and their amount of exposure to and use of the language is comparatively much more than that of Singapore's bilingual population.

4. Summary of Key Findings

As bilingual learners with dyslexia were diagnosed only in English, their English reading and all cognitive-linguistic skills were found to be significantly poorer than those without dyslexia and all cognitive-linguistic skills were significant unique predictors of English reading development. The present result not only supported the double deficit theory of dyslexia, but it also indicated the unique predictive roles of morphological awareness and orthographic knowledge after rapid naming and phonological awareness were considered. Although the present study did not formally identify poor readers of Chinese in its sample, bilingual learners with dyslexia in English were found to be poorer in Chinese reading and all cognitive-linguistic skills than those without dyslexia. In addition, rapid naming and morphological awareness were the only strong predictors of Chinese reading development. This present study's result supplemented the previous local studies that found morphological awareness a significant contributor to English and Chinese reading ability and indicated the possibility of morphological awareness a predictor for dyslexia in Chinese for English-Chinese bilingual learners in

Singapore. The findings from this study also have implications on the current educational practices in Singapore.

5. Theoretical and Educational Implications of the Study

Evidence from the present study supports the need for advocacy for the testing of reading ability and cognitive-linguistic skills to be done separately in English and Chinese for bilingual learners (McBride, 2019; McBride-Chang et al., 2012). The findings from this study also inform the ongoing debate about the identification and assessment of dyslexia, as the manifestation of reading difficulties and association of cognitive-linguistic skills differ in different languages (e.g., Elliott & Gibbs, 2008; Elliott & Grigorenko, 2014; Landerl et al., 2022; Poole, 2003; Smythe & Everatt, 2002) and different context in which the biological, cognitive and behavioural factors interact with the environmental factors (Frith, 1999, 2002). This is especially so in a bilingual context, like Singapore's, where dyslexia is diagnosed only based on the first language (Brookes et al., 2011; MOE, 2018). The assessment of dyslexia in Singapore can be problematic if the definition only focuses on phonological processing and processing speed deficits, and English language only (Elliott, 2020; Elliott & Gibbs, 2008; Elliott & Grigorenko, 2014; Gibbs & Elliott, 2020). Although the present study has not formally identified poor bilingual readers of Chinese in its sample, the individual differences in Chinese reading performance seem to indicate a different pattern of cognitive-linguistic skills as predictors to English reading, though some caution is needed here given the stepwise models were not identical. The key cognitive-linguistic skills that contribute to Chinese reading development are morphological awareness and processing speed, based on the findings of this study.

Dyslexia in Singapore's context can only be satisfactorily defined and diagnosed if a more comprehensive and broad approach is adopted in considering various factors contributing to the learner's reading development in both languages and a pedagogical approach in supporting reading difficulties in both languages related to dyslexia. As the present study results have suggested, all of the "fab four" cognitive-linguistic skills in English should be considered although more work is required on improving the psychometric properties of the task measures, especially the English Orthographic

Knowledge task. However, the present study currently suggests rapid naming and morphological awareness in Chinese only, probably due to the lack of purposively sampled good and poor Chinese readers to fully study the deficit model for poor reading development in Chinese. Nonetheless, McBride (2019) argued for a global perspective on understanding dyslexia beyond just English language and her proposed set of cognitive constructs found significant differences between bilingual learners with and without dyslexia in Singapore. Interventions can be more targeted to the specific difficulties assessed in each cognitive-linguistic skills to support bilingual learners who struggle with reading in either or both languages. As the current practice of identifying and assessing dyslexia takes place in two types of approaches in Singapore (i.e., the RTI approach and the use of comprehensive standardised psycho-educational assessments), some assessment of reading and cognitive-linguistic skills in Chinese should be part of the progress monitoring and assessment process for dyslexia in English-Chinese bilinguals. Although there is a lack of standardised assessment tools for Chinese language, most of the cognitive-linguistic task measures in this present study were found to be of good internal consistency reliability and can be considered in exploring the use of these task measures.

The present study may be the first research conducted specifically in Singapore's context in understanding the manifestation of dyslexia in English-Chinese bilingual learners, as there are no similar studies conducted on bilingual learners whose first language is English and second language is Chinese. It has served as an initial step in shedding some light on the cognitive-linguistic skills that underlie reading development in both languages, which informs how dyslexia can be identified and supported in a bilingual educational setting. Limitations of the study and some recommended directions for future research are discussed in the 'Conclusion' chapter.

CONCLUSION

1. Overview of the Study

This thesis research is an initial study that investigates dyslexia and the cognitive-linguistics skills of English-Chinese bilingual learners, as there are no similar studies conducted specifically in Singapore's context where first language is English and second language is Chinese. There were two main research aims in the thesis. The first research interest was to investigate whether the English-Chinese bilingual learners with dyslexia diagnosed in English in Singapore are weaker in reading and all four cognitive-linguistic skills in both languages or either language, as compared to their typical counterparts. The second research interest was to investigate which cognitive-linguistic constructs are strong predictors of reading in each language in English-Chinese bilingual learners in Singapore. To answer the research questions, the thesis research tested McBride's (2019, p. 34) "the fab four: cognitive constructs for word reading" model by investigating English-Chinese bilingual learners' phonological awareness, orthographic knowledge, morphological awareness and fluency (i.e., rapid naming) in relation to dyslexia and reading development in both languages.

It can be concluded that dyslexia may manifest differently in reading and cognitive-linguistic skills of both English and Chinese languages in English-Chinese bilingual learners, based on the two different predictive models with different empirically and theoretically supported orders of cognitive-linguistic skills as predictors for reading development in the two languages. The difference in the unique contributions of the four cognitive-linguistic skills underlying the reading development of both languages suggests the difference in language structure and instruction. The results not only supported the double deficit theory in explaining for dyslexia, but it also indicated the unique predictive roles of morphological awareness and orthographic knowledge in English reading development, which suggests that there is more to atypical reading development in English than the double deficit theory alone. The results also indicated rapid naming and morphological awareness as the only significant contributors of Chinese reading development, suggesting the possibility of these two cognitive-linguistic skills as predictors for atypical reading development in Chinese for English-

Chinese bilingual learners in Singapore. In addition, the non-standardised task measures utilised in this study have been assessed to have good level of internal consistency reliability and can be explored for future use in assessing reading ability and cognitive-linguistic skills for English-Chinese bilingual learners in Singapore.

2. Limitations of the Study

The present study's results should be taken into account that there were limitations and constraints to the methodological process, in terms of sampling and data collection. The methodological process of the study was constrained by the worsening of Covid-19 situation in Singapore during the recruitment and data collection period, and so the administration of reading and cognitive-linguistic tasks was done in one sitting for each participant and in either physical or online mode. The online mode of testing and the mandatory wearing of masks during physical mode of testing may have compromised the quality of sound and speech when both the researcher and participants interact. Although the tasks were scored as best as the situation allows (i.e., researcher clarified and asked the participant to repeat), the low quality of sound may be produced due to technological issues and mask wearing. Repeated clarification from the researcher may have also affect the participants' responses to the tasks. Some participants were observed to change their answers when they were asked to repeat their responses. Hence, these extraneous factors may inevitably have some effect on the scoring of the tasks.

The participants in this study may not be fully representative of Singapore's English-Chinese bilingual population as they were recruited through convenience sampling. Moreover, the different ways of recruitment for both groups could be a confounding factor. The dyslexia group were mostly recruited from the DAS, and the control group were mostly recruited from two mainstream primary schools and through opportunity sampling. The overall sample size was small for both dyslexia and control groups ($n = 40$ and $n = 30$ respectively). A recommendation is to have a more representative sample of Singapore's population with a larger number of participants recruited from more primary schools and other local organisations (Heiman, 2011).

Although the control group participants were chronologically age matched with the dyslexia group participants, no reading age matched control group participants were recruited in this study. The present study's results that show significant differences in reading and cognitive-linguistic skills between age-matched bilingual learners with and without dyslexia cannot be determined if they are special characteristics due to dyslexia or maturity (Jackson & Butterfield, 1989). Additionally, the present results that indicate the cognitive-linguistic skills as predictors of reading development is based on a correlational design and not a casual design. A 2X3 factorial design that compares between dyslexia group with chronological age matched control and reading age matched control groups will be able to assess the causal relationship between the cognitive-linguistic skills and reading (Jackson & Butterfield, 1989). This design allows for the potential causes of different cognitive-linguistic skills in reading development to be tested while controlling for the possible extraneous influence of maturity, which some Chinese-English bilingual studies adopted (e.g., Chung & Ho, 2010b; Zhou et al., 2014). Recommendations for future research stemming from this limitation is discussed in the Section 3.

The present study was also limited by the availability of established assessment tools to measure various cognitive-linguistic skills, especially for Chinese. The task measures used for all Chinese reading and cognitive-linguistic skills as well as English orthographic and morphological skills were non-standardised, and the availability of the established tasks was subjected to the approvals obtained by the original authors (i.e., Cunningham et al., 2001; Lin et al., 2016; O'Brien et al., 2021). The established non-standardised tasks were adapted to better suit the present study's sample by amending and translating the task instructions, transforming the presentation of tasks for the purpose of online mode of testing (i.e., PowerPoint slides and audio-recorded reading of test items), and modification of test items. All the task measures, including standardised tasks, were assessed to be of good internal consistency reliability (Dornyei, 2007; Taber, 2018), except for the English and Chinese Rapid Naming tasks which could not be assessed for test-retest reliability. Rapid Naming tasks were used in this study, following McBride's (2019) recommendation for measuring fluency as one of the 'fab four' cognitive-linguistic skills for reading development. It is noted in literature that some studies

adopted the measurement of reaction time for fluency, in addition to reading accuracy of each task (e.g., Meng et al., 2019; Poulsen & Elbro, 2013; Zhao et al., 2017). In the present study, the administration and scoring of Rapid Naming tasks in English and Chinese followed the procedures of CTOPP-2's Rapid Letter Naming subtest in which the number of seconds the participant took to name all the English letters or Chinese number characters correctly, and no score awarded if the participant was unable to name all the practice items correctly or misnamed more than four items on the test page. Moving forward, reaction time taken for each reading and cognitive-linguistic task can be considered. The English Orthographic Knowledge task was modified with new test items, based on observations and feedback received from the pilot study. However, the new task measure was not piloted again to assess for its suitability. Although the preliminary results showed a possible ceiling effect and a reduced internal consistency reliability coefficient after the modification, the coefficient still indicated a good level of internal consistency reliability. Moving forward, this task will need improvements in its psychometric properties by reconsidering the construct definition and validation of new test items before actual implementation in future research (Irwing & Hughes, 2018).

3. Recommendations for Future Research

This present study can be the first of programmatic research in which a series of studies can be conducted with purposively sampled groups of English-Chinese bilingual participants, to extend the findings from this study to establish causal links between cognitive-linguistic skills and reading development. With the view that bilingual learners may vary in their reading proficiency (Hoff et al., 2012; Yang, 2017) and the possibility of bilinguals with dyslexia who can be poor in reading of either language only (Ho & Fong, 2005; McBride-Chang et al., 2012; Wydell & Butterworth, 1999; Wydell & Kondo, 2003), future research stemming from this present study may explore conducting a series of factorial designs to compare English-Chinese bilingual learners with good and poor reading performance in either language and with and without dyslexia, which includes chronological and reading age matched controls.

Another recommendation for future research is to evaluate and improve the psychometric properties of the non-standardised task measures utilised in the present study, especially for the English Orthographic Knowledge task. Irwing and Hughes (2018) suggested stages of test development from construct definition to piloting of test items by using a combination of both confirmatory factor analysis and item response theory to explore the psychometric properties of the task measures. With improved psychometric properties, cross language effects can also be explored, as some studies investigated language effects using standardised tests or tests with good reliability across years based on the same population in longitudinal research (e.g., Chung & Ho, 2010b; Chung & Lam, 2020; McBride-Chang et al., 2012). As the task measures used in the present study were mostly non-standardised with no good reliability across years based on the same population and test items were not comparable across tasks in English and Chinese, it is difficult to meaningfully compare the mean scores. In addition, new task measures can also be included for a more comprehensive set of cognitive-linguistic skills assessment for English-Chinese bilingual learners in Singapore. Elision awareness assessment should be included in the phonological awareness tasks, given that research has shown bilingual effects on metalinguistic development of phonological skills (Kuo et al., 2016; Kuo & Anderson, 2010, 2012; Marinova-Todd et al., 2010) and metalinguistic skills is often found to be deficient in children with reading difficulties (Bryen & Gerber, 1987; Goswami, 2000; Melby-Lervåg et al., 2012). Tone awareness could also be included, since Chinese is a tonal language. The Chinese phonological task used in the present study required the participants to delete syllable, onset or rime without changing the tones (e.g., say /wāng/ without /w/ and the answer should be /āng/ and not /àng/). It was observed that some participants had some difficulties maintaining the same tone during the task, especially those with dyslexia or were poorer in Chinese. Tone awareness was found to be an important aspect of Chinese phonological awareness for early literacy and Chinese character recognition in pre-schoolers (Shu et al., 2008) and deficient in older Cantonese-speaking children with dyslexia (Li & Ho, 2011). It will be helpful to understand if such deficit in tone awareness is present in English-Chinese bilingual learners with dyslexia and whether it is specific to or across all age groups.

An examination on the suitability of these task measures can also be further extended to different age groups across the primary school students (e.g., 10 years 0 month to 10 years 11 months, 11 years 0 month to 11 years 11 months, 12 years 0 months to 12 years 11 months, etc) and with larger sample size, to assess English-Chinese bilingual learners who face difficulties in learning to read in either or both languages in Singapore. In the present study, the *t*-test and regression analyses did not control for variables such as general ability, gender, ethnicity and social class effects. Hence, future studies could consider controlling for these variables as well.

It is hoped that the present study serves as an initial step in investigating dyslexia in Singapore's bilingual context and a platform for similar research to extend current findings, as there are no similar studies conducted specifically on bilingual learners whose first language is English and second language is Chinese. The Chinese assessment tools can be further adapted and assessed for validity and reliability for Singapore's English-Chinese bilingual population across different age groups to understand the prevalence of poor readers in either and both languages, following similar previous studies conducted by Lin et al (2020) on prevalence of dyslexia across age groups in Mainland China as well as McBride-Chang et al. (2013) and Tong et al. (2015) on prevalence of poor readers in either and both languages across areas of Mainland China and Hong Kong. As Malay and Tamil are also the other two official languages for Mother Tongue, it is also hoped that the present study serves as a reference for future research on understanding dyslexia in English-Malay and English-Tamil bilingual groups in Singapore, where distinct patterns of cognitive-linguistic skills contributing to reading development could be hypothesised based on the language structure and writing systems.

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APPENDICES

Appendix 1. Research Ethics Application Approval by IOE Research Ethics Committee

Institute of Education



Doctoral Student Ethics Application Form

Anyone conducting research under the auspices of the Institute of Education (staff, students or visitors) where the research involves human participants or the use of data collected from human participants, is required to gain ethical approval before starting. This includes preliminary and pilot studies. Please answer all relevant questions in simple terms that can be understood by a lay person and note that your form may be returned if incomplete.

Registering your study with the UCL Data Protection Officer as part of the UCL Research Ethics Review Process

If you are proposing to collect personal data i.e. data from which a living individual can be identified **you must be registered with the UCL Data Protection Office before you submit your ethics application for review**. To do this, email the complete ethics form to the [UCL Data Protection Office](#). Once your registration number is received, add it to the form* and submit it to your supervisor for approval. If the Data Protection Office advises you to make changes to the way in which you propose to collect and store the data this should be reflected in your ethics application form.

Please note that the completion of the [UCL GDPR online training](#) is mandatory for all PhD students.

Section 1 – Project details

- a. Project title: **An Investigation on Cognitive-Linguistic Skills of English-Chinese Bilingual Learners with and without Dyslexia in Singapore**
- b. Student name and ID number (e.g. ABC12345678): **Shen Peixin (SHE14121463)**
- c. ***UCL Data Protection Registration Number: Z6364106/2021/05/57**
 - a. Date Issued: **12 May 2021**
- d. Supervisor/Personal Tutor: **Dr Robert Savage & Dr Fotini Diamantidaki**
- e. Department: **IOE**
- f. Course category (Tick one):

PhD	<input type="checkbox"/>
EdD	<input checked="" type="checkbox"/>
DEdPsy	<input type="checkbox"/>
- g. **If applicable**, state who the funder is and if funding has been confirmed.
- h. Intended research start date: **1 May 2021**
- i. Intended research end date: **31 Dec 2021**
- j. Country fieldwork will be conducted in: **Singapore**
- k. If research to be conducted abroad please check the [Foreign and Commonwealth Office \(FCO\)](#) and submit a completed travel risk assessment form (see guidelines). If

Section 10 – Declaration

I confirm that to the best of my knowledge the information in this form is correct and that this is a full description of the ethical issues that may arise in the course of this project.

I have discussed the ethical issues relating to my research with my supervisor.

Yes No

I have attended the appropriate ethics training provided by my course.

Yes No

I confirm that to the best of my knowledge:

The above information is correct and that this is a full description of the ethics issues that may arise in the course of this project.

Name Shen Peixin

Date 19 April 2021

Please submit your completed ethics forms to your supervisor for review.

Notes and references

Professional code of ethics

You should read and understand relevant ethics guidelines, for example:

[British Psychological Society](#) (2018) *Code of Ethics and Conduct*

Or

[British Educational Research Association](#) (2018) *Ethical Guidelines*

Or

[British Sociological Association](#) (2017) *Statement of Ethical Practice*

Please see the respective websites for these or later versions; direct links to the latest versions are available on the [Institute of Education Research Ethics website](#).

Disclosure and Barring Service checks

If you are planning to carry out research in regulated Education environments such as Schools, or if your research will bring you into contact with children and young people (under the age of 18), you will need to have a Disclosure and Barring Service (DBS) CHECK, before you start. The DBS was previously known as the Criminal Records Bureau (CRB). If you do not already hold a current DBS check, and have not registered with the DBS update service, you will need to obtain one through at IOE.

Doctoral student ethics application form Version 2.1

Last updated 02/12/20

Ensure that you apply for the DBS check in plenty of time as will take around 4 weeks, though can take longer depending on the circumstances.

Further references

Robson, Colin (2011). *Real world research: a resource for social scientists and practitioner researchers* (3rd edition). Oxford: Blackwell.

This text has a helpful section on ethical considerations.

Alderson, P. and Morrow, V. (2011) *The Ethics of Research with Children and Young People: A Practical Handbook*. London: Sage.

This text has useful suggestions if you are conducting research with children and young people.

Wiles, R. (2013) *What are Qualitative Research Ethics?* Bloomsbury.

A useful and short text covering areas including informed consent, approaches to research ethics including examples of ethical dilemmas.

Departmental Use

If a project raises particularly challenging ethics issues, or a more detailed review would be appropriate, the supervisor must refer the application to the Research Development Administrator via email so that it can be submitted to the IOE Research Ethics Committee for consideration. A departmental research ethics coordinator or representative can advise you, either to support your review process, or help decide whether an application should be referred to the REC. If unsure please refer to the guidelines explaining when to refer the ethics application to the IOE Research Ethics Committee, posted on the committee's website.

Student name:

Student department:

Course:

Project Title:

Reviewer 1

Supervisor/first reviewer name: Fotini Diamantidaki

Do you foresee any ethical difficulties with this research?

No



Supervisor/first reviewer signature:

Doctoral student ethics application form Version 2.1
Last updated 02/12/20

Date: 13.05.2021

Reviewer 2

Second reviewer name: Robert Savage

Do you foresee any ethical difficulties with this research? No

Second reviewer signature: 

Date: 13.05.2021

Decision on behalf of reviewers

Approved

Approved subject to the following additional measures

Not approved for the reasons given below

Referred to the REC for review

Points to be noted by other reviewers and in report to REC:

Comments from reviewers for the applicant:

Once it is approved by both reviewers, students should submit their ethics application form to the Centre for Doctoral Education team: IOE.CDE@ucl.ac.uk.

Appendix 2. Participant Information Sheets and Consent Forms (Parent and Child versions)

Institute of Education



Participant Information Sheet for Parents

Dear Parent,

I would like to invite you and your child to participate in my research project which is part of my Doctoral Thesis.

Research Project title: An Investigation on Cognitive-Linguistic Skills of English-Chinese Bilingual Learners with and without Dyslexia in Singapore

Research objective: In Singapore, the diagnosis of dyslexia is done through use of standardised tests which are conducted only in English. However, our children are bilingual learners and dyslexia may affect different languages differently. The research study has taken interest in investigating how different are our bilingual learners who are diagnosed with dyslexia in Singapore, in terms of their cognitive-linguistic skills specifically in English and Chinese, as compared to their typical peers. The research study aims to investigate the key differences in the cognitive-linguistic skills between English-Chinese bilingual learners with and without dyslexia, as well as the cognitive-linguistic skills that are associated to reading development in both English and Chinese languages of bilingual learners in Singapore. The research hopes to point to future directions in identifying deficits in certain cognitive-linguistic skills and elicit an evidence-based response to intervention for English-Chinese bilingual learners with dyslexia in Singapore.

I am writing to you because your child is aged between 9 years 0 month and 9 years 11 months old, and currently taking English and Chinese language subjects in school. I have obtained an approval from the Ministry of Education to collect data at the school which your child is studying in. Hence, I would like to seek your consent to participate in my research project with your child.

Participation is voluntary. Your and your child's participation is highly appreciated. However, you and your child can withdraw from the research at any time and without consequences.

What is the commitment for you and your child in the research: There will be a parents' questionnaire which will be emailed to you and will take approximately 15 minutes to complete. The questionnaire will ask for information such as your child's gender, race, date of birth, past school results for English and Chinese language subjects, and psychological report of dyslexia (if any), as well as your education background and type of dwelling, etc. This is to find out the suitability of your child's participation in the study. When found suitable, your child will be invited to take English and Chinese reading tests to assess his/her proficiency level

which will take approximately 30 minutes. Your child will also be informed of the aims and purposes of this study, and his/her written consent will also be sought. If your child is further found to be suitable for the study, your child will be invited again to undertake four other assessment tasks to assess his/her cognitive-linguistic skills in both English and Chinese which will take approximately 45 minutes.

Your child's assessment will be conducted at your child's school at a time that is convenient for you and your child. In view of the current COVID-19 situation, safe management measures will be put in place such as temperature taking, wearing of masks at all times and your child seated at least 1 metre apart from the researcher. If there are further restrictions due to COVID-19 safe distancing measures, your child's assessment may be conducted online. An advisory on COVID-19 Safe Management Measures will be sent to you when you consent to participate in the study.

All information and data collected from you and your child will be anonymised and kept confidential. In the event your child is not found suitable, you will be duly informed. All information and data collected from you and your child will not be used in the study and will be deleted permanently by means of shredding (physically and electronically).

Risks and Discomforts: Should you and your child feel uncomfortable during the research due to sensitivity of the questionnaire or assessment tasks, you and your child are allowed to reject continuing and/or request to withdraw from the research.

Benefits: You will receive first-hand updates of the study findings. The scores of your child's assessments can be shared with you upon request. The research findings and literature will also be shared with you when the study is completed.

Anonymous and Confidential Data Collection: All the information and data collected during the research will be kept strictly confidential. You and your child will not be able to be identified in any ensuing reports or publications. All information and data will also be stored securely with UCL's data service network. Only the researcher (myself) and my supervisors will have access to the research data.

Confidentiality of records: All the information and data collected during the research will be kept in a secured database which can only be accessed by the researcher (myself) and my supervisors. All data will be anonymized to protect your and your child's identity. The data will be kept for 5 years after the Thesis Report has been submitted. They will be completely destroyed after 5 years. Method of destruction is by way of shredding (physically and electronically). Steps will be undertaken to ensure all copies of the data are destroyed, including back-up copies, access copies, and copies stored near line, off-line and on physical storage devices. Should there be details contained on any record labels, they will be obliterated.

Personal Data:

By signing the Consent Form attached, you (*or your legally acceptable representative, if relevant*) are authorizing (i) collection, access to, use and storage of your "Personal Data", and (ii) disclosure to, and use and storage by, authorised service providers and relevant third parties, whether located in Singapore or overseas, for the purposes of the study.

“**Personal Data**” means data about you which makes you identifiable: (i) from such data; or (ii) from that data and other information which an organisation has or likely to have access. This includes medical conditions, medications, investigations and treatment history.

Research arising in the future, based on this “Personal Data”, will be subject to review by the relevant institutional review board.

Data collected are the property of the University College London. In the event of any publication regarding this study, your identity will remain confidential.

Notice:

The controller for this project will be University College London (UCL). The UCL Data Protection Officer provides oversight of UCL activities involving the processing of personal data, and can be contacted at data-protection@ucl.ac.uk

This ‘local’ privacy notice sets out the information that applies to this particular study. Further information on how UCL uses participant information can be found in our ‘general’ privacy notice:

For participants in research studies, click [here](#)

The information that is required to be provided to participants under data protection legislation (GDPR and DPA 2018) is provided across both the ‘local’ and ‘general’ privacy notices.

The lawful basis that will be used to process your personal data is: ‘Public task’ for personal data.

Your personal data will be processed so long as it is required for the research project. If we are able to anonymise or pseudonymise the personal data you provide we will undertake this, and will endeavour to minimise the processing of personal data wherever possible.

If you are concerned about how your personal data is being processed, or if you would like to contact us about your rights, please contact UCL in the first instance at data-protection@ucl.ac.uk

The results of the research will be written up for a Doctoral Thesis, which is due to be completed in 31 Dec 2021. It is possible that after the Thesis Report has been submitted, other researchers may look at the data as part of the review process, but you and your child will not be able to be identified.

Who to contact with questions: The Research Ethics Committee of University College London has approved the ethics application for the study. The UCL Research Ethics Committee can be contacted by emailing IOE.CDE@ucl.ac.uk for any further enquiries pertaining to ethics. If you have any questions, please feel free to contact me at xxxxxxxx or by email peixin.shen.14@ucl.ac.uk (Priscillia Shen). You can also contact my supervisors: robert.savage@ucl.ac.uk (Dr Robert Savage) or f.diamantidaki@ucl.ac.uk (Dr Fontini Diamantidaki).

Consent Form for Parents

If you are happy to participate in this study, please complete this consent form and return it to Priscillia Shen via email at peixin.shen.14@ucl.ac.uk.

	Yes	No
I have read, discussed and understand the information and procedures in the study information sheet attached to this consent form.	<input type="checkbox"/>	<input type="checkbox"/>
I acknowledge that I am participating in this study of my own free will.	<input type="checkbox"/>	<input type="checkbox"/>
I understand that the results of this research will be shared through publications and presentations.	<input type="checkbox"/>	<input type="checkbox"/>
I understand that if any of my information are used in reports or presentations, they will not be attributed to me.	<input type="checkbox"/>	<input type="checkbox"/>
I understand that my child and I can opt out of this research project at any time, and that any data contributed by my child and me will not be used.	<input type="checkbox"/>	<input type="checkbox"/>
I understand that I can contact Priscillia Shen at any time and request for my data to be removed.	<input type="checkbox"/>	<input type="checkbox"/>
I agree that the data my child and I provide will be archived at the UK Data Service, and that other authenticated researchers will have access to this data, but only if they agree to preserve the confidentiality of the information as requested in this form.	<input type="checkbox"/>	<input type="checkbox"/>

Name: _____ Contact No.: _____

Email: _____

Signed: _____ Date: _____

Participant Information Sheet for Students

Dear Student,

I would like to invite you to participate in my research project which is part of my Doctoral Thesis.

Research Project title: An Investigation on Cognitive-Linguistic Skills of English-Chinese Bilingual Learners with and without Dyslexia in Singapore

Research objective: The research study aims to investigate the differences between English-Chinese bilingual learners with and without dyslexia in Singapore, and how the differences are associated to reading in both English and Chinese languages. The research hopes to point to future directions in identifying the differences and elicit an intervention for English-Chinese bilingual learners with dyslexia in Singapore.

I am writing to you because you are aged between 9 years 0 month and 9 years 11 months old, and currently taking English and Chinese language subjects in school. I have obtained an approval from the Ministry of Education to collect data at the school which you are studying in. Hence, I would like to seek your consent to participate in my research project.

Participation is voluntary. Your participation is highly appreciated. However, you can leave the research at any time and without consequences.

What is the commitment for you in the research: There will be English and Chinese reading tasks which will take approximately 30 minutes. If you are further found to be suitable for the study, you will be invited again to undertake four other tasks to in both English and Chinese which will take approximately 45 minutes. There are no right or wrong answers, and you only have try your very best.

The tasks will be done at your centre at a time that is convenient for you. In view of the current COVID-19 situation, there will be safe management measures such as temperature taking, wearing of masks at all times and sitting at least 1 metre apart from me. If there are further restrictions due to COVID-19 safe distancing measures, the tasks may be done online.

All information and data collected from you will be anonymised and kept confidential. In the event you are not continuing with the study, you will be informed. All information and data collected from you will not be used in the study and will be deleted permanently by means of shredding (physically and electronically).

Risks and Discomforts: Should you feel uncomfortable during the research due to sensitivity of the tasks, you are allowed to stop continuing and/or request to leave the research.

Benefits: You will receive first-hand updates of the study findings when the research is completed.

Anonymous and Confidential Data Collection: All the information and data collected during the research will be kept strictly confidential. You will not be able to be identified in any ensuing reports or publications. All information and data will also be stored securely with UCL's data service network. Only the researcher (myself) and my supervisors will have access to the research data.

Confidentiality of records: All the information and data collected during the research will be kept in a secured database which can only be accessed by the researcher (myself) and my supervisors. All data will be anonymized to protect your identity. The data will be kept for 5 years after the Thesis Report has been submitted. They will be completely destroyed after 5 years. Method of destruction is by way of shredding (physically and electronically). Steps will be undertaken to ensure all copies of the data are destroyed, including back-up copies, access copies, and copies stored near line, off-line and on physical storage devices. Should there be details contained on any record labels, they will be obliterated.

Personal Data:

By signing the Consent Form attached, you (*or your legally acceptable representative, if relevant*) are authorizing (i) collection, access to, use and storage of your "Personal Data", and (ii) disclosure to, and use and storage by, authorised service providers and relevant third parties, whether located in Singapore or overseas, for the purposes of the study.

"**Personal Data**" means data about you which makes you identifiable: (i) from such data; or (ii) from that data and other information which an organisation has or likely to have access. This includes medical conditions, medications, investigations and treatment history.

Research arising in the future, based on this "Personal Data", will be subject to review by the relevant institutional review board.

Data collected are the property of the University College London. In the event of any publication regarding this study, your identity will remain confidential.

Notice:

The controller for this project will be University College London (UCL). The UCL Data Protection Officer provides oversight of UCL activities involving the processing of personal data, and can be contacted at data-protection@ucl.ac.uk

This 'local' privacy notice sets out the information that applies to this particular study. Further information on how UCL uses participant information can be found in our 'general' privacy notice:

For participants in research studies, click [here](#)

The information that is required to be provided to participants under data protection legislation (GDPR and DPA 2018) is provided across both the 'local' and 'general' privacy notices.

The lawful basis that will be used to process your personal data is: 'Public task' for personal data.

Your personal data will be processed so long as it is required for the research project. If we are able to anonymise or pseudonymise the personal data you provide we will undertake this, and will endeavour to minimise the processing of personal data wherever possible.

If you are concerned about how your personal data is being processed, or if you would like to contact us about your rights, please contact UCL in the first instance at data-protection@ucl.ac.uk

The results of the research will be written up for a Doctoral Thesis, which is due to be completed in 31 Dec 2021. It is possible that after the Thesis Report has been submitted, other researchers may look at the data as part of the review process, but you will not be able to be identified.

Who to contact with questions: The Research Ethics Committee of University College London has approved the ethics application for the study. The UCL Research Ethics Committee can be contacted by emailing IOE.CDE@ucl.ac.uk for any further enquiries pertaining to ethics. If you have any questions, please feel free to contact me at xxxxxxxx or by email peixin.shen.14@ucl.ac.uk (Priscillia Shen). You can also contact my supervisors: robert.savage@ucl.ac.uk (Dr Robert Savage) or f.diamantidaki@ucl.ac.uk (Dr Fontini Diamantidaki).

Consent form for Students

If you are happy to participate in this study, please complete this consent form and return it to Ms Priscillia Shen:

	Yes	No
I have read, discussed and understand the information and procedures in the study information sheet attached to this consent form.	<input type="checkbox"/>	<input type="checkbox"/>
I acknowledge that I am participating in this study of my own free will.	<input type="checkbox"/>	<input type="checkbox"/>
I understand that the results of this research will be shared through publications and presentations.	<input type="checkbox"/>	<input type="checkbox"/>
I understand that if any of my information are used in reports or presentations, they will not be attributed to me.	<input type="checkbox"/>	<input type="checkbox"/>
I understand that I can opt out of this research project at any time, and that any data contributed by me will not be used.	<input type="checkbox"/>	<input type="checkbox"/>
I understand that I can contact Priscillia Shen at any time and request for my data to be removed.	<input type="checkbox"/>	<input type="checkbox"/>
I agree that the data I provide will be archived at the UK Data Service, and that other authenticated researchers will have access to this data, but only if they agree to preserve the confidentiality of the information as requested in this form.	<input type="checkbox"/>	<input type="checkbox"/>

Name: _____

Signed: _____

Date: _____

Appendix 3. Covid-19 Safe Measure Management Advisory

Institute of Education



Dear Parent/Participant,

Thank you for your consent to participate in my research project which is part of my Doctoral Thesis.

Research Project title: An Investigation on Cognitive-Linguistic Skills of English-Chinese Bilingual Learners with and without Dyslexia in Singapore

This is an advisory on COVID-19 Safe Management Measures to adhere to as you participate in my research.

When arranging for data collection from participants:

- Researcher's meeting with participants will be one-to-one (only 2 persons in a room).
- Researcher's meeting with participants will be at the school or DAS centre which the participants are in.
- Researcher's meeting with participants will be in a room with good air circulation.
- Researcher's meeting time with participants will be arranged to avoid peak hours for public transport.
- Researcher's meeting time with each participant will be staggered (i.e. 30 minutes apart) to avoid cross-mingling between the participants before and after each meeting.
- Researcher should be informed prior to the meeting if the participant is feeling unwell. The participant should not turn up if he/she is feeling unwell.
- In the event the participant or researcher is unwell, the meeting will be rearranged to another date and time.

During data collection with participants:

- Researcher will take temperature and declare via SafeEntry at the school or DAS centre where data collection will be conducted.
- There will be temperature-taking using a contactless thermometer for participant to ensure he/she is well before the start of data collection.
- In the event the participant or researcher is found unwell, the meeting will be rearranged to another date and time.
- Participant should check-in using TraceTogether token or SafeEntry App at the school or DAS centre before meeting the researcher.
- Both researcher and participant should wear masks at all times and use the hand sanitizer in the room when needed.
- Both researcher and participant must maintain at least 1 metre safe distancing and have own set of materials and stationery to use.
- Before and after each meeting with participant, the researcher will sanitize the table, chair and stationery.

If you have any questions, please feel free to contact me at xxxxxxxx or by email peixin.shen.14@ucl.ac.uk (Priscillia Shen).

Appendix 4. Research Approvals from MOE and DAS



1 North Buona Vista Drive
Singapore 138675
Robinson Road P.O. Box 746
Telephone : (65) 68722220
Facsimile : (65) 67755826
Website : www.moe.gov.sg
Email : contact@moe.gov.sg

Ministry of Education SINGAPORE

EDUN N32-07-005

Request No.: **RQ46-21(09)**

16 September 2021

Ms Shen Peixin



Dear Peixin,

AN INVESTIGATION ON COGNITIVE-LINGUISTIC SKILLS OF ENGLISH-CHINESE BILINGUAL LEARNERS WITH AND WITHOUT DYSLEXIA IN SINGAPORE

I refer to your application for approval to collect data from schools.

2. I am pleased to inform you that the Ministry has no objections to your request to conduct the research in **2 primary schools**, subjected to the following conditions:

- a) the approved research proposal is adhered to during the actual study in the school;
- b) the data collected is kept strictly confidential and used for the stated purpose only; and
- c) the findings are not published without written approval from the Ministry and a copy of the findings is shared with the Ministry upon completion of the study.

3. When conducting the data collection in the school, please ensure that the following are carried out:

- a) consent is obtained from the Principal for the study to be conducted in the school;
- b) written parental consent is obtained before conducting the study with the students;
- c) students are informed that participation in the study is voluntary and they do not need to provide any sensitive information (e.g. name and NRIC No.);
- d) participation by the school is duly recorded in Annex A; and
- e) the data collection in the school is completed within 1 year from the date of this letter.

4. Please show this letter and all the documents included in this mail package (i.e. the application form, research proposal and research instrument(s) marked as seen by MOE) to seek approval from the Principal and during the actual study.

Yours sincerely

Goh Heng Ting (Ms)
Senior Manager, Research Administration
Corporate Research Office
Research and Management Information Division
for Permanent Secretary (Education)

Note to Principal: Please refer to MOE notification PA/02/17 for the Guidelines on Data Collection from Schools.

This is a computer-generated letter. No signature is required.



Integrity, the Foundation • People, our Focus • Learning, our Passion • Excellence, our Pursuit



**DYSLEXIA ASSOCIATION
OF SINGAPORE**
HELPING DYSLEXIC PEOPLE ACHIEVE

PATRON: MRS GOH CHOK TONG

Research Committee

Project approval code: RC-21-04-PRISCILLIA

27th May 2021

Name of PI: Priscillia Shen

DAS RESEARCH COMMITTEE APPROVAL

Project title:

An Investigation on Cognitive-Linguistic Skills of English-Chinese Bilingual Learners with and without Dyslexia in Singapore.

I refer to your application for approval for the above project. The committee has deliberated on your application and is pleased to inform you that your project application is now approved. Please note that you are to adhere closely to the methodology and timeline as per your application. If you deviate from the above, you should inform the committee.

Please use the project approval code for future correspondences.

CC: Geetha Shantha Ram (Head of DAS Research Committee, Director, SAS, ELL & SPD), June Siew Hui Li (Head of DAS Academy) & Deon Poh (Learning Centre Manager)

Appendix 5. Chinese Single Word Reading Task Word List

Primary 1:

我	土	起	四	包	舌
人	鸟	回	还	左	用
床	母	元	红	祝	爪
场					

Primary 2

阿	演	片	先	旁	桥
冰	教	雷	蚂	搭	提
吐	抢	玉	遍	除	观
窗					

Primary 3

希	瘦	吸	健	或	凉
邻	线	竹	环	废	喷
洞	胡	痛	舞	底	

Primary 4

众	帽	察	归	烧	训
随	通	沟	貌	秒	烈
弹	拳	舒	壁		

Primary 5

筒	格	状	冻	钞	层
迹	免	瘾	基	湾	甲
诗	浓	欧			


Primary 6

严	谐	咸	质	创	江
局	译	索	致		

Note: Every 5th Chinese characters were systematically selected from each learning unit of each primary level in the Primary School Chinese Syllabus Word List 2015 (MOE, 2015b)

Appendix 6. Email approval to use tasks from Lin et al. (2016) study

3/26/2021 Gmail - FW: Quick question

 P [REDACTED]

FW: Quick question

LIN, Dan [PS] <lindan@eduhk.hk> Tue, Jul 16, 2019 at 9:58 AM
To: Priscillia Shen <[REDACTED]>
Cc: "Savage, Robert" <robert.savage@ucl.ac.uk>

Dear Priscillia,

I'm so sorry for my late response. Trying to clear up things before vacation, and get very busy.

Are you able to read Chinese? Attached are the tasks (all in Chinese) of phonological awareness (syllable deletion, onset deletion, rime deletion) and orthographic awareness I used in Beijing before. I also attached a reading accuracy task I used in Hong Kong. For your reference. This read task has been published before. You may cite Lin, D., Sun, H., & Zhang, X. (2016). Bidirectional relationship between visual-spatial skills and Chinese character reading ability in Chinese kindergartners: A cross-lagged analysis. *Contemporary Educational Psychology*. 46, 94-100.

If you also want to get Prof. Shu Hua's reading task, you may email directly to Dr. LI Hong (psy.lihong@bnu.edu.cn), Prof. Shu's formal student, and ask for it. I will help you to have a word with her. Please let me know.


You may also want to get the morphological awareness task. Cammie developed the most original version of compounding production, suitable to for young children. Later Her formal student Dr. LIU Duo (duoliu@eduhk.hk) modified and created a more advanced version, suitable for primary school students. You may see your needs and contact them respectively.

Feel free to let me know if I can help further.

Dan

[Quoted text hidden]

4 attachments

 **Orthographic awareness stimulus book_Beijing.pdf**
212K

Phonological awareenss, Orthographic awareness_Beijing.docx

<https://mail.google.com/mail/u/0?ik=95fec0ebc8&view=pt&search=all&permmsgid=msg-f%3A1639178355805128142&siml=msg-f%3A16391783558...> 1/2

Appendix 7. Adapted Phonological Awareness Task in Chinese

Phonological Awareness 语音意识 - Chinese¹

Subtests: syllable deletion, onset, and rime deletion

第一部分: Syllable deletion

注意: 测试时, 注意一定要让被试跟读, 在确保其读准后, 再继续测验。

指导语 (with English translation):

- 我现在念三个字, 我想请你跟着我念一次, 然后不念其中一个字, 看看还有什么留下来? I will say some Chinese words and I would like you to repeat after me. After that, we will not say some part of the words.
例如: 我说“红太阳”, 你可以跟着说吗? (让孩童跟着说“红太阳”) 现在不说“红”, 还剩下“太阳”。我们在试多一个, 我说“牙书鱼”, 你可以跟着说吗? (让孩童跟着说“牙书鱼”) 现在不说“鱼”, 还剩下什么? (看孩童能不能说“牙书”, 不然可以告诉孩童答案)。For example, I will say “红太阳”, can you repeat after me? Ok, now don't say “红”, we are left with “太阳”. Let's try another one, I say “牙书鱼”, can you repeat after me? Now, don't say “鱼”, what is left?
- 除了用真字之外, 我们还会说一些不是真的字。Besides using real Chinese words, we will also say some nonsense words.
例如: gā s í yu è, 你可以跟着说吗? (让孩童跟着说 gā s í yu è) 现在不说 gā, 还剩下什么? (看孩童能不能说 s í yu è, 不然可以告诉孩童答案)。For example, I say gā s í yu è, can you repeat? Now, don't say gā, what is left?
- 明白了吗? 接下来, 我不会告诉你答案。如果不知道, 你可以猜或说不知道。不明白? 好, 现在我们正式开始。Do you understand now? If you are not sure, you may guess or say “don't know”. Ok, let's start.

记录规则: 正确=1, 错误=原始答案, 孩童自我改正的项目算其读对, 不知道=N。

施测老师笔记:

(1) Syllable deletion	(2) Onset deletion	(2) Rime deletion	Total
8	6	6	20

¹ adapted from *Phonological Awareness Tasks (Syllable deletion, Onset deletion, Rime deletion)* (Lin, Sun and Zhang, 2016)

正式测验(请勿提供反馈):

1) 请跟我说大门口, 不说大, 还剩____ (门口) Can you say 大门口, don' t say 大, we are left with ____ (门口)	
2) 请跟我说汽车站, 不说站, 还剩____ (汽车) Can you say 汽车站, don' t say 站, we are left with ____ (汽车)	
3) 请跟我说红绿灯, 不说绿, 还剩____ (红灯) Can you say 红绿灯, don' t say 绿, we are left with ____ (红灯)	
4) 请跟我说巧克力, 不说巧, 还剩____ (克力) Can you say 巧克力, don' t say 巧, we are left with ____ (克力)	
5) 请跟我说 kú pò sě, 不说 kú, 还剩____ (pò sě) Can you say kú pò sě, don' t say kú, we are left with ____ (pò sě)	
6) 请跟我说 dē pǎ bǎn, 不说 bǎn, 还剩____ (dē pǎ) Can you say dē pǎ bǎn, don' t say bǎn, we are left with ____ (dē pǎ)	
7) 请跟我说 mi ù sé nōng, 不说 sé, 还剩____ (mi ù nōng) Can you say mi ù sé nōng, don' t say sé, we are left with ____ (mi ù nōng)	
8) 请跟我说 zhōng làng bó, 不说 zhōng, 还剩____ (làng bó) Can you say zhōng làng bó, don' t say zhōng, we are left with ____ (làng bó)	

施测老师笔记:

第二部分: Onset and Rime deletion

(一) onset deletion 首音: “我现在会念一些音, 请你跟我念一遍这些音, 然后不说开头的音。例如: 叉 (*chā*) 不说开头的 *ch*, 还剩下 *ā*, 又如, 快 (*kuài*) 不说开头的 *k*, 还剩下 *wài*。我们来试一下。” Now we will remove the beginning sounds of a word. For example, can you say *chā*, now don't say *ch*, we are left with *ā*. Let's try another one, can you say *kuài*, don't say *k*, we are left with *wài*. Let's practice some more.

练习 (请提供正确答案并尽量解释至被试理解实验任务)

A. 请跟我说 梳 (<i>shū</i>) 不说开头的 <i>sh</i> , 还剩____ (<i>ū</i>) Can you say <i>shū</i> , don't say <i>sh</i> , we are left with __ (<i>ū</i>)	
B. 请跟我说 盖 (<i>gài</i>) 不说开头的 <i>g</i> , 还剩____ (<i>ài</i>) Can you say <i>gài</i> , don't say <i>g</i> , we are left with __ (<i>ài</i>)	

“明白了吗? 接下来, 我不会告诉你答案。如果不知道, 你可以说不知道。明不明白? 好, 现在我们正式开始。” Do you understand now? If you do not know the answer, you may say “don't know”. Ok, let's start.

正式测试 (请勿提供任何反馈)

1) 请跟我说 <i>mā</i> , 不说 <i>m</i> , 还剩____ (<i>ā</i>) Can you say <i>mā</i> , don't say <i>m</i> , we are left with __ (<i>ā</i>)	
2) 请跟我说 <i>bǎi</i> , 不说 <i>b</i> , 还剩____ (<i>ǎi</i>) Can you say <i>bǎi</i> , don't say <i>b</i> , we are left with __ (<i>ǎi</i>)	
3) 请跟我说 <i>páo</i> , 不说 <i>p</i> , 还剩____ (<i>áo</i>) Can you say <i>páo</i> , don't say <i>p</i> , we are left with __ (<i>áo</i>)	
4) 请跟我说 <i>zhàn</i> , 不说 <i>zh</i> , 还剩____ (<i>àn</i>) Can you say <i>zhàn</i> , don't say <i>zh</i> , we are left with __ (<i>àn</i>)	
5) 请跟我说 <i>shuí</i> , 不说 <i>sh</i> , 还剩____ (<i>uí</i>) Can you say <i>shuí</i> , don't say <i>sh</i> , we are left with __ (<i>uí</i>)	
6) 请跟我说 <i>lǎi</i> , 不说 <i>l</i> , 还剩____ (<i>ǎi</i>) Can you say <i>lǎi</i> , don't say <i>l</i> , we are left with __ (<i>ǎi</i>)	

(二) Rime deletion 尾音:

“我现在会说一些字，我想你尝试说这些字，但不用说结尾的音。例如：叉 (*ch ā*) 不说结尾的 *ā*，还剩 *ch*。我们来试一下。” Now we will remove the beginning sounds of a word. For example, can you say *ch ā*, now *don' t say ā*, we are left with *ch*. Let' s practice some more.

练习 (请提供反馈):

A. 树 (<i>sh ù</i>) 不说结尾的 <i>ù</i> , 还剩____ (<i>sh</i>) Can you say <i>sh ù</i> , don' t say <i>ù</i> , we are left with __ (<i>sh</i>)	
B. 改 (<i>g ǎ i</i>) 不说结尾的 <i>ǎ i</i> , 还剩____ (<i>g</i>) Can you say <i>g ǎ i</i> , don' t say <i>ǎ i</i> , we are left with __ (<i>g</i>)	

“明白了吗? 接下来, 我不会告诉你答案。如果不知道, 你可以说不知道。明不明白? 好, 现在我们正式开始。” Do you understand now? If you do not know the answer, you may say “don' t know”. Ok, let' s start.

正式测试 (请勿提供反馈):

1) 请跟我说 <i>g ā n</i> , 不说 <i>ā n</i> , 还剩____ (<i>g</i>) Can you say <i>g ā n</i> , don' t say <i>ā n</i> , we are left with __ (<i>g</i>)	
2) 请跟我说 <i>m è i</i> , 不说 <i>è i</i> , 还剩____ (<i>m</i>) Can you say <i>m è i</i> , don' t say <i>è i</i> , we are left with __ (<i>m</i>)	
3) 请跟我说 <i>y ǎ n g</i> , 不说 <i>ǎ n g</i> , 还剩____ (<i>i</i>) Can you say <i>y ǎ n</i> , don' t say <i>ǎ n</i> , we are left with __ (<i>i</i>)	
4) 请跟我说 <i>sh u ō</i> , 不说 <i>u ō</i> , 还剩____ (<i>sh</i>) Can you say <i>sh u ō</i> , don' t say <i>u ō</i> , we are left with __ (<i>sh</i>)	
5) 请跟我说 <i>x ì e</i> , 不说 <i>ì e</i> , 还剩____ (<i>x</i>) Can you say <i>x ì e</i> , don' t say <i>ì e</i> , we are left with __ (<i>x</i>)	
6) 请跟我说 <i>r ē n g</i> , 不说 <i>ē n g</i> , 还剩____ (<i>r</i>) Can you say <i>r ē n g</i> , don' t say <i>ē n g</i> , we are left with __ (<i>r</i>)	

施测老师笔记:

Appendix 8. Email approval to use orthographic task from Cunningham et al. (2001) study

Shen, Priscillia

From: Anne E. CUNNINGHAM <acunning@berkeley.edu>
Sent: Tuesday, 13 July 2021 4:55 AM
To: Shen, Peixin
Cc: Savage, Robert; Diamantidaki, Fotini
Subject: Re: FW: Enquiry to have access to your tests for orthographic processing skills
Attachments: AC.Convergingevidencefortheconceptoforthographicprocessing.pdf

Dear Priscillia,

Thank you for your email, your study sounds like a very important and interesting one! I am sorry for the delay while I am on summer retreat. You are more than welcome to use our stimuli from our orthography paper attached here. All best wishes to you in your studies!

Sincerely, Anne Cunningham

On Sat, Jun 19, 2021 at 12:36 AM Shen, Peixin <peixin.shen.14@ucl.ac.uk> wrote:

Dear Dr Cunningham,

I have written in to you previously via the email address: acunning@socrates.berkeley.edu. However, I am not sure if the email reached you. I found another email address of yours from an article that you co-authored with Dr Iva Chen.

I am writing in again, because I am very keen to use your tests: (1) Orthographic Choice and (2) Homophone Choice which were published in your article:

Cunningham, A. E., Perry, K. E. and Stanovich, K. E. (2001). 'Converging evidence for the concept of orthographic processing'. Reading and Writing: An Interdisciplinary Journal, 14, pp. 549–568.

In your article, there are lists of words from your tests. I hope to use your test which includes the instructions and questions for my Thesis research. The students I am investigating in my study are aged 9yrs 0mth to 9yrs 11mths and are bilinguals of English language as first language.

I sincerely hope you would consider my request favourably. I look forward to hearing from you.

Appendix 9. Orthographic Knowledge Task Word List

No.	Word pairs		Test item type
1	[A] take	[B] taik	Original test items from Cunningham et al. (2001) study
2	[A] gote	[B] goat	
3	[A] sleap	[B] sleep	
4	[A] hole	[B] hoal	
5	[A] rume	[B] room	
6	[A] snoe	[B] snow	
7	[A] face	[B] fase	
8	[A] hert	[B] hurt	
9	[A] sheep	[B] sheap	
10	[A] smoak	[B] smoke	
11	[A] bowl	[B] boal	
12	[A] cloun	[B] clown	
13	[A] word	[B] wurd	
14	[A] cote	[B] coat	
15	[A] rain	[B] rane	
16	[A] stoar	[B] store	
17	[A] lurn	[B] learn	
18	[A] nice	[B] nise	
19	[A] scair	[B] scare	
20	[A] skate	[B] skait	
21	[A] true	[B] trew	
22	[A] streem	[B] stream	
23	[A] wize	[B] wise	
24	[A] scruf	[B] scruff	New test items created after pilot study
25	[A] beak	[B] beack	
26	[A] scortch	[B] scorch	
27	[A] phone	[B] fone	
28	[A] wrist	[B] rist	
29	[A] nead	[B] knead	
30	[A] quill	[B] quil	
31	[A] beidge	[B] beige	
32	[A] shiney	[B] shiny	
33	[A] traper	[B] trapper	
34	[A] emptied	[B] emptyed	
35	[A] hoping	[B] hopeing	
36	[A] sailling	[B] sailing	
37	[A] prettiest	[B] prettyest	
38	[A] writting	[B] writing	
39	[A] joined	[B] joined	
40	[A] hungryly	[B] hungrily	

Appendix 10. Email approval to use Morphological tasks from O'Brien et al. (2021) study

7/7/22, 1:22 PM Gmail - Can I use your morphological test from your CRCD project?

 [REDACTED] >

Can I use your morphological test from your CRCD project?

O'Brien Beth Ann (Dr) <beth.obrien@nie.edu.sg> Thu, Jun 17, 2021 at 5:27 AM
To: SHEN PEIXIN # <[REDACTED]>

Dear Priscillia,

Thanks for the update – good to hear you can move ahead.

Yes, you can use the tasks – we are still piloting them, but as long as you cite our pre-registration DOI on the task, will be fine (I'll forward it to you once posted). I think it is a good idea to potentially include both tasks. We may have initial data to help inform which would be more sensitive for your age group, as we used it with P1,2, and 3 students.

Best,
Beth

[Quoted text hidden]

CONFIDENTIALITY: This email is intended solely for the person(s) named and may be confidential and/or privileged. If you are not the intended recipient, please delete it, notify us and do not copy, use, or disclose its contents.
Towards a sustainable earth: Print only when necessary. Thank you.

<https://mail.google.com/mail/u/0/?ik=95fec0ebc8&view=pt&search=all&permmsgid=msg-f%3A1702760393265459787&simpl=msg-f%3A1702760...> 1/1

Appendix 11. Parent Questionnaire

Institute of Education



Parent Questionnaire

Dear Parent,

Thank you for your consent to participate in my research project which is part of my Doctoral Thesis.

Research Project title: An Investigation on Cognitive-Linguistic Skills of English-Chinese Bilingual Learners with and without Dyslexia in Singapore

The questionnaire will take approximately 15 minutes to complete.

By checking this box, you agree to the following:

- The researcher may contact me via the details provided in this questionnaire to update me on the suitability of my child in the research, make arrangements for my child to undertake assessment tasks and share with me the results of the study.
- The information provided in this questionnaire are true and to the best of my knowledge.

Please provide information about your child.

Child's name: _____

Child's gender: Male / Female

Child's date of birth: _____

Child's **first** language spoken/learnt: English / Chinese / Others (*please state*): _____

Please put a tick in the boxes below where relevant:

- My child is a Singaporean.
- My child is exempted from learning Chinese language as an examinable subject.
- My child is attending / has attended Language Support Programme (LSP) in school.
Please state when: From _____ to _____.

- My child is attending Mother Tongue Support Programme (MTSP) in school.
- My child has been diagnosed with dyslexia. *Please state when the child has been diagnosed:* _____
- My child has been diagnosed with other difficulties besides dyslexia. *Please state what diagnosis and when the child was diagnosed:* _____

- My child has a valid psychological report on his/her diagnosis. *Please attach a copy of only the front page of the psychological report for verification purpose only.*
- My child speaks English at home:
always / often / sometimes / seldom / never (*please circle one*)
- My child speaks Mandarin at home:
always / often / sometimes / seldom / never (*please circle one*)
- My child speaks a dialect at home:
always / often / sometimes / seldom / never (*please circle one*)
- My child speaks another language as well at home. *Please state:* _____
- My child is receiving tuition or additional support in learning English.
Please state where: _____
Please state how many hours per week: _____
- My child is receiving tuition or additional support in learning Chinese.
Please state where: _____
Please state how many hours per week: _____

Child's latest English language subject result in school: _____ / 100

Child's latest Chinese language subject result in school: _____ / 100

Please provide information about you and your spouse.

Mother's name: _____

Mother's contact number(s): _____

Mother's email address: _____

Mother's birthplace: _____

Mother's highest education: _____

Father's name: _____

Father's contact number(s): _____

Father's email address: _____

Father's birthplace: _____

Father's highest education: _____

Please provide information about the household.

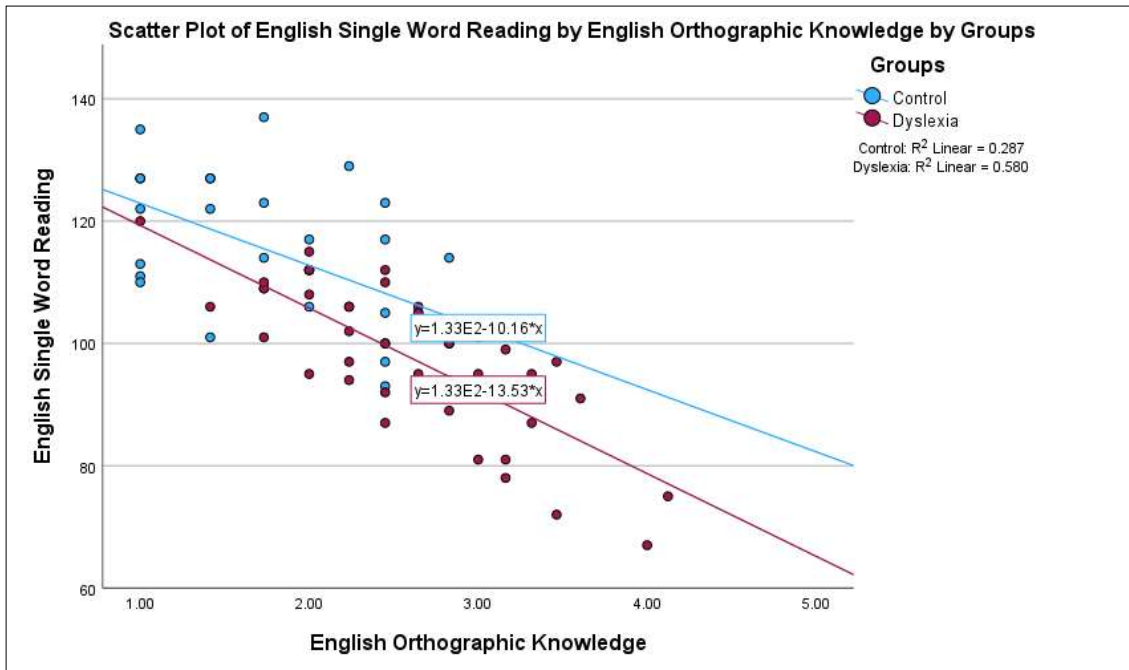
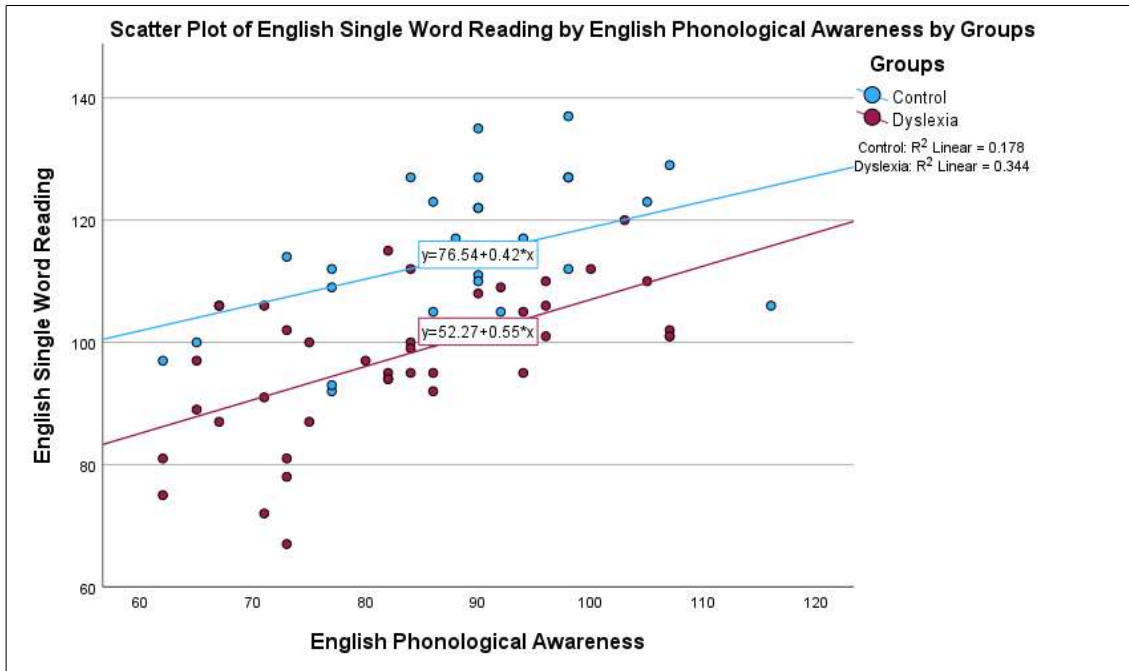
Type of dwelling (please tick):

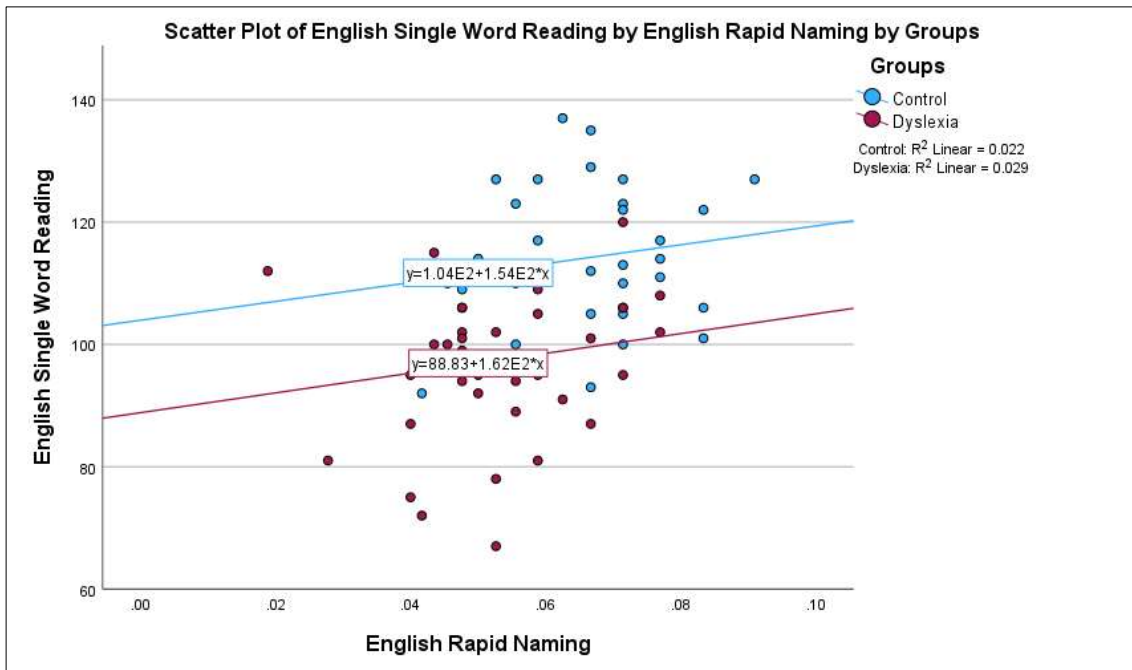
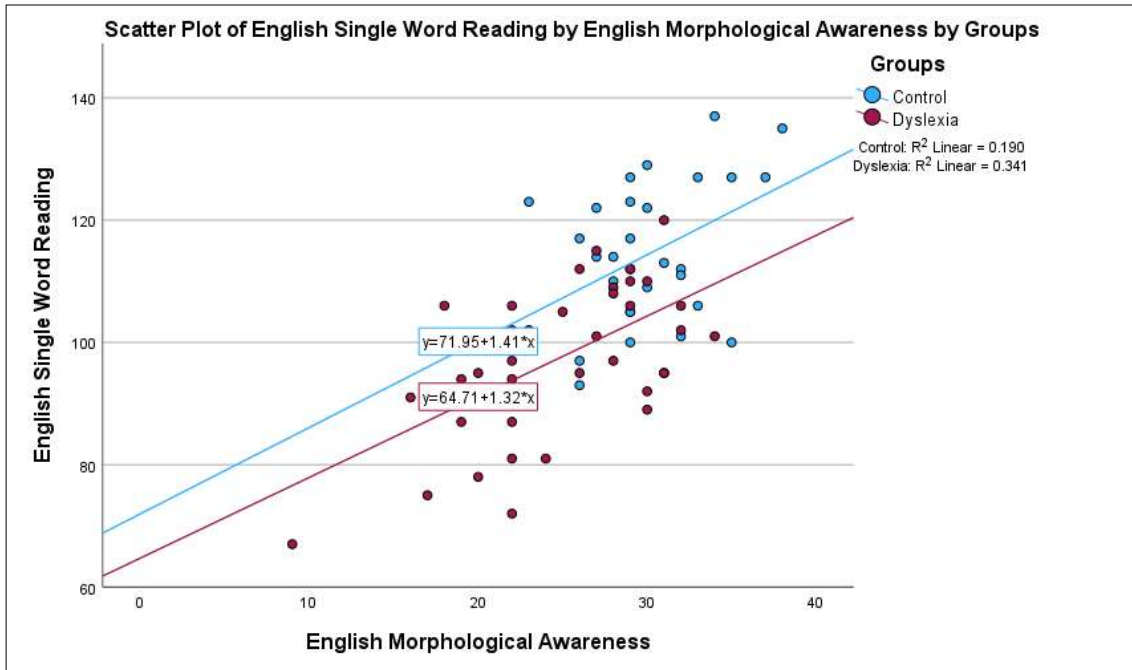
- 1-Room Flat (HDB)
- 2-Room Flat (HDB)
- 3-Room Flat (HDB)
- 4-Room Flat (HDB)
- 5-Room Flat (HDB)
- Executive Flat (HDB)
- HUDC or DBSS Flat (excluding those privatised)
- Studio Apartment (HDB)
- Bungalow/ Detached House
- Semi-Detached House
- Terrace House
- Condominium (except Executive Condominium)
- Executive Condominium
- Other Apartments, please state: _____

Thank you for completing the Parent Questionnaire. You will be duly informed if your child is suitable for the study. You will be contacted via the contact information provided in this questionnaire. If found suitable, your child will be invited to undertake various assessment tasks as detailed in the Participant Information Sheet.

If you have any questions, please feel free to contact me at 96480302 or by email peixin.shen.14@ucl.ac.uk (Priscillia Shen). You can also contact my supervisors: robert.savage@ucl.ac.uk (Dr Robert Savage) or f.diamantidaki@ucl.ac.uk (Dr Fontini Diamantidaki).

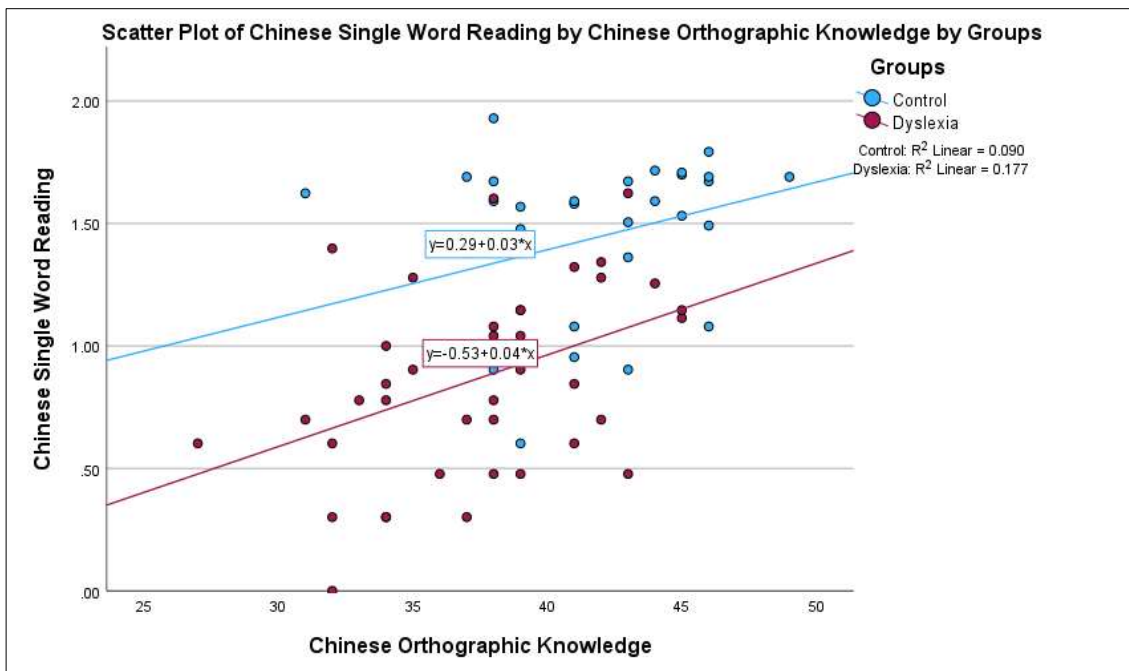
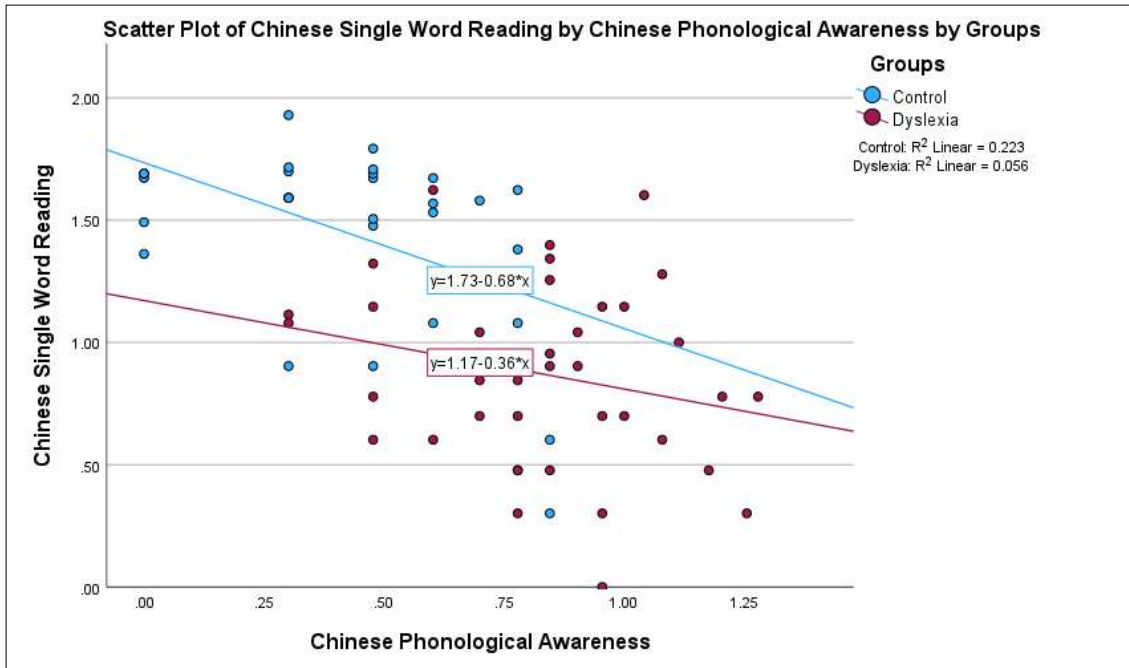
Appendix 12. Scatter plots with linear regression lines for English task measures

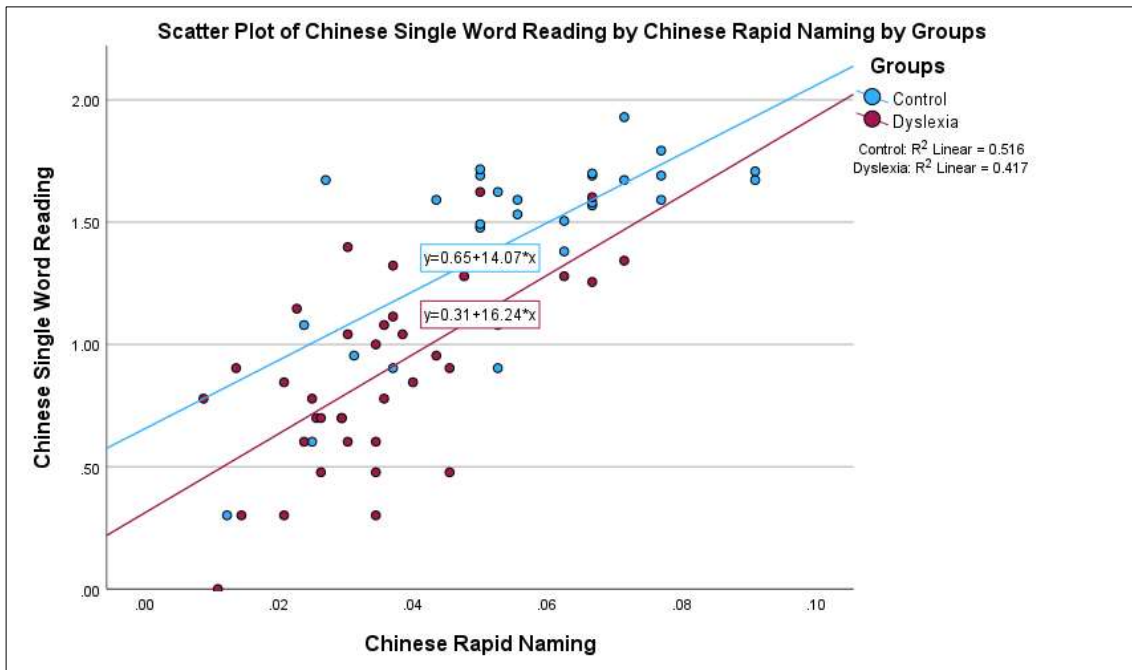
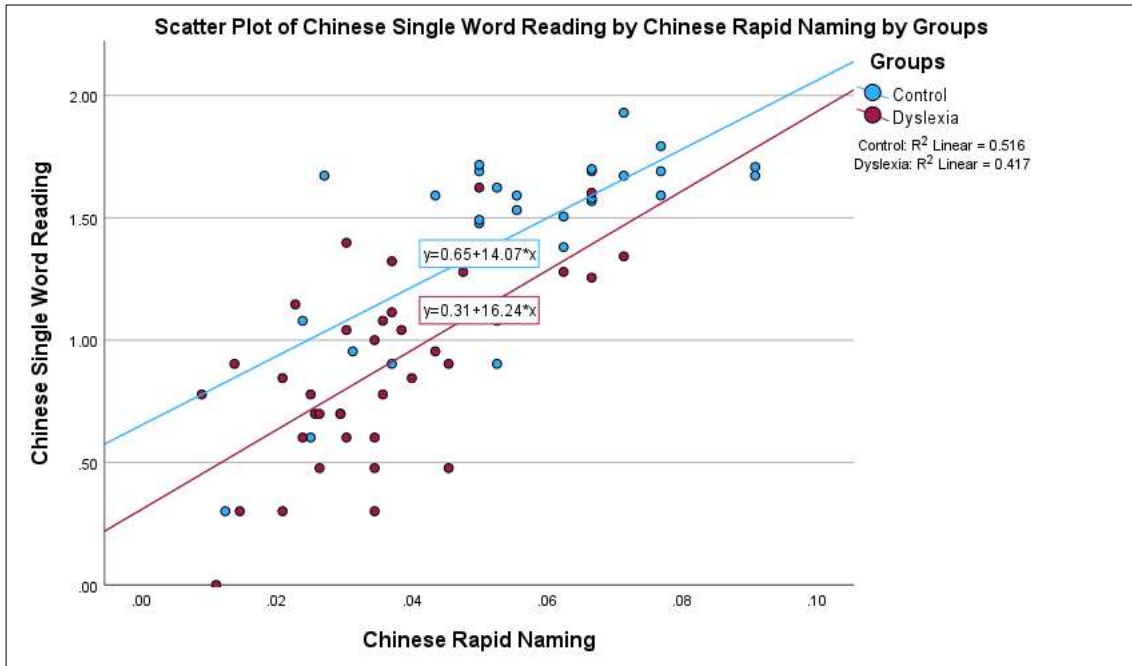




It is important to note that the English task scores are after data transformation. It is noted that the English Orthographic Knowledge scores were transformed using a reflected “square root” method, and hence the negative correlation.

Appendix 13. Scatter plots with linear regression lines for Chinese task measures





It is important to note that the Chinese task scores are after data transformation. It is noted that the Chinese phonological awareness scores were transformed using a reflected “logarithmic” method, and hence the negative correlation.

Appendix 14. Data-driven Regression Analysis on English Cognitive-linguistic skills as predictors of English Reading

Step	Independent Variable	Unstandardised Coefficients		Standardised Coefficients	R^2	R^2 Change	F Change	Sig. F Change	Collinearity Statistics	
		B	Std Error	$Beta$					Tolerance	VIF
1	Orthographic Knowledge - English ^c	-9.824	2.027	-.510	.580	.580	94.060	<.001	.496	2.017
	Morphological Awareness - English ^b	.577	.284	.211	.623	.043	7.607	.007	.510	1.960
	Phonological Awareness - English (CTOPP-2) ^a	.166	.105	.147	.637	.014	2.572	.114	.638	1.568
	Rapid Naming - English (CTOPP2) ^d	90.855	84.906	.087	.644	.006	1.145	.289	.829	1.206

Note. ^a scaled score. ^b raw score. ^c raw score transformed using reflected “square root” method. ^d raw score transformed using “inverse” method.

Unlike the theory-driven regression analysis where each variable was deliberately entered at each step, all the variables were entered at Step 1 and the SPSS programme added each variable at each step according to its contribution to the model’s R^2 . The regression analysis established that Orthographic Knowledge and Morphological Awareness contributed significantly to the prediction of English reading, $p < .001$ and $p = .007$ respectively.

Appendix 15. Data-driven Regression Analysis on Chinese Cognitive-linguistic skills as predictors of Chinese Reading

Step	Independent Variable	Unstandardised Coefficients		Standardised Coefficients	R^2	R^2 Change	F Change	Sig. F Change	Collinearity Statistics	
		B	Std Error	$Beta$					Tolerance	VIF
1	Chinese language use at home	-.027	.038	-.063	.372	.372	39.144	<.001	.523	1.913
	Morphological Awareness - Chinese ^a	.025	.007	.356	.626	.254	44.085	<.001	.423	2.361
2	Rapid Naming - Chinese ^d	10.031	2.141	.425	.733	.107	25.762	<.001	.489	2.045
	Phonological Awareness - Chinese ^c	-.169	.125	-.116	.747	.014	3.426	.069	.551	1.814
	Orthographic Knowledge - Chinese ^a	.008	.008	.081	.751	.004	.984	.325	.598	1.672

Note. ^a raw score. ^b raw score transformed using “logarithmic” method. ^c raw score transformed using reflected “logarithmic” method. ^d raw score transformed using “inverse” method.

Unlike the theory-driven regression analysis where each variable was deliberately entered at each step, the control variable was first entered at Step 1 and the remaining variables were entered at Step 2, and the SPSS programme added each variable at each step according to its contribution to the model's R^2 . The regression analysis established that Morphological Awareness and Rapid Naming contributed significantly to the prediction of Chinese reading, $p < .001$.