Developmental Interdependence Between Word Decoding, Vocabulary Knowledge, and Reading Comprehension in Young L2 Readers of Chinese

Chapter · December 2023

Dongbo Zhang
University of Exeter

Developmental Interdependence Between Word Decoding, Vocabulary Knowledge, and Reading Comprehension in Young L2 Readers of Chinese

Dongbo Zhang*

University of Exeter

Xiaoxi Sun

University of Exeter

* Corresponding Author

Graduate School of Education

University of Exeter

St Luke's Campus

Exeter, Devon

United Kingdom

EX1 2DX

Phone: +44 (0) 1392724723

Email: d.zhang4@exeter.ac.uk

Abstract

This chapter reports on a study that explored developmental interdependence between lexical competence and reading comprehension in young L2 readers of Chinese. Participants were ethnic Chinese children with English as the dominant home language in Singapore. The same battery of tests was administered three times across a year, that is, end of Grade 3 (Time 1), middle of Grade 4 (Time 2), and end of Grade 4 (Time 3), to measure children's word decoding, oral vocabulary knowledge, and reading comprehension. The three waves of data were fitted to a cross-lagged panel model where in addition to its earlier performance predicting its later performance (i.e., autoregressive effect), each of the three literacy variables was hypothesized to predict the other two at an immediate later time (i.e., crossed effect). It was found that word decoding, as opposed to vocabulary knowledge, surfaced as a unique longitudinal lexical predictor of reading comprehension; this was similarly the case from Time 1 to Time 2 and from Time 2 to Time 3. Conversely, however, reading comprehension was not found to be a significant longitudinal predictor of either decoding or vocabulary after accounting for the respective autoregressive effect.

Key words: word decoding, vocabulary knowledge, reading comprehension, Chinese as a Second Language, cross-lagged panel analysis

Developmental Interdependence Between Word Decoding, Vocabulary Knowledge, and Reading Comprehension in Young L2 Readers of Chinese

Text comprehension necessitates simultaneous execution of a number of cognitive and psycholinguistic processes (Cain & Barnes, 2017; Grabe, 2009; Perfetti, 1999; Perfetti, Landi, & Oakhill, 2005). Notably, for smooth comprehension of a text, readers need to rapidly identify words in the text and access the meanings of those words (Perfetti, 2010; Perfetti et al., 2005). Reading comprehension development thus depends on lexical development, including word decoding and vocabulary knowledge (Duke & Carlisle, 2011). Conversely, lexical development also depends on reading experience and comprehension (Nagy, 2005; Nagy & Scott, 2000). Developmentally, written texts are a fundamental source of information for exposure to new sound-grapheme patterns and consolidation of knowledge of existing patterns; and understanding the context where unknown words appear is also important for incidental learning of those words and vocabulary expansion.

The aforementioned insights are encapsulated in many models of reading, including, for example, the Verbal Efficiency model (Perfetti, 1985) and the Lexical Quality Hypothesis (Perfetti, 2007). Perfetti (2010) characterizes the complex relationships between word decoding (D), vocabulary knowledge (V), and reading comprehension (C) in light of "*the Golden Triangle of Reading Skill*" (hereafter, the DVC Triangle). Although the DVC Triangle is not intended as a reading *development* model, the theoretical outlining does imply some developmentally interdependent relationships between the component skills, which have been supported by some longitudinal evidence. Yet, the evidence is not always consistent, and has been largely on monolingual or L1 reading. In the L2 literature, the evidence was mostly based on *concurrent* correlations (Jeon & Yamashita, 2014). Longitudinal relationships, particularly how the growth in L2 word decoding and vocabulary knowledge may be predicted by reading comprehension, have been rarely tested on L2 readers. Additionally, existing longitudinal studies focused primarily on alphabetic languages; little longitudinal research aimed to test developmental interdependence between lexical competence and reading comprehension in readers of Chinese in general, and L2 readers of Chinese in particular.

The present study aimed to fill this research gap. Three waves of data were collected across a year, from Grade 3 to Grade 4, from a group of children in Singapore who had English as the dominant home language and learned Chinese through school instruction. The data were fitted to a trivariate, cross-lagged panel model and analyzed through path analyses where the longitudinal effects of decoding and vocabulary on reading comprehension, and those of reading comprehension on decoding and vocabulary, were tested and compared across time points.

"*The Golden Triangle of Reading Skill*"

Perfetti's (2010) DVC Triangle (see Figure 1) aims to disentangle the complex interaction between word decoding, vocabulary knowledge, and reading comprehension. To begin with, it underscores bidirectional, causal relationships between vocabulary knowledge and reading comprehension. On the one hand, comprehending a text requires the "ability to access the meaning of the word, as it applies in the context of this particularly text" (p. 293). This instrumentalist view on the importance of vocabulary knowledge for reading comprehension has long been recognized (Anderson & Freebody, 1981). On the other hand, the reader needs to understand the discourse context where an unknown word appears, that is, comprehension, for lexical inferencing or incidental learning of that word to happen (Nagy, 2005). In this respect, comprehension "can cause the reader to learn something about the meaning of that word" (p. 293).

The DVC Triangle also contends on bi-directional causal relationships between decoding and vocabulary. As Perfetti (2010) argues, successful word decoding during text reading triggers the retrieval of meanings for familiar words and hence strengthens or consolidates form-meaning connections that have been formed in the mental lexicon. Additionally, it can "establish context-dependent links between unfamiliar words and meaning-bearing contexts" (p. 292). Conversely, vocabulary knowledge also affects decoding because "decoding a word whose meaning is known strengthens the connection between the word's orthographic form (its spelling) and its meaning" (p. 292). In this respect, decoding and vocabulary strengthen each other toward high-quality lexical representations (phonology, orthography, morphology, and semantics).

Insert Figure 1 about here

The DVC Triangle does not, however, hypothesize any causal relationship between decoding and reading comprehension. Instead, it highlights a pivotal, mediating role of vocabulary. Perfetti (2010) argues that "the effects of decoding on comprehension are mediated by knowing the meaning of the decoded words." In other words, decoding words in a text, while serving as the initial basis for comprehending that text, will not in itself result in comprehension unless the meanings of those words are activated and subsequently integrated. Conversely, the effect of comprehension on decoding "are mediated by achieving enough meaning from the text to verify the identity of a decoded word" (p. 294). Perfetti further argues that the assumption about the lack of "decoding-comprehension effects" in the DVC Triangle "rests on the logic of cognitive event sequences in reading and not on correlations of skill assessments" (p. 294).

The DVC Triangle serves as a heuristic for understanding complex interaction between lexical processes and reading comprehension in skilled reading. It is unclear, though, how the hypothesized relationships based on "cognitive event sequences" may be *developmentally* valid. In other words, how may the relationships be manifested in developing readers; and how may any interdependent relationships change across stages of reading development? Additionally, the DVC Triangle is largely contextualized in monolingual English reading. How the three skills may be developmentally related as such in L2 readers of Chinese remains to be explored.

In what follows, we review some longitudinal studies that shed light on developmental relationships between decoding, vocabulary, and reading comprehension.[1] Because of the purpose of this study, the relationships between decoding and vocabulary are not a focus of the review. Whereas some studies only focused on one direction of developmental effects, such as Lervåg and Aukrust (2010), which only tested the effects of decoding and vocabulary on growth in reading comprehension, others examined reciprocal or bi-directional relationships, such as Verhoeven and Van Leeuwe (2008). For clarity of discussion, the review is divided into two separate sections: the first on the impact of decoding and vocabulary on reading comprehension development; and the second on that of reading comprehension on the development of decoding and vocabulary.

Decoding and Vocabulary in L2 Reading Comprehension Development

This section focuses on reviewing longitudinal effects of decoding and vocabulary on reading comprehension, including those in L2 readers. Based on cross-lagged panel analysis, Santos, Cadime, Viana, and Ribeiro (2019), for example, found Portuguese-speaking children's Grade 2 decoding significantly predicted Grade 3 reading comprehension over and above Grade 2 reading comprehension (i.e., the autoregressor); this longitudinal effect was similarly found from Grade 3 to Grade 4. Quinn, Wagner, Petscher, and Lopez (2015) found significant growth of both vocabulary knowledge and reading comprehension in English-speaking children from Grade 1 to Grade 4. Their latent change score modeling analysis revealed that children's initial vocabulary scores as well as the speed of vocabulary growth significantly predicted the growth speed of reading comprehension. Verhoeven and Van Leeuwe (2008) tracked the development of decoding, vocabulary (and listening comprehension), and reading comprehension in Dutch-speaking children throughout the six years of elementary school. Cross-lagged panel analyses revealed that, controlling for Grade 3 reading comprehension (and Grade 3 decoding), Grade 3 vocabulary knowledge significantly predicted Grade 4 reading comprehension. A similar effect was found from Grade 5 to Grade 6. Yet, it did not surface from Grade 2 to Grade 3 and from Grade 4 to Grade 5. For decoding, the only unique, longitudinal effect was found from Grade 5 to Grade 6. Over and above Grade 5 reading comprehension (and Grade 5 vocabulary knowledge, for which $\beta = .33$), Grade 5 decoding had a significant yet small effect ($\beta = .04$) on Grade 6 reading comprehension.

A few studies also examined the longitudinal effects in L2 readers (e.g., Lam et al., 2012; Lervåg & Aukrust, 2010). In Lervåg and Aukrust (2010), L1 and L2 readers of Norwegian were first tested on word decoding, vocabulary knowledge, and reading comprehension when they had received formal instruction in Norwegian for four months in school; and subsequently further tested on reading comprehension for three more times with an interval of six months. The initial level of both decoding and vocabulary was a unique, significant predictor of the intercept (or initial level) of two different comprehension measures in both L1 and L2 readers. Yet, when the criterion variable was the slope or growth speed, some discrepancy was found between decoding and vocabulary. For both groups, particularly L2 readers, controlling for decoding, vocabulary was a unique, significant predictor of the growth in reading comprehension, suggesting that those who had greater initial vocabulary knowledge tended to show faster growth in reading comprehension. This effect, however, did not surface for decoding; and this was consistently the case for the L2 readers across the two comprehension measures.

The above findings suggested that vocabulary, compared to decoding, tended to have a more consistent and salient effect on reading comprehension development in young, developing readers, which seems to support its pivotal role underscored in the DVC Triangle. The evidence, however, was all based on alphabetic readers (e.g., English, Portuguese, Dutch, and Norwegian). Different from alphabetic languages, Chinese is a morpho-syllabic language based on character/morpheme-syllable mapping (DeFrancis, 1989; Taylor & Taylor, 2014). Most Chinese characters (about 80% to 90%) are semantic-phonetic compounds composed of a semantic and a phonetic radical. These two orthographic components have varied spatial configurations and canonical positions (e.g., left-right, top-bottom, surrounding, and half-surrounding). A phonetic radical provides clue to the host character's pronunciation, while a semantic radical provides clue to the meaning of that character. For example, in 梅 /méi/ (plum), the left component 木 (wood) is the semantic radical, which indicates that 梅 is related to wood; the right component 每 /měi/ (every) is the phonetic radical, which has the same pronunciation (except the tone) of 梅 but has nothing to do with its meaning. Many Chinese characters, however, are unlike the near-perfect illustration in 梅 in that the phonetic information in a phonetic radical is often not reliable (the same holds true for the semantic information in the semantic radical as well) (Zhou, 1978). For example, in 海 /hǎi/ (ocean), while 氵 suggests that 海 is related to water, 每 does not at all provide any clue to the sound of 海.

Another unavoidable issue for examining word knowledge in Chinese is what constitutes a word in the language. A character is typically a morpheme. Many characters are free morphemes or words themselves. There are, however, only a few thousand commonly used characters in modern Chinese (Zhao & Zhang, 2007); Chinese words are mostly multi-morphemic and formed largely through compounding. In written texts, those words are represented in multiple characters and are not spaced like in English (Taylor & Taylor, 2014). For example, in 篮球是一项很受欢迎的体育运动 (*Basketball is a popular sport*), 篮球 /lánqiú/ (basketball) is a two-morpheme/character compound word where both 篮 and 球 are a semantic–phonetic compound character and mean *basket* and *ball*, respectively.

The properties briefly outlined above of Chinese orthography and lexis suggest that word decoding based on phonological recoding, which characterizes alphabetic languages, does not quite pertain to Chinese. The utility of phonetic strategies is very restricted in Chinese; and orthographic processing is far more important (Leong, 2015; Perfetti, Cao, & Booth, 2013). Developmentally, this suggests that, unlike the limited effect reviewed earlier on alphabetic readers, the decoding component of the DVC Triangle may have a far more salient role in Chinese. This should perhaps pertain to all developing readers and may be particularly the case in L2 readers, for whom characters are typically learned in a way that form (e.g., pronunciation, stroke order, and orthographic structure) and meaning are taught together. Due to this instructional effect, decoding a character, which relies on visual-orthographic processing (Leong, 2015), should be expected to activate the meaning of that character (Everson, 1998; Zhang, Lin, Zhang, & Choi, 2019). A learner not knowing 篮 /lán/, for example, is likely unable to decode it; conversely, correct decoding of 篮 implies that the learner knows its meaning.

The above analysis on form-meaning co-activation during decoding should not be interpreted to mean that decoding individual characters is the whole of the lexical support required for reading comprehension and its development in L2 Chinese. Tens of thousands of words in modern Chinese are formed based on a few thousand common characters (Zhao & Zhang, 2007). The ability to decode the constituent characters of a word (e.g., 业务), and the knowledge of the respective meaning of each character (业 and 务), does not in itself represent a knowledge of the whole word, at least not a precise knowledge. Decoding individual characters without vocabulary support would also be unable to deal with the challenge of word segmentation required of reading Chinese texts. In summary, while theoretically decoding is fundamental for Chinese text reading and its effect on comprehension may be more salient than in alphabetic languages, vocabulary knowledge should also be expected to play a distinct role like in alphabetic languages.

Little longitudinal research has directly examined the effects of decoding and vocabulary on reading comprehension development in Chinese. The limited evidence, nonetheless, lends some support to the above analysis. Yeung, Ho, Chan, and Chung (2016) aimed to construct a componential model of reading in Chinese. Informed by the Simple View of Reading (SVR) (Gough & Tunmer, 1986), the authors collected two waves of data from native Chinese-speaking elementary school students in Hong Kong. Children were first tested in Grade 1 on a number of oral (word definition and listening comprehension) and reading skills (word decoding, reading fluency, and sentence and passage comprehension). Two years later (Grade 3), their sentence and passage comprehension were tested a second time. Among the many findings, Grade 1 decoding predicted Grade 3 sentence comprehension, controlling for Grade 1 sentence comprehension and other related skills; a similar effect was found of Grade 1 reading fluency on Grade 3 passage comprehension. Overall the findings provided some longitudinal evidence on the importance of decoding for reading comprehension development in native Chinese-speaking children. There was, however, no evidence on the longitudinal effect of vocabulary, and the relative longitudinal effects of vocabulary and decoding. The word definition measure did tap children's oral vocabulary knowledge; yet, because the authors' concern about its unsatisfactory reliability, it was not included in any statistical modeling.

Wong (2017) is a notable study given its focus on L2 readers of Chinese. Also informed by the SVR, Wong measured twice, from Grade 4 to Grade 5, ethnic minority children learning L2 Chinese in Hong Kong on character decoding, listening comprehension, and reading comprehension. Cross-lagged path modeling showed that Grade 5 decoding ($\beta = .41$) and listening comprehension ($\beta = .20$) both uniquely predicted Grade 5 reading comprehension, controlling for Grade 4 reading comprehension; and decoding seemed to have a larger effect. The study did not consider vocabulary knowledge, though. Considering that vocabulary should strongly underpin listening comprehension, it may be inferred that decoding and vocabulary were both important predictors of change in reading comprehension; and decoding might have played an even greater role. In terms of longitudinal modeling, the study, however, has a notable limitation, that is, the crossed-effect predictors would need to be Grade 4 measures.

Impact of Comprehension on L2 Lexical Development

The DVC Triangle hypothesizes that comprehension is fundamental for incidental learning of vocabulary through reading. Developmentally reading comprehension should predict vocabulary growth in that better comprehenders would be more likely to pick up new words from reading experience. Poor readers, compared to good readers, tend to be less motivated to read and thus would lose learning opportunities that reading can offer (Stanovich, 1986).

Theoretically, the dependence of vocabulary development on reading experience and comprehension should pertain to any language and any reader, particularly L2 readers (esp. foreign language learners) because written texts could be a dominant source of (lexical) input. Empirical evidence, however, is limited and often inconsistent.

Quinn et al. (2015), as reviewed earlier, found an effect of vocabulary knowledge on English-speaking children's reading comprehension growth from Grade 1 to Grade 4. Conversely, however, no significant effect was found of the initial reading comprehension level and its growth speed on the growth speed of vocabulary knowledge. The authors cautioned that the finding should not be interpreted to mean that reading is unimportant for vocabulary development; instead they argued that developmental effects may depend on how sensitive literacy measures are to change. Verhoeven and Van Leeuwe (2008) reported that Dutch-speaking children's Grade 2 reading comprehension ($\beta = .61$) significantly predicted Grade 3 vocabulary knowledge, controlling for Grade 2 vocabulary knowledge. A much smaller yet significant effect was found from Grade 4 to Grade 5 ($\beta = .06$). Similar effects, however, did not surface during other periods of elementary school.

Chen et al. (2019) tracked the development of vocabulary and reading comprehension for a year in three cohorts (Grades 1, 3, and 5) of native Chinese-speaking children in China. Vocabulary knowledge was measured through explaining the meanings of orally presented words. Cross-lagged panel analysis revealed a significant effect of earlier reading comprehension on later vocabulary knowledge (controlling for the autoregressor) in the two older cohorts as opposed to the youngest cohort. The authors explained the discrepancy between the cohorts in light of their different developmental stages. The older cohorts, compared to the youngest one, were transitioning to learning to read, at which stage they tended to read more independently and the texts they read were also more complex and diverse, which should have provided a greater opportunity for their incidental learning and vocabulary expansion.

The DVC Triangle hypothesizes that any effect of reading comprehension on decoding should be mediated by vocabulary. If this contention holds for developmental relationships, that is, the effect of reading comprehension on decoding development is fully mediated by vocabulary knowledge, then in longitudinal modeling, reading comprehension should not be expected to directly predict change in decoding, particularly in the presence of vocabulary. Few studies have aimed to test these relationships. In Verhoeven and Van Leeuwe (2008), controlling for earlier decoding, earlier reading comprehension was never a significant predictor of later word decoding across six elementary school years. This result might be related to Dutch being a transparent orthography. In other words, growth in decoding may well be a manifestation of gradual mastery of the alphabetic principle rather than a function of reading comprehension. Wong (2017) examined the developmental independence between character decoding, listening comprehension, and reading comprehension in ethnic minority children learning Chinese in Hong Kong. In addition to the finding reviewed earlier on the effect of decoding on reading comprehension, Grade 4 reading comprehension also significantly predicted Grade 5 decoding, over and above Grade 4 decoding. The discrepancy in the findings of the two studies might indicate that reading comprehension may have a notable role to play in decoding development in (L2) readers of Chinese as opposed to alphabetic readers.

The Present Study

Longitudinal research is limited on developmental relationships between decoding, vocabulary, and reading comprehension. While there seemed to be consistent evidence on the effect of vocabulary on reading comprehension development, existing findings on that of decoding seemed to differ between alphabetic languages and Chinese on the one hand and between L1 and L2 readers on the other. Conversely on the effect of reading comprehension on decoding and vocabulary development, the evidence was even more limited and inconsistent. With a notable exception of Wong (2017), little research has addressed those issues with a focus on L2 readers of Chinese. Drawing upon the data of a large project that examined Singaporean children's biliteracy development, the present study aimed to address this gap and explore how decoding, vocabulary, and reading comprehension may be developmentally interdependent in young L2 readers of Chinese. It aimed to answer the following three questions.

1. How do word decoding and vocabulary knowledge (relatively) predict developmental change in reading comprehension in young L2 readers of Chinese?

2. Do the (relative) longitudinal effects of word decoding and vocabulary knowledge change over time?

3. Reciprocally, does reading comprehension predict developmental change in word decoding and vocabulary knowledge?

Method

Participants and Dataset

This study was based on a large, longitudinal project that examined Singaporean children's biliteracy development (Zhang, 2017a; Zhang, Chern, & Li, 2017; Zhang, Koda, & Leong, 2016). In that project, a battery of tests was administered three times over a year, that is, at end of Grade 3 (Time 1), in the middle of Grade 4 (Time 2), and at the end of Grade 4 (Time 3), to measure children's reading and its related skills in English as well as their respective ethnic language. In addition, a questionnaire was administered to parents at Time 1 to elicit patterns of home language use. For the purpose of this study, we drew upon the three waves of data on

Chinese word decoding, vocabulary knowledge, and reading comprehension in those children with English as the dominant home language.

Singapore is a multilingual country in Southeast Asia with four official languages, including English and the languages of the three major ethnic groups (Chinese of the Chinese, Malay of the Malays, and Tamil of the Indians) (Shepherd, 2005). Chinese is the largest ethnic group, accounting for about 75% of the population. Singapore adopts a bilingual education policy. Students of all ethnic groups are required to learn their respective ethnic language (locally called the Mother Tongue or MT) as a school subject, while also developing proficiency in English, which is also the medium of school instruction. Over the past few decades, the globalized influence of English as a lingua franca has had strong ramifications on the sociolinguistic milieu in Singapore. A significant one is the gradual home language shift from MT to English, which is particularly true of the Chinese group (Zhao & Liu, 2010). As a result, ethnic Chinese children, though all learn Chinese in school, bring diverse experiences into the process of learning. While some Chinese families still use Chinese (Mandarin and/or a dialect of Chinese such as Hokkien, Teochew, or Cantonese) as the dominant home language, in many other families, children grew up using English as the sole or dominant home language. The latter group usually have had no or very limited oral language and print experience in Chinese prior to formal schooling. They essentially learn to read Chinese as an L2.

When the longitudinal, biliteracy project mentioned earlier first started in Grade 3, the three participating schools' record showed that a total of 677 students were studying in 19 classes, and 415 of them were studying Chinese as the MT subject. (Not all participated initially or stayed on, though.) Among those Chinese-studying students, a large majority were ethnic Chinese born in Singapore; there were also a very small number of non-ethnic Chinese who were immigrants from other countries (e.g., South Korea or Thailand). The participants for the study reported here were ethnic Chinese children with English as the dominant home language. They were purposively selected from the 415 Chinese-studying students following the following steps. To begin with, 66 students were first removed from the list, because their parents either did not consent for them to participate in the project (in other words, they were not tested at all throughout the project) or did not complete the questionnaire. Among the 349 students who remained on the list, a variety of home language patterns were revealed. Only those ethnic Chinese children from an English-dominant family, that is, both parents used English as the dominant language, were selected. This step left 123 students in the dataset. The final step was to adopt listwise deletion such that only those with data on decoding, vocabulary, as well as reading comprehension in all three waves were retained. The final dataset for the present study included 89 ethnic Chinese children with English as the dominant home language. Their mean age was 9.4 years when they were first tested at the end of Grade 3.

Measures

The same battery of tasks described below was administered, together other skills in Chinese (and English), three times with an interval of about six months. The decoding task was administered individually by trained research assistants in a quiet space in children's respective school. Vocabulary and reading comprehension were group-tested in their Chinese classes. All tasks had strong internal consistency reliability across all waves (see Table 1).

Word decoding. Children were asked to read aloud 30 multi-character words printed on cards. The words were sampled from the textbooks developed by the Singapore Ministry of Education for elementary school students (Grades 1 to 6). They included words from textbooks that had been learned by the children at the time of the study as well as those from textbooks that had not been learned (e.g., Grades 5 and 6 textbooks). A point would be awarded for a word only if both/all component characters were pronounced correctly.

Vocabulary knowledge. Oral, receptive vocabulary knowledge was measured with a researcher-developed picture selection task modeled after the form of the PPVT-IV (Dunn & Dunn, 2007). It included five sets of 12 multi-syllabic words of various frequency levels based on the Modern Chinese Frequency Dictionary (Beijing Language Institute, 1986). All 60 words were read aloud to children; and they were asked to circle the number of the picture, from among four, that represented the meaning of a word.

Reading comprehension. Reading comprehension was measured with a researcher-developed multiple-choice passage comprehension task, which included three passages, including one narrative and two informational texts, with a mean length of about 350 characters. Each passage was followed by five questions that tested different sub-skills of comprehension (e.g., resolution of co-referential relationships, inferential comprehension, and gist); and each question was followed by four choices. Altogether there were 15 questions.

Cross-Lagged Panel and Path Analysis

The three-wave data were fitted to a trivariate, cross-lagged panel (CLP) with the developmental relationships analyzed using path analysis (Newsom, 2015; Selig & Little, 2012). Figure 2 shows a simple CLP model with two observed variables (A and B) measured at three time points (indicated by the subscripts 1, 2, and 3, respectively). In the model, for crossed effects, A1 predicts B2 (c1) and A2 predicts B3 (c2); and conversely, B1 predicts A2 (d1) and B2 predicts A3 (d2). Additionally, a variable's earlier performance also predicts its immediately later performance, that is, a1 and a2; and b1 and b2, which are lagged effects or autoregressive control. In this way, CLP modeling allows for testing developmental interdependence or prediction of each other's change over time between two or more variables.

Insert Figure 2 about here

Specifically for the present study, each reading skill at Time 2 was predicted by all three skills (decoding, vocabulary, and reading comprehension) at Time 1. Likewise, each skill at Time 3 was predicted by all three skills at Time 2. Residual covariances were also estimated for both Times 1 and 3. The model shown in Figure 3 was tested on M*plus* 8 (Muthén & Muthén, 1998-2017) with Maximum Likelihood estimation. As suggested by Hu and Bentler (1999), we reported Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Standardized Mean Square Residual (SRMR) for evaluating the goodness of model fits. Cutoff values of CFI ≥ .95, RMSEA ≤ .06, or SRMR ≤ .08 indicated very good model fits.

Results

Descriptive Statistics and Estimates of Normality and Reliability

Table 1 shows children's performance on the three skills at the three times with the skewness and kurtosis estimates of each skill at each time. Those estimates were generally lower than the rule-of-thumb values for univariate normality (i.e., ±2 for both skewness and kurtosis); they were also below the critical values found to result in significant deviation from multivariate normality (i.e., ±2 for skewness and ±7 for kurtosis) (Curran, West, & Finch, 1996).

Insert Table 1 about here

A series of repeated ANOVA was conducted to compare children's performance across the three times. A statistically significant time difference was found for all three skills. For decoding, $F(1, 88) = 108.46$, $p < .001$. Post-hoc pairwise comparisons with Bonferroni adjustment showed that decoding at Time 1 was significantly lower than that at Times 2 and 3 ($p < .001$); and Time 2 decoding was also lower than Time 3 decoding ($p = .011$). For vocabulary knowledge, $F(1, 88) = 54.342$, $p < .001$. Post-hoc comparisons showed Time 1 vocabulary knowledge was significantly lower than that at Times 2 and 3 ($p < .001$). There was, however, no significant difference between Times 2 and 3 ($p = .694$). Finally, for reading comprehension, $F(1, 88) = 16.979$, $p < .001$. Post-hoc comparisons showed no significant difference between Times 1 and 2 ($p = .071$); yet, the performance at both Time 1 ($p < .001$) and Time 2 ($p = .024$) was significantly lower than that at Time 3.

Concurrent and Longitudinal Correlations

Table 2 shows the bivariate, concurrent as well as longitudinal correlations, which were all significant (all *p*s < .001). Notably, Time 1 decoding ($r = .530$) and vocabulary ($r = .488$) significantly correlated with Time 2 reading comprehension; likewise, Time 2 decoding ($r = .633$) and vocabulary ($r = .575$) also significantly correlated with Time 3 reading comprehension. The longitudinal correlations appeared to become slightly stronger over time. Time 1 reading comprehension also significantly correlated with Time 2 decoding ($r = .460$) and vocabulary ($r = .510$). Likewise, the correlations of Time 2 reading comprehension with Time 3 decoding ($r = .523$) and vocabulary ($r = .496$) were also significant.

Insert Table 2 about here

Cross-Lagged Path Analysis

Path analysis showed that the CLP model in Figure 3 overall had very good model fits (see the fit indexes of Model 1 in Table 3). Tables 4 and 5 show the parameter estimates from Time 1 to Time 2 and from Time 2 to Time 3, respectively. As shown in Table 4, over and above Time 1 reading comprehension ($\beta = .549$, $p < .001$) and vocabulary, Time 1 decoding significantly predicted Time 2 reading comprehension ($\beta = .301$, $p < .001$). This unique effect, however, did not surface for Time 1 vocabulary ($\beta = .015$, $p = .890$). Altogether the three Time 1 predictors explained about 52.1% of the variance in Time 2 reading comprehension. The pattern of the longitudinal effect of decoding on reading comprehension appeared similar from Time 2 to Time 3. As shown in Table 5, controlling for Time 2 reading comprehension ($\beta = .385$, $p < .001$) and vocabulary, Time 2 decoding significantly predicted Time 3 reading comprehension ($\beta = .321$, $p < .001$). The unique effect of vocabulary, however, was only marginally significant ($\beta = .181$, $p = .056$). The three Time 2 predictors, including the autoregressor, explained about 54.7% of the variance in Time 3 reading comprehension.

Insert Tables 3-5 about here

Insert Figure 3 about here

Conversely, with the autoregressive control considered, the longitudinal effect of reading comprehension on neither decoding nor vocabulary was significant. Later decoding was largely a function of earlier decoding rather than earlier reading comprehension. This was similarly the case for vocabulary knowledge. Specifically, over and above Time 1 decoding (β = .860, p < .001) and vocabulary, Time 1 reading comprehension did not significantly predict Time 2 decoding (β = .035, p = .438). The effect of Time 2 reading comprehension on Time 3 decoding was similar (β = .029, p = .477). Likewise, controlling for Time 1 vocabulary (β = .786, p < .001) and decoding, Time 1 reading comprehension did not significantly predict Time 2 vocabulary (β = .027, p =.688). This pattern also appeared similar for the effect of Time 2 reading comprehension on Time 3 vocabulary (β = .029, p = .557).

Comparing Path Coefficients

The standardized path coefficients presented in Tables 4 and 5 seem to suggest that compared to vocabulary, decoding had a greater longitudinal effect on reading comprehension during both periods, that is, from Time 1 to Time 2 and from Time 2 to Time 3. Additionally, whereas the longitudinal effect of decoding on reading comprehension appeared similar across the two periods, that of vocabulary on reading comprehension appeared to have strengthened. To statistically test the relative effect of decoding and vocabulary on reading comprehension on the one hand, and whether the effect of either lexical predictor changed across the two periods, four additional path models were run with equivalence constraints imposed on coefficients of interest.

To compare the relative longitudinal effect of decoding and vocabulary on reading comprehension, the coefficients of the paths from Time 1 decoding to Time 2 comprehension and from Time 1 vocabulary to Time 2 comprehension were first constrained to be the same. As shown Table 3, this new, constrained model (Model 2a) overall showed good model fits; yet, it significantly deviated from the baseline model (Model 1): $\Delta\chi^2(1) = 4.143$, p = .041, which means the null hypothesis should be rejected and a conclusion be made that Time 1 decoding had a significantly larger effect on Time 2 reading comprehension than did Time 1 vocabulary.

As the next step, the equivalence constraint was placed on the coefficients of the paths from Time 2 decoding to Time 3 comprehension and from Time 2 vocabulary to Time 3 comprehension. This constrained model (Model 2b) showed very good model fits and did not significantly deviate from the baseline model (Model 1): $\Delta\chi^2(1) = 1.477$, $p = .224$. The null model should thus be retained. In other words, different from the previous period, the unique, longitudinal effect of decoding and vocabulary on reading comprehension, from Time 2 to Time 3, did not show any significant difference.

Two additional models with equivalence constraints were run to test whether the unique, longitudinal effect of either decoding or vocabulary on reading comprehension changed across the two periods. In Model 3a (see Table 3), the path coefficient of Time 1 decoding to Time 2 reading comprehension and that of Time 2 decoding to Time 3 reading comprehension were constrained to be the same. Model 3a showed good model fits and did not differ from Model 1 significantly: $\Delta\chi^2(1) = .225$, $p = .635$. The null model was thus be retained, which means there was no significant change in the unique effect of decoding over time.

Likewise, in Model 3b, equivalence constraint was placed on the path coefficients of Time 1 vocabulary to Time 2 reading comprehension and Time 2 vocabulary to Time 3 reading comprehension. Model 3b also showed good model fits; and it did not differ from Model 1 significantly: $\Delta\chi^2(1) = 2.289$, $p = .130$. This model comparison result again suggests that the null model should be retained; and an inference was thus made that there was no significant change in the unique effect of vocabulary on reading comprehension over time.

Discussion

This study aimed to explore developmental interdependence between decoding, vocabulary, and reading comprehension in L2 readers of Chinese. To answer the three research questions, decoding, as opposed to vocabulary knowledge, surfaced as a unique, longitudinal predictor of reading comprehension; its effect on change in reading comprehension was similar over time. From Time 1 to Time 2, the effect of decoding was also stronger than that of vocabulary; from Time 2 to Time 3, however, there was no significant difference between the two lexical predictors. Finally, no significant effect was found of reading comprehension on change in decoding or vocabulary for both periods.

Longitudinal Effects of Decoding and Vocabulary on Reading Comprehension

Earlier decoding consistently predicted later reading comprehension with autoregressive control considered. From Time 1 to Time 2, decoding also had a greater effect than did vocabulary knowledge on change in reading comprehension. Overall decoding seemed to have a more salient effect on reading comprehension development. This finding differs notably from previous longitudinal studies on alphabetic readers, including L2 readers (e.g., Lervåg & Aukrust, 2010), where vocabulary, as opposed to decoding, tended to have a more consistent and salient effect on growth in reading comprehension. Considering how decoding prioritizes sub-skills differentially in alphabetic languages and Chinese (Leong, 2015; Perfetti et al., 2013), the finding on decoding did not seem to be a surprise in the present study. Decoding in Chinese relies heavily on orthographic processing; and phonetic strategies have very restricted utility. This should be the case for any readers of Chinese, including L2 readers. L2 character learning typically involves integrated teaching of form and meaning; successful decoding of a character tends to suggest that the learner "knows" the character and there is meaning activation during decoding. In Everson's (1998) study on beginning university learners of L2 Chinese in the United States, there was a near-perfect correlation (r = .96) between saying Chinese words out loud (i.e., decoding) and explaining their meanings in English. It was also estimated that when participants were able to pronounce a word correctly, there was a probability of 90.7% that they would be able to give the meaning of the word. This implies that for L2 readers, character decoding ability entails a consternation of skills, including importantly knowledge of character meanings, that are fundamental for text reading and comprehension. In this respect, it is not surprising that in both the present study and Wong (2017), decoding was an important longitudinal predictor of reading comprehension in L2 readers of Chinese.

What is puzzling is why vocabulary knowledge did not surface as a unique predictor? As discussed earlier in this paper, decoding constituent characters of words alone should not be sufficient to meet the various requirements for text comprehension. Notably, text reading in Chinese requires proper word segmentation, which necessitates the support of vocabulary knowledge. In addition, being able to sound out the common characters (and activate their meanings) that make up a multi-character word does not in itself suggest the reader knows the meaning of the *whole* word. For understanding 这/家/公司的/业务/很/广泛, for example, a learner may successfully decode 公 and 司 because s/he might have learned the two characters respectively from the words 公园 and 司机 from the textbook; likewise, s/he may successfully decode 业 and 务, because s/he might have learned them respectively from 作业 and 服务. Yet, the meanings learned of those individual characters in other lexical contexts may not translate into those of the new, whole words, despite potential help from morphological/compound awareness (Zhang, 2019b). This semantic gap would not only in itself impair the construction of a propositional meaning but pose a challenge for correct word segmentation. In a nutshell, vocabulary should hypothetically have predicted change in reading comprehension in this study.

Instead of concluding that vocabulary was unimportant for reading comprehension development in L2 readers of Chinese, we argue that in this study, the lack of a unique effect of vocabulary, in the presence of character/word decoding in the model, may only temporarily characterize L2 reading development at an early stage. In other words, in the early stage of L2 reading, decoding may tend to have a more crucial influence on text reading and comprehension development. As learners pass the initial stage (able to recognize a number of common characters and starting to read more complex texts), vocabulary may gradually emerge as an important – if not more important than decoding – unique predictor of developmental change in reading comprehension. In fact, from Time 2 to Time 3, vocabulary had a marginally significant effect on reading comprehension (see Table 5) and its effect did not significantly differ from that of decoding. Presumably, had the longitudinal project gone further to the rest of the participants' elementary school years (Grades 5 and 6), a unique and more salient effect of vocabulary might have emerged; and the relative effects of decoding and vocabulary might have further changed showing a greater effect of vocabulary. That would show convergence with the many findings in the general L1 and L2 reading literature that meaning gradually plays a far more important role than code-based skills in reading comprehension and its development (García & Cain, 2014).

Longitudinal Effects of Reading Comprehension on Decoding and Vocabulary

This study did not find any significant longitudinal effect of reading comprehension on vocabulary knowledge. Although this finding seems to corroborate some previous studies (e.g., Quinn et al., 2015), it came as a surprise. The DVC Triangle (Perfetti, 2010) contends that comprehension is essentially for incidental learning of vocabulary during reading. To unlock the meaning of a word in a text, the reader needs to understand at least the local discourse and obtain contextual clues (Nagy, 2005). Good comprehenders, compared to poor comprehenders, are thus better word learners (e.g., Cain, Oakhill, & Elbro, 2003). This could be even more salient in Chinese as learners need contextual support to segment words properly and establish the lexical identity for an unknown word. Developmentally comprehension should thus be expected to predict vocabulary development.

Previous studies sometimes explained the lack of a developmental effect found of comprehension on vocabulary development in light of how sensitive literacy measures may be to change (e.g., Quinn et al., 2015). Although this explanation may pertain to this study as well, we argue that our finding may be attributed to the short interval between waves of data in specific and the short duration of the project in general. Specifically, although participants' skills were measured three times, the intervals were only about half a year (and the three waves only spanned about a year). Readers would perhaps need to read widely over a sufficiently long period of time, over and beyond learning the school curriculum, to realize the potential benefit of comprehension for incidental word learning and vocabulary expansion. Even though good comprehenders possess an advantage for incidental learning, if they do not read widely and create opportunities for that learning to happen, there would be little to expect of that for vocabulary growth. Chen at al. (2019) explained the developmental effect of reading comprehension on vocabulary in the older cohorts (grades 3 and 5), as opposed to the youngest cohort (grade 1), in light of the older cohorts' independent reading and exposure to complex and diverse texts. Note, however, that Chen et al.'s participants were native Chinese-speaking children in China where the medium of school instruction is Chinese. It is questionnaire that those authors' characterization of reading experience would similarly hold for the third/fourth graders of the present study, who learned Chinese primarily through classroom instruction in an English-medium educational system. In other words, the participants of this study might not have read (sufficiently) widely during the project periods for any potential effect of comprehension on vocabulary expansion to emerge. Very constrained exposure to written texts or extra-curricular reading experience would unlikely result in any effect of comprehension on lexical growth.

This study did not find any longitudinal effect of reading comprehension on word decoding either. While the above explanation for vocabulary may hold for decoding as well, we speculate that this result might be due to the fact that L2 readers learn characters primarily through classroom instruction where pronunciation, together with orthographic features and meaning, is taught. In other words, L2 Chinese decoding could be primarily be the result of classroom instruction. Unless written texts are annotated with *pinyin* (the alphabetic system used for initial learning to read in Chinese) or the learner looks up a character dictionary for the pronunciation of an unknown character, reading would not result in incidental learning of character sound. While self-teaching of sound-letter mapping patterns through reading is a possible mechanism for learning to read or decoding development in English (Share, 1995), it is hardly the case for Chinese (Leong, 2015; Perfetti et al., 2013). In other words, individual differences in L2 Chinese decoding may well be a manifestation of learners' differential effects of learning a curriculum. In fact, the words in the decoding task for this study were all sampled from the elementary school textbooks that children had learned or would learn in upper grades.

Limitations and Future Research

The present study has a few limitations. To begin with, the study was conducted in Singapore where Chinese-studying students were almost all ethnic Chinese. Our participants were all ethnic Chinese children with English as their dominant home language. There were actually a small number of non-ethnic Chinese students who were definitely L2 learners of Chinese as well, such as immigrant children from South Korea or Thailand. They were excluded for this study because compared to their ethnic Chinese peers, there was qualitative difference in home language patterns, not to mention distinctions in light of sociocultural factors for learning Chinese in Singapore. It would be interesting in the future to study those learners and compare them with the ethnic Chinese L2 learners. Likewise, future research could also consider learners of Chinese in other contexts such as young foreign language learners in Chinese immersion programs in a place like the United States (Lü, 2019). It would also be interesting to compare how the patterns of relationships may or may not hold for native Chinese-speaking children.[2]

Another limitation is the relatively short period for a longitudinal study. The short duration might have constrained the insights generated in several ways. For example, as discussed earlier, had the project lasted longer, a more salient role of vocabulary knowledge might have begun to appear. Additionally, reading experience might have been accumulated to a level for an effect of comprehension on vocabulary development to emerge.

More refined consideration for measuring skills might produce a more nuanced insight into developmental patterns. For example, as L2 readers progress in Chinese learning, decoding fluency, as opposed to basic accuracy of decoding, may better represent the decoding component of the DVC Triangle for exploring developmental relationships. Although it was discussed earlier that L2 readers' decoding development may be primarily a function of classroom learning, extra-curricular text reading should provide contextualized experiences for consolidating the learned connections between sound (and other formal features such as orthographic structure) and meaning. In this respect, decoding fluency may better manifest the quality of lexical representations (Perfetti, 2007); and change in decoding fluency, as opposed to that in basic accuracy, may be more sensitive to reading experience and comprehension.

There are many conceptual discussions on how reading is important for lexical development. As hypothesized in the DVC Triangle (Perfetti, 2010), comprehension "causes" learning of new words. However, developmentally, nobody – no matter how good they are at comprehension at a particular time point – would be able to benefit from incidental learning for vocabulary expansion if reading experience is not there! For research, this means that to obtain a more nuanced understanding about the mechanism of developmental change, such as the Matthew Effect in reading ("the rich get richer and the poor become poorer" in reading development) (Stanovich, 1986), it would be important to consider individual differences in the quantity and quality of learners' reading experience (Bast & Reitsma, 1998).

Finally, a limitation pertains to the use of CLP and path analysis to examine developmental interdependence. CLP has the advantage for testing developmentally reciprocal effects between two or more variables. However, it has a limitation in that it focuses only on individual differences (i.e., inter-individual variability). "Although the parameters of the panel model are affected by intraindividual change," they are not "sensitive to the type of individual-level change" (Selig & Little, 2012, p. 267). It will thus be desirable for further research to adopt longitudinal modeling methods, such as Latent Growth Curve Modeling (Newsome, 2015), that can account for both inter- and intra-individual variability.

Conclusions

This study explored developmental interdependence between decoding, vocabulary, and reading comprehension in young L2 readers of Chinese. To our knowledge, it is the first of its kind that aimed to directly test this issue in L2 readers. Despite its relatively short period as a longitudinal study, it has generated some interesting findings. For example, decoding was consistently an important longitudinal predictor of reading comprehension; there was also emergence of vocabulary knowledge as a unique lexical predictor of reading comprehension development as well. The study also sheds light on some important issues for further research with a longer duration and more rigorous methodological considerations.

To guide the present study, the DVC Triangle was referred to as the conceptual basis for discussing the relationships between decoding, vocabulary, and reading comprehension. We explored how the DVC Triangle, which intends to outline the complex interaction between lexical processes and reading comprehension in skilled reading and is largely contextualized in monolingual English reading, may accommodate developmental associations in L2 readers of Chinese. Although limited empirical evidence has prevented us from a sound evaluation of the developmental validity of the DVC Triangle, it is noteworthy that decoding played a critical role in L2 Chinese reading comprehension development; and there was no evidence to suggest that any developmental effect of decoding on reading comprehension would have to go through the mediation of vocabulary in L2 Chinese readers. Another insight was that any conceptualization of the effect of comprehension on lexical development would perhaps need to consider learners' reading experience and the instructional context.

Notes

1. Longitudinal studies are defined here as those where more than one wave of data is collected from a same cohort(s) of readers; additionally, statistical inference involves more than concurrent correlational relationships. In particular, data analysis should include the effect of a predictor (e.g., decoding and/or vocabulary knowledge) on the change or growth of a criterion variable (e.g., reading comprehension). This developmental effect could be based on controlling for an autoregressor (e.g., earlier reading comprehension) or predicting the growth of a criterion variable (e.g., the slope in latent growth curve modeling analysis). Compared with studies based on concurrent correlations obtained from one or more groups/cohorts of students, longitudinal research so defined is very limited. Yet, it is longitudinal evidence that directly informs *change* or *development* and is of immediate interests here.

2. We actually explored the DVC developmental interdependence in children who had Chinese (as opposed to English) as the dominant home language. Although those children were essentially bilingual readers (that is, Chinese and English) and thus unlike those native Chinese-speaking children in places like China (e.g., Chen et al., 2019), and they were not included in this paper given the study's L2 focus, the same CLP modeling revealed some interestingly different findings. Notably, from Time 1 to Time 2 as well as from Time 2 to Time 3, both decoding ($\beta = .153$, $p = .020$ and $\beta = .288$, $p < .001$, respectively) and vocabulary ($\beta = .171$, $p = .008$ and $\beta = .208$, $p < .001$, respectively) were a unique longitudinal predictor of reading comprehension. The oral language experience those children had at home, which distinguished them from the participants of the study reported in this chapter, could perhaps well explain the presence of a significant, unique effect of oral vocabulary (and more balanced effects between decoding and vocabulary) during both periods. In fact, and perhaps without any surprise, those children also

significantly outperformed their L2 peers on all three skills at all three times. Taking into consideration the trend of vocabulary emerging as a significant, unique predictor from Time 2 to Time 3 in the L2 readers, these findings together perhaps suggest that, whether an effect of vocabulary would appear, over and above decoding, on developmental change in Chinese reading comprehension may involve complex reader (L1 vs. L2) X time (or learning/ developmental stage) interaction.

The CLP modeling on those from Chinese-dominant families, conversely, found the same pattern that reading comprehension did not significantly predict change in either decoding or vocabulary. This might be similarly explained in light of the constrained reading experience discussed earlier of the L2 readers. After all, although those children used Chinese as the dominant home language, the medium of instruction in Singapore is English and English is expectedly their primary literacy in Grade 3/4. Those children, like their peers from English-dominant families (but likely unlike those native-speaking children at their age in a monolingual society like China), might not highly value reading in Chinese, over and beyond the learning of the school curriculum.

References

Anderson, R. C., & Freebody, P. (1981). Vocabulary knowledge. In J. T. Guthrie (Ed.), *Comprehension and teaching: Research reviews* (pp. 77–117). Newark, DE: International Reading Association.

Bast, J., & Reitsma, P. (1998). Matthew effects in reading: A comparison of latent growth curve models and simplex models with structured means. *Multivariate Behavioral Research, 32*, 135–167. https://doi.org/10.1207/s15327906mbr3202_3

Beijing Language Institute. (1986). *现代汉语频率词典* (*Modern Chinese frequency dictionary*). Beijing, China: Beijing Language Institute Press.

Cain, K., & Barnes, M.A. (2017). Reading comprehension: What develops and when? In K. Cain, D.L.Compton, & R.K. Parrila (Eds.), *Theories of reading development* (pp. 257–282). Amsterdam: John Benjamins Publishing. https://doi.org/10.1075/swll.15.15cai

Cain, K., Oakhill, J., & Elbro, C. (2003). The ability to learn new word meanings from context by school-age children with and without language comprehension difficulties. *Journal of Child Language, 30*, 681–694. https://doi.org/10.1017/S0305000903005713

Chen, H., Zhao, Y., Wu, X., Sun, P., Xie, R., & Feng, J. (2019). The relation between vocabulary knowledge and reading comprehension in Chinese elementary children: A cross-lagged study. *Acta Psychologia Sinica, 51*, 924–934. https://doi.org/10.3724/SP.J.1041.2019.00924

Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological Methods, 1*, 16–29. https://doi.org/10.1037/1082-989X.1.1.16

DeFrancis, J. (1989). *Visible speech: The diverse oneness of writing systems*. Honolulu, HI: University of Hawaii Press.

Duke, N. K., & Carlisle, J. F. (2011). The development of comprehension. In M. L. Kamil, P. D. Pearson, E. B. Moje, & P. Afflerbach (Eds.), *Handbook of reading research Volume 4* (pp. 199–228). New York, NY: Routledge.

Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test* (4th ed.). Bloomington, MN: Pearson Assessments.

Everson, M. (1998). Word recognition among learners of Chinese as a Foreign Language: Investigating the relationship between naming and knowing. *The Modern Language Journal, 82*, 194–204. https://doi.org/10.1111/j.1540-4781.1998.tb01192.x

García, J. R., & Cain, K. (2014). Decoding and reading comprehension: A meta-analysis to identify which reader and assessment characteristics influence the strength of the relationship in English. *Review of Educational Research*, *84*, 74–111. https://doi.org/10.3102/0034654313499616

Grabe, W. (2009). *Reading in a second language: Moving from theory to practice*. New York: Cambridge University Press. https://doi.org/10.1017/S0272263110000355

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading and reading disability. *Remedial and Special Education*, *7*, 6–10. https://doi.org/10.1177/074193258600700104

Hu, L.-Z., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1–55. https://doi.org/10.1080/10705519909540118

Jeon, E. H., & Yamashita, J. (2014). L2 reading comprehension and its correlates: A meta-analysis. *Language Learning, 64*, 160–212. https://doi.org/10.1111/lang.12034

Lam, K., Chen, X., Geva, E., Luo, Y. C., & Li, H. (2012). The role of morphological awareness in reading achievement among young Chinese-speaking English language learners: a longitudinal study. *Reading and Writing: An Interdisciplinary Journal, 25*, 1847–1872. https://doi.org/10.1007/s11145-011-9329-4

Lervåg, A., & Aukrust, V. G. (2009). Vocabulary knowledge is a critical determinant of the difference in reading comprehension growth between first and second language learners. *Journal of Child Psychology and Psychiatry, 51*, 612–620. https://doi.org/10.1111/j.1469-7610.2009.02185.x

Leong, C. K. (2015). Functional components of reading with reference to Chinese. In T. Papadopoulos, R. K. Parrila, & J. R. Kirby (Eds.), *Cognition, intelligence, and achievement: A tribute to J. P. Das* (pp. 149–171). Amsterdam: Elsevier. https://doi.org/10.1016/B978-0-12-410388-7.00009-9

Lü, C. (2019). *Chinese literacy learning in an immersion program*. New York, NY: Palgrave Macmillan.

Muthén, L, K., & Muthén, B. O. (1998–2017). *Mplus user's guide* (8th ed.). Los Angeles: Muthén & Muthén.

Nagy, W. (2005). Why vocabulary instruction needs to be long-term and comprehensive. In E. H. Hiebert & M. L. Kamil (Eds.), *Teaching and learning vocabulary: Bring research to practice* (pp. 27–44). Mahwah, NJ: Lawrence Erlbaum Associates.

Nagy, W. E., & Scott, J. (2000). Vocabulary Processes. In M. Kamil, P. Mosenthal, P. D. Pearson, & R. Barr (Eds.)*, Handbook of reading research*, *Volume III* (pp. 269–284). Mahwah, NJ: Lawrence Erlbaum Associates.

Newsom, J. T. (2015). *Longitudinal structural equation modeling: A comprehensive introduction*. New York, NY: Routledge. https://doi.org/10.4324/9781315871318

Perfetti, C. A. (1985). *Reading ability*. New York: Oxford University Press.

Perfetti, C. A. (1999). Comprehending written language: A blueprint for the reader. In C. Brown & P. Hagoort (Eds.), *Neurocognition of language* (pp. 167–208). Oxford: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198507932.003.0006

Perfetti, C. A. (2007). Reading ability: Lexical quality to comprehension. *Scientific Studies of Reading, 11*, 357–383. https://doi.org/10.1080/10888430701530730

Perfetti, C. A. (2010). Decoding, vocabulary, and comprehension. In M. G. McKeown & L. Kucan (Eds.), *Bridging reading research to life* (pp. 291–303). New York, NY: The Guilford Press.

Perfetti, C., Cao, F., & Booth, J. (2013). Specialization and universals in the development of reading skill: How Chinese research informs a universal science of reading. *Scientific Studies of Reading, 17*, 5–21. https://doi.org/10.1080/10888438.2012.689786

Perfetti, C. A., Landi, N., & Oakhill, J. (2005). The acquisition of reading comprehension skills. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook* (pp. 227–247). Malden, MA: Blackwell. https://doi.org/10.1002/9780470757642.ch13

Quinn, J. M., Wagner, R. K., Petscher, Y., & Lopez, D. (2015). Developmental relations between vocabulary knowledge and reading comprehension: a latent change score modeling study. *Child Development, 86*, 159–175. https://doi.org/10.1111/cdev.12292

Santos, S., Cadime, I., Viana, F. L. & Ribeiro, I. (2019). Cross-Lagged relations among linguistic skills in European Portuguese: A longitudinal study. *Reading Research Quarterly, 55*, 177–192.

Selig, J. P., & Little, T. D. (2012). Autoregressive and cross-lagged panel analysis for longitudinal data. In B. Laursen, T. D. Little, & N. A. Card (Eds.), *Handbook of developmental research methods* (pp. 265–278). New York, NY: Guilford Press.

Share, D. L. (1995). Phonological recoding and self-teaching: *sin qua non* of reading acquisition. *Cognition, 55*, 151–218. https://doi.org/10.1016/0010-0277(94)00645-2

Shepherd, J. (2005). *Striking a balance: The management of language in Singapore*. Frankfurt, Germany: Peter Lang.

Stanovich, K. (1986). Mathew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21*, 360–407. https://doi.org/10.1177/0022057409189001-204

Taylor, I., & Taylor, M. M. (2014). *Writing and literacy in Chinese, Korean and Japanese*. Philadelphia, PA: John Benjamins. https://doi.org/10.1075/swll.14

Verhoeven, L., & Van Leeuwe, J. (2008). Prediction of the development of reading comprehension: A longitudinal study. *Applied Cognitive Psychology, 22*, 407–423. https://doi.org/10.1002/acp.1414

Wong, Y. K. (2017). Relationships between reading comprehension and its components in young Chinese-as-a-second-language learners. *Reading and Writing, 30*, 969–988. https://doi.org/10.1007/s11145-016-9708-y

Yeung, P.-S., Ho, C. S.-H., Chan, D. W.-O., & Chung, K. K.-H. (2016). A componential model of reading in Chinese. *Learning and Individual Differences, 45*, 11–24. https://doi.org/10.1016/j.lindif.2015.11.007

Zhang, D. (2017a). Derivational morphology in reading comprehension of Chinese-speaking learners of English. *Applied Linguistics*, 38, 871–895. https://doi.org/10.1093/applin/amv072

Zhang, D. (2017b). Multidimensionality of morphological awareness and reading comprehension among young Chinese readers in a multilingual context. *Learning and Individual Differences, 53*, 13–23. https://doi.org/10.1016/j.lindif.2017.04.009

Zhang, D., Chin, C.-F., & Li, L. (2017). Metalinguistic awareness Malay-English bilingual children's word reading: A cross-lagged panel study on transfer facilitation. *Applied Psycholinguistics, 38*, 395–426. https://doi.org/10.1017/S0142716416000278

Zhang, D., Lin, C.-H., Zhang, Y., & Choi, Y. (2019). *Pinyin* or no *pinyin*: Does access to word pronunciation matter to the assessment of Chinese learners' vocabulary knowledge? *Language Learning Journal,* 47(3), 344–353. https://doi.org/10.1080/09571736.2017.128923

Zhang, D., Koda, K., & Leong, C. K. (2016). Morphological awareness and bilingual word learning: A longitudinal Structural Equation Modeling study. *Reading and Writing, 29*, 383–407. https://doi.org/10.1007/s11145-015-9603-y

Zhao, S., & Liu, Y. (2010). Chinese education in Singapore: Constraints of bilingual policy from the perspectives of status and prestige planning. *Language Problem and Language Planning, 34*, 236–258. https://doi.org/10.1075/lplp.34.3.03zha

Zhao, S., & Zhang, D. (2007). The totality of Chinese characters: A digital perspective. *Journal of Chinese Language and Computing, 17*, 107–125.

Zhou, Y. G. (1978). 现代汉字中声旁的表音功能问题 (To what degree are the phonetics of present-day Chinese characters still phonetic?) *Zhongguo Yuwen, 146,* 172–177.

Table 1.

Descriptive Statistics, Normality Estimates, and Reliability

	Mean	*SD*	Skewness	Kurtosis	Reliability (α)
Word Decoding (*MSP* = 30)					
Time 1	11.830	5.940	0.436	0.488	.925
Time 2	13.970	6.125	0.043	0.153	.940
Time 3	14.640	6.698	-0.051	-0.109	.946
Vocabulary Knowledge (*MSP* = 60)					
Time 1	35.200	8.116	-0.579	1.468	.877
Time 2	38.720	7.790	-0.846	2.635	.904
Time 3	39.220	9.141	-0.982	1.762	.911
Reading Comprehension (*MSP* = 15)					
Time 1	4.830	2.773	1.101	1.239	.732
Time 2	5.350	2.370	1.135	1.057	.718
Time 3	5.990	2.830	0.482	0.028	.767

Notes. MSP: Maximum Score Possible; Time 1: end of Grade 3; Time 2: mid of Grade 4; Time 3: end of Grade 4

Table 2.

Bivariate Correlations Between Literary Measures at Three Different Times

		1	2	3	4	5	6	7	8	9
Time 1 measures										
1	Word Decoding	–								
2	Vocabulary Knowledge	.637	–							
3	Reading Comprehension	.434	.567	–						
Time 2 measures										
4	Word Decoding	.933	.659	.460	–					
5	Vocabulary Knowledge	.599	.856	.510	.619	–				
6	Reading Comprehension	.530	.488	.671	.529	.515	–			
Time 3 measures										
7	Word Decoding	.926	.634	.416	.948	.594	.523	–		
8	Vocabulary Knowledge	.667	.828	.487	.709	.903	.496	.687	–	
9	Reading Comprehension	.601	.561	.553	.633	.575	.644	.589	.604	–

Notes. All *p*s < .001. Time 1: end of Grade 3; Time 2: mid of Grade 4; Time 3: end of Grade 4.

Table 3.

Goodness-of-Fit Indexes of Path Models Comparing Effects Across Predictors and Times

	χ^2(*df*)	*p*	χ^2/df	CFI	RMSEA (CI)	SRMR
Model 1	20.754(12)	.054	1.730	.989	.091(.000 .154)	.017
Constrained Models for Comparing Effects of Decoding and Vocabulary						
Model 2a	24.897(13)	.024	1.915	.985	.101(.036 .161)	.023
Model 2b	22.231(13)	.052	1.710	.989	.089(.000 .151)	.019
Constrained Models for Comparing Effects Across Times						
Model 3a	20.979(13)	.073	1.614	.990	.083(.000 .146)	.017
Model 3b	23.043(13)	.041	1.773	.988	.093(.019 .154)	.020

Notes. Model 1: baseline model; Model 2a: equivalence constraint on the paths from Time 1 decoding and vocabulary to Time 2 reading comprehension; Model 2b: equivalence constraint on the paths from Time 2 decoding and vocabulary to Time 3 reading comprehension; Model 3a: equivalence constraint on the paths from Time 1 decoding to Time 2 reading comprehension and from Time 2 decoding to Time 3 reading comprehension; Model 3b: equivalence constraint on the paths from Time 1 vocabulary to Time 2 reading comprehension and Time 2 vocabulary to Time 3 reading comprehension.

Table 4.

Parameter Estimates of Cross-Lagged Panel Analysis Testing Developmental Interdependence Between Measures from Time 1 to Time 2

Time 2 Criterion Variables	Time 1 Predictors	R^2 (p)	β	p
Reading Comprehension		.521 (<.001)		
	Reading Comprehension		.549	<.001
	Word Decoding		.301	<.001
	Vocabulary Knowledge		.015	.890
Word Decoding		.879 (<.001)		
	Word Decoding		.860	<.001
	Vocabulary Knowledge		.090	.088
	Reading Comprehension		.035	.438
Vocabulary Knowledge		.738 (<.001)		
	Vocabulary Knowledge		.786	<.001
	Word Decoding		.086	.224
	Reading Comprehension		.027	.688

Table 5.

Parameter Estimates of Cross-Lagged Panel Analysis Testing Developmental Interdependence Between Measures from Time 2 to Time 3

Time 3 Criterion Variables	Time 2 Predictors	R^2 (p)	β	p
Reading Comprehension		.547 (<.001)		
	Reading Comprehension		.385	<.001
	Word Decoding		.321	<.001
	Vocabulary Knowledge		.181	.056
Word Decoding		.900 (<.001)		
	Word Decoding		.932	<.001
	Vocabulary Knowledge		.002	.970
	Reading Comprehension		.029	.477
Vocabulary Knowledge		.852 (<.001)		
	Vocabulary Knowledge		.762	<.001
	Word Decoding		.252	.224
	Reading Comprehension		.029	.557

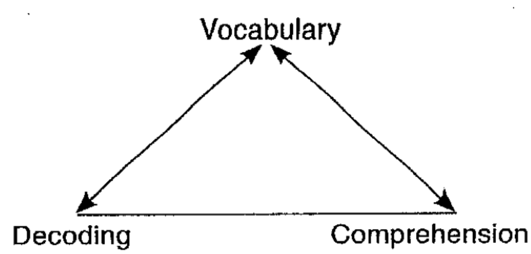

Figure 1. The DVC reading skill triangle (Perfetti, 2010, p. 293)

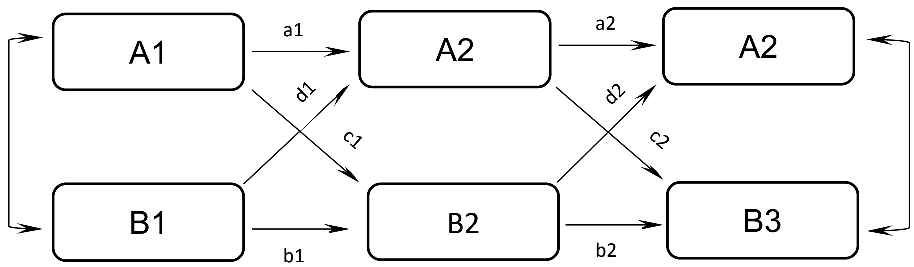

Figure 2. Cross-Lagged Panel analysis with three-wave data

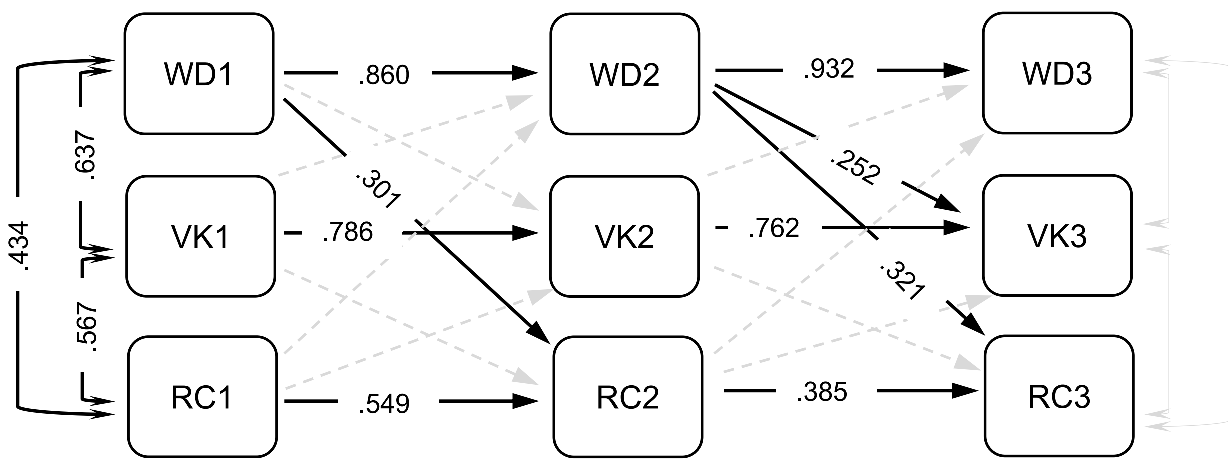

Figure 3. Cross-Lagged Path analysis on developmental interdependence between word decoding, vocabulary knowledge, and reading comprehension

Notes. Significant path coefficients are shown in black solid lines (all *p*s < .001); paths not statistically significant shown in grey dash lines. WD: word decoding; VK: vocabulary knowledge; RC: reading comprehension. Subscripts 1, 2, and 3 represent Times 1, 2, and 3, respectively.