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The unique role of executive function skills in predicting Hong Kong kindergarteners' reading comprehension

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Background. Word reading and linguistic comprehension skills are two crucial components in reading comprehension, according to the Simple View of Reading (SVR). Some researchers have posited that a third component should be involved in reading and understanding texts, namely executive function (EF) skills.

Aim. This study was novel in two ways. Not only did we tested EF skills as a predictor of reading comprehension in a non-alphabetic language (i.e., Chinese) to extend the theoretical model of SVR, we also examined reading comprehension further in kindergarten children (age 5) in Hong Kong, in the attempt to reveal possible early precursors of reading comprehension.

Sample(s). A group of 170 K3 kindergarteners was recruited in Hong Kong.

Methods. Children's word reading was assessed. Their linguistic comprehension was assessed with phonological awareness, verbal short-term memory, and vocabulary knowledge. Using a structured observation task, Head-Toes-Knees-Shoulders (HTKS), we measured their composite scores for EF skills.

Results. Head-Toes-Knees-Shoulders performance predicted unique variance in children's Chinese reading comprehension concurrently beyond word reading and a set of linguistic comprehension skills.

Conclusions. The results highlight the important role of EF skills in beginning readers' reading comprehension.

Reading comprehension can be conceptualized as the capacity to extract or construct an appropriate mental representation or situational model from written text (Hoover & Gough, 1990). The Simple View of Reading (SVR; Hoover & Gough, 1990) framework assumes that reading comprehension performance is a product of decoding and linguistic comprehension skills; it fails if either is lacking. Previous reading comprehension studies, adopting SVR, have focused on identifying its metalinguistic predictors in elementary and secondary school children (e.g., Kendeou, Van den Broek, White, & Lynch, 2009). This

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study hypothesized that, from an early age, reading comprehension requires the involvement of a third component, executive function (EF) skills. EF skills collectively serve the purpose of managing one's actions to complete goals. The construct has strong roots in neuropsychology; the frontal lobe of the brain is responsible for these cognitive skills (Perret, 1974).

The specificity of the association between EF skills and literacy activities depends crucially upon children's development. Some prior work has failed to find a strong relationship between vocabulary and EF skills in young children (Fuhs, Nesbitt, Farran, & Dong, 2014; Lonigan, Allan, Goodrich, Farrington, & Phillips, 2017). Others have found that the involvement of EF skills diminished in letter identification from prekindergarten to kindergarten years (e.g., Fuhs *et al.*, 2014). The implication of this research is that, over development, when a literacy activity (e.g., vocabulary) becomes mature and automatized, less involvement of EF skills is expected (Fuhs *et al.*, 2014; McClelland *et al.*, 2014; Ponitz, McClelland, Matthews, & Morrison, 2009). Thus, rather than think of EF skills as being absent in some literacy activities and present in others, it is useful to consider their role in literacy activities that are demanding for certain age ranges. For kindergarteners, reading comprehension is largely a sophisticated literacy activity requiring application and integration of individuals' knowledge of words (form and meaning), which draws on EF skills to coordinate various cognitive skills (Scarborough, 2001).

In the kindergarten years, EF skills (inhibitory control, working memory, cognitive flexibility) are found to be quite undifferentiated and inextricable; they are entwined to predict children's academic skills and behaviour (Lee, Bull, & Ho, 2013; Monette, Bigras, & Lafrenière, 2015; Usai, Viterbori, Traverso, & De Franchis, 2014; Wiebe, Espy, & Charak, 2008). The Head-Toes-Knees-Shoulders (HTKS) task (McClelland *et al.*, 2014; Ponitz *et al.*, 2008) was adopted to measure kindergarteners' EF skills in the present study. In this task, inhibitory control, working memory, and cognitive flexibility are conceptualized to interact actively with each other to regulate behaviour outcomes towards a future goal (Birgisdóttir, Gestsdóttir, & Thorsdóttir, 2015; Cameron *et al.*, 2012), which is compatible with the idea that various executive skills are quite inseparable in preschoolers and should be interpreted as a unitary factor (Garon, Bryson, & Smith, 2008; Hughes, Ensor, Wilson, & Graham, 2009; Wiebe *et al.*, 2008).

Support for the predictive power of HTKS on children's general literacy achievement, vocabulary, and word reading has been reported in Chinese children from both Beijing and Taiwan (Wanless *et al.*, 2011, 2016). However, very few studies have investigated the role of HTKS in reading comprehension in Hong Kong children. The instructional features (e.g., literacy instruction starts at 3 years of age), spoken language (i.e., Cantonese dialect), and written language (i.e., traditional Chinese characters) of Hong Kong are all distinct from those of other Chinese societies. It is theoretically and practically useful, therefore, to investigate the role of HTKS in reading comprehension in Hong Kong to test similarity and potential variation of the SVR framework.

Word reading, linguistic comprehension, and reading comprehension

The SVR framework, which postulates that reading comprehension consists of two components of decoding and linguistic comprehension, has guided many studies and garnered ample supporting evidence though mostly from alphabetic languages (e.g., Kendeou *et al.*, 2009).

The decoding component in SVR acknowledges the importance of 'word-level' processes (Kirby & Savage, 2008). Word reading has been found to be a powerful measure

to reflect the 'word-level' processing (Johnston & Kirby, 2006; Kirby & Savage, 2008). The Reading Systems Framework (Perfetti & Stafura, 2014) has proposed that word-level knowledge (both form and meaning) plays a relative central role in reading comprehension because recognizing a word activates the mental lexicon and the meaning-retrieval process (Perfetti & Hart, 2002; Perfetti, Matron, & Foltz, 1996).

Linguistic comprehension skills actually encompass a number of spoken language skills to acknowledge the importance of 'language-level' processing. This study assessed three factors to represent children's manipulation, storage, and understanding of spoken language (Harlaar *et al.*, 2010; Kirby & Savage, 2008). Phonological awareness involves the manipulation of units of spoken language (Anthony & Francis, 2005; Høien, Lundberg, Stanovich, & Bjaalid, 1995). Verbal short-term memory is related strongly to linguistic comprehension by allowing learners to hold spoken language information in memory (Florit, Roch, Altoe, & Levorato, 2009). Vocabulary language involves semantic understanding of spoken words; to understand word-level meaning is a prerequisite for paragraph-level comprehension (Adlof, Catts, & Little, 2006; Goff, Pratt, & Ong, 2005).

A third component in SVR: EF skills

In addition to the two classic components of the SVR framework, recent theoretical frameworks (Cutting & Scarborough, 2012; Scarborough, 2001) and several lines of evidence have suggested that EF skills are highly involved in reading comprehension (e.g., Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014; Georgiou & Das, 2016; Kieffer, Vukovic, & Berry, 2013). EF skills tie various skills together to allow their 'fluent execution and coordination' in comprehension (Scarborough, 2001). Reading Systems Framework (Perfetti & Stafura, 2014) states a similar idea that reading comprehension is a highly active integration process in which readers process each word to integrate into a dynamic mental model of texts to construct a coherent understanding of texts. The whole integration process requires continuous updating of text understanding as reading proceeds. To support this process, EF skills are necessary.

In normally developing children, certain executive skills (e.g., inhibition, working memory, and attentional control) have been found to be predictors of reading comprehension, even when other metalinguistic skills and background variables (e.g., socioeconomic status) were controlled (e.g., Cain, Oakhill, & Bryant, 2004; Christopher *et al.*, 2012).

Another line of evidence comes from studies showing that some reading comprehension deficits are not associated with word reading deficits but rather with EF deficits (Leach, Scarborough, & Rescorla, 2003). Cutting, Materek, Cole, Levine, and Mahone (2009) revealed that the children with adequate word reading accuracy but specific reading comprehension deficits showed significantly lower EF performances than those with comprehension deficits associated with poor word reading accuracy. The low performance in EF skills in elementary children with deficits in reading comprehension was found to be independent of phonological processing skills (Locascio, Mahone, Eason, & Cutting, 2010).

In addition, a large portion of late-emerging reading difficulties discovered in upper-elementary grades is related to EF deficits (Leach *et al.*, 2003). Children may have average word reading skills, but still have deficits in constructing meaning out of words, sentences, and passages, integrating text meanings with their background knowledge (Pearson, Hansen, & Gordon, 1979), making inferences (Cain & Oakhill, 1999), or monitoring their understanding of texts (Oakhill & Yuill, 1996; Ruffman, 1996). They may demonstrate adequate reading skills in lower elementary grades, when EF demands are relatively low, but, as EF demands increase in upper grades with the introduction of more

expository texts and longer passages, their EF deficits may begin to manifest as reading comprehension deficits (Cutting *et al.*, 2009; Leach *et al.*, 2003).

Reading comprehension in Hong Kong kindergarten children

English reading studies have demonstrated the involvement of EF skills in reading comprehension in primary school students within the SVR framework (e.g., Leach *et al.*, 2003). In Hong Kong, we assume that the SVR framework is specific in terms of the relative importance of the two components, that is, word reading and linguistic comprehension skills (Yeung *et al.*, 2011; Zhang *et al.*, 2014). EF skills are hypothesized to be crucial in reading comprehension in Hong Kong, for the specific characteristics of the Hong Kong context.

In investigating Hong Kong children's comprehension, research has largely shown that character reading plays a relatively central role, while linguistic comprehension skills do not (Yeung *et al.*, 2011; Zhang *et al.*, 2014); this is a variation to the SVR framework. However, these studies did not consider EF skills together with the two components within the SVR framework. The following analysis of the two components in the SVR framework within the Hong Kong context attempts to address how and why EF skills are important in Hong Kong children's reading comprehension. At the character reading level, Chinese characters have multiple kinds of features and are visually complex. Some characters are ideophonetic – they have orthographic features called phonetics that provide some information (albeit unreliable) about their sounds (Ho & Bryant, 1997). Some are ideographic, which means their visual shapes give clues to their meanings (Ho, Ng, & Ng, 2003; Shu & Anderson, 1997; Yin & McBride, 2015). Readers need to inhibit their irrelevant activations at the character level, retrieve the correct sounds and meanings from long-term memory to apply to the ongoing texts, and switch flexibly between attending to phonetics, radicals, whole characters, etc. (Wanless *et al.*, 2011). Additionally, the characters used in Hong Kong are traditional Chinese characters, which are more complex than the simplified characters used in Mainland China. For example, the simplified Chinese character 体 (seven strokes) has 22 strokes (體) in traditional Chinese. Thus, it takes more cognitive resources in learning Chinese for Hong Kong children. Second, in Hong Kong, there is inconsistency between linguistic comprehension and reading comprehension. In oral dialogue, it is to comprehend the Cantonese dialect. In this dialect, two syllables 'tung4maai4' mean 'and'. In the written language used in Hong Kong, there are two forms. One form, in this example, is the formal written conversion of the two syllables, that is, '同埋'. The second form is used in formal texts, books, newspapers, etc. In this case, people use '和' to mean 'and'. Reading comprehension measures in Hong Kong always refer to reading and comprehending the formal texts, which is distinct from the dialect in both vocabulary and syntax. EF skills are expected to coordinate the mismatch between linguistic comprehension and reading comprehension by activating the vocabulary and syntax suited in each condition.

The Hong Kong context also provides an opportunity to investigate reading comprehension in kindergarteners to reveal whether EF skill is one of the early predictors of reading comprehension. In Hong Kong, literacy instruction begins in the first of 3 years of kindergarten (K1), when children are around the age of three. By the third year of kindergarten (K3), they are capable of reading comprehension at the word and sentence levels. With regard to prior work focusing mainly on elementary and secondary Hong Kong students (Leong, Tse, Loh, & Hau, 2008; Yeung *et al.*, 2011; Zhang *et al.*, 2014), tests of reading comprehension at the passage level in older children may mask the

individual differences that arise at the sentence and word levels. Word- and sentence-level comprehension is considered to be a basis for paragraph comprehension (Yeung *et al.*, 2011), because this is basically a process of word-to-text integration (Perfetti & Stafura, 2014). In the kindergarten years, the two components within the SVR framework (i.e., word reading and linguistic comprehension skills) are developing. Prior research thus assumes that word-level processing restricts children's reading comprehension in the early years and neglects the role of EF skills. Actually, EF skills develop rapidly between the ages of 3 and 5, both qualitatively and quantitatively (Diamond, 2013). As formal literacy instruction takes place between these ages in Hong Kong, EF is likely to be heavily involved in literacy learning in early childhood. Therefore, EF skills are hypothesized to play a significant role in young children's reading comprehension.

The present study

The present study investigated EF skills in Chinese reading comprehension beyond word reading and linguistic comprehension in Hong Kong kindergarteners. There were two main goals. First, we hypothesized a positive link between EF and Chinese reading comprehension, with an attempt to reveal both similarity and variation of the SVR framework previously established in alphabetic languages in a non-alphabetic language (i.e., Chinese) with inconsistent oral language (i.e., Cantonese as the dialect) and written script. The other goal was to establish an earlier link of EF in reading comprehension, that is, from primary graders to kindergartners, as well as that reading comprehension being previously assessed at the passage level to the word and sentence levels. Given the earlier push of formal education in kindergarten age in Hong Kong, we hypothesized a significant association of EF and reading comprehension emerged in kindergarteners.

Methods

Participants and procedure

One hundred seventy K3 children were tested in the January or February of their final semester of kindergarten. The children's mean age was 67.21 months (SD = 6.09). Among 153 fathers and 158 mothers who reported their educational levels, 23.5% of the fathers and 15.2% of the mothers had undergraduate degrees or above. The participants were from local Cantonese-as-medium-of-instruction kindergartens in Hong Kong. All children were Hong Kong children and spoke Cantonese as their native language. Trained undergraduate experimenters tested each child individually. Parental consent was obtained prior to testing. The children received stickers as rewards for their participation.

Measures

Reading comprehension

Children completed a silent reading comprehension task consisting of 40 items. A version of the task printed in simplified Chinese had been administered successfully to kindergarteners by Dong, Li, Wu, Rao, and Zhu (2014) in Beijing. Each item consists of text printed in traditional Chinese and four pictures. The children were instructed to choose the picture that represented the text. The items were arranged in an increasing level of difficulty. The texts in the first 20 items as well as the two practice items were words. Those in items 21–40 were sentences ranging from 4 to 30 characters long. One point was awarded for each correct response.

Non-verbal IQ

Non-verbal IQ is needed to process visual spatial relations, identify patterns in the matrix, and solve problems. Sets A and B of Raven's Colored Progressive Matrices were administered (Raven, Court, & Raven, 1996). The same task has been used to measure non-verbal IQ in previous studies with Hong Kong samples (Lin *et al.*, 2012; McBride-Chang, Cheung, Chow, Chow, & Choi, 2006). Given a matrix with a missing piece and six figures, the children were required to select a figure to complete the matrix. Each correct item was awarded one point. The total number of items was 24.

Word reading

Chinese word reading was assessed with 27 single-character words plus 34 double-character words (Ho & Bryant, 1997) and 150 double-character words from the Hong Kong Test of Specific Learning Difficulties (HKT-SpLD; Ho, Chan, Tsang, & Lee, 2000). These tasks have been used successfully in previous studies with Hong Kong samples to test young children's reading abilities (e.g., Lin *et al.*, 2012; McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003). Each correctly read item was awarded one point.

Linguistic comprehension skills

Phonological awareness

A syllable deletion task with 16 items was administered in Cantonese. Similar tasks have been used widely to measure Hong Kong children's phonological awareness in previous studies (e.g., Chow, McBride-Chang, & Burgess, 2005; McBride–Chang & Kail, 2002; McBride-Chang *et al.*, 2003, 2006). Upon hearing a 3-syllable utterance, the children were required to repeat it. They were then asked to delete the initial, middle, or final syllable and say the resulting two-syllable utterance. The first five items were real words, followed by six items of non-words made up of real syllables. The last five items were non-words made up of syllables that do not correspond to any characters in Cantonese. The testing stopped when the children gave incorrect responses to four items consecutively. One point was awarded for each correct item.

Verbal short-term memory

Digit span forward, from WISC-IV HK, was used to assess the children's verbal short-term memory (Wechsler, 2010). Similar tasks have been used widely to measure verbal short-term memory in previous studies with Hong Kong samples (e.g., Chung, Liu, McBride, Wong, & Lo, 2017). After the experimenter had presented a string of digits orally, the subject repeated the string of digits. The number of digits increased from 2 to 11 with each number of digits being tested in two trials. There were totally 20 test trials. The testing stopped when a subject failed to answer both trials for the same number of digits.

Vocabulary knowledge

The Peabody Picture Vocabulary Test-Chinese (Dunn & Dunn, 1981; Lu & Liu, 1998) was used to assess the children's vocabulary size. Similar tasks have been used widely to assess vocabulary knowledge in previous studies with Hong Kong samples (McBride-Chang *et al.*, 2006). The experimenter said a word aloud while the children were given four

pictures and asked to point to the one that represented the word. A total of 60 items was administered to all children. One point was awarded for each correct item.

EF skills

The Head-Toes-Knees-Shoulders task (HTKS, McClelland & Cameron, 2012), appropriate for children aged 4–8 years, was used to assess EF skills. HTKS has been administered successfully in various Chinese societies (Chung *et al.*, 2017; Duh *et al.*, 2016; Wanless *et al.*, 2011, 2016). The children were required to give the opposite behavioural responses to the experimenter's instructions. There were three sections, each made up of 10 items. In section 1, the children were required to touch their heads when the experimenter said, 'touch your toes', and vice versa. In section 2, another rule was added. In addition to the rule from section 1, the children were required to touch their knees when the experimenter said, 'touch your shoulders', and vice versa. In section 3, the rules from previous sections were jumbled, for example, the correct response to 'touch your toes' was touching one's shoulders. On each item, the children received two points for a correct response, one for self-correction or reaching a correct response after an initially incorrect one, and none for incorrect responses. The ceiling rule stated that children must earn four or more points in a section to progress to the subsequent one. The reaction time was not considered; accuracy rather than speed is a better measurement at this age (Kegel & Bus, 2014). The scores ranged from 0 to 60.

Data analysis

The research questions were addressed with path analysis in Mplus (Muthén & Muthén, 1998-2010). Some data (see Table 1) were missing due to children's absence on the testing days. Age information was not collected from the 23 participants. As our missingness was not related to participants' performances on any measures but simply due to their absence on the testing days, the missingness can be considered to be random to a large extent (Graham, 2009; Schafer & Graham, 2002). To deal with the missing data, the path model was estimated using full information maximum-likelihood estimation within Mplus. The MLR estimator was used (Muthén & Muthén, 1998-2010). The correlations among all independent variables were included.

Model fit was evaluated using the following five indexes. A non-significant chi-square suggested a good model fit. Other model indices included Root Mean Square of Error Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Standardized Root Mean Square Residual (SRMR). Values below .05 on RMSEA and SRMR and above .95 on the CFI and TLI indicate a good fit to the observed data (Hu & Bentler, 1999).

Results

The reliabilities, skewness, kurtosis, means, standard deviations, and correlations are shown in Table 1.

First, we included all variables in one model to examine the unique role of EF skills in reading comprehension beyond age, non-verbal IQ, word reading, phonological awareness, verbal short-term memory, and vocabulary knowledge. The model was a saturated one, in which there were an equal number of parameters being estimated to

Table 1. Reliabilities, means, standard deviations, skewness, Kurtosis, and correlations of all variables

	N	Reliability	Means	*SD*	Skewness	Kurtosis	1	2	3	4	5	6	7	8
1. Age	147	–	67.21	6.09	4.60	37.89	–							
2. Non-verbal IQ	152	.812	10.76	4.32	−0.10	−0.72	.280**	–						
3. Word reading	169	.99	49.18	35.80	1.27	1.57	.029	.320**	–					
4. Phonological awareness	169	.888	9.57	4.57	−0.31	0.15	.063	.274**	.436**	–				
5. Verbal short-term memory	157	.807	11.15	2.82	−0.73	2.64	.098	.126	.243**	.310**	–			
6. Vocabulary knowledge	167	.816	36.40	7.37	−0.40	1.96	.185*	.263**	.364**	.377**	.347**	–		
7. EF skills	150	.878	40.61	11.51	−0.55	0.20	.085	.265**	.181*	.369**	.228**	.204*	–	
8. Reading comprehension	154	.872	20.14	7.82	0.01	−0.71	.042	.397**	.768**	.429**	.277**	.362**	.351**	–

Note. *$p < .05$; **$p < .01$.

degrees of freedom available for the model. The results showed that EF skills were a significant predictor of comprehension (B = .122, SE = .034, p < .001, β = .175). Among the control variables, non-verbal IQ (B = .251, SE = .121, p = .038, β = .137) and word reading (B = .151, SE = .012, p < .001, β = .672) were significant.

Next, we conducted a parsimonious model in which these four non-significant pathways were set to zero, increasing the degrees of freedom to 4 and allowing for model fit indices to be discussed. The model showed a reasonably good model fit to the data, χ^2 (4, N = 170) = 6.299 (p = .178), RMSEA = .058, CFI = .991, TLI = .941, SRMR = .019. Figure 1 shows that the paths of non-verbal IQ (B = .219, SE = .109, p = .045, β = .120), word reading (B = .159, SE = .012, p < .001, β = .709), and EF skills (B = .138, SE = .033, p < .001, β = .197) were significant. Overall, the model explained 67.0% variance in comprehension (p < .01).

In contrast to the SVR framework, linguistic comprehension measures did not significantly predict reading comprehension. By looking at the correlation results, we suspected that linguistic comprehension may work on reading comprehension through word reading in Hong Kong Chinese kindergarteners. This possibility is tested and Figure 2 shows the results. The mediation model showed a good fit, χ^2 (8, N = 170) = 11.454 (p = .1773), RMSEA = .050, CFI = .983, TLI = .954, SRMR = .037. The indirect effects of phonological awareness and vocabulary knowledge through word reading on reading comprehension were both significant (ps < .01). This result suggested some potential variations of the SVR framework; linguistic comprehension (vocabulary and phonological awareness in the current study) may play a relatively indirect role in reading comprehension among Hong Kong kindergarteners, while word reading and EF skills are more direct predictors.

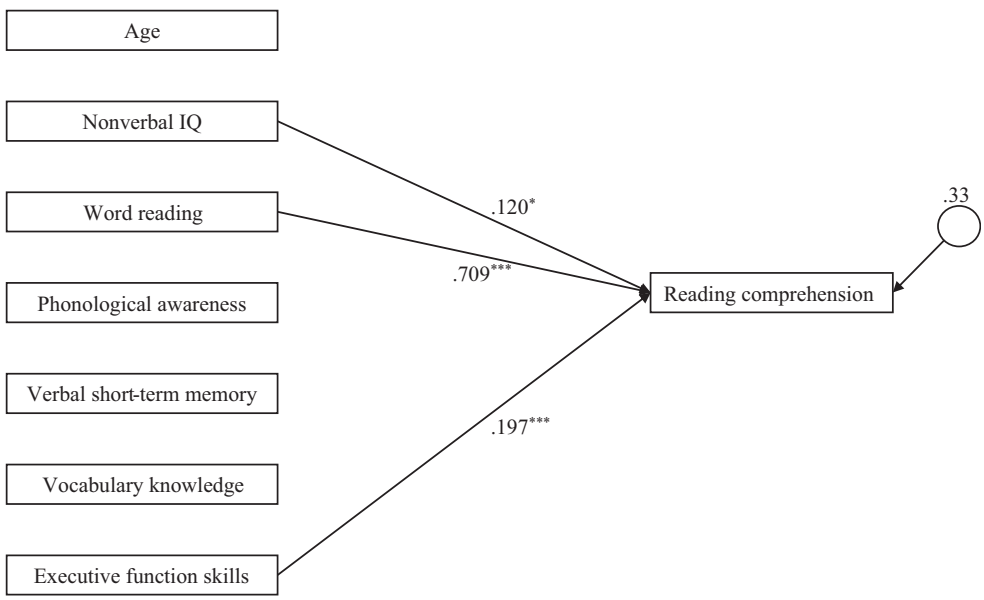

Figure 1. The final model predicting reading comprehension. The correlations between predictors were not presented for the simplicity of presentation. *p < .05. **p < .01. ***p < .001.

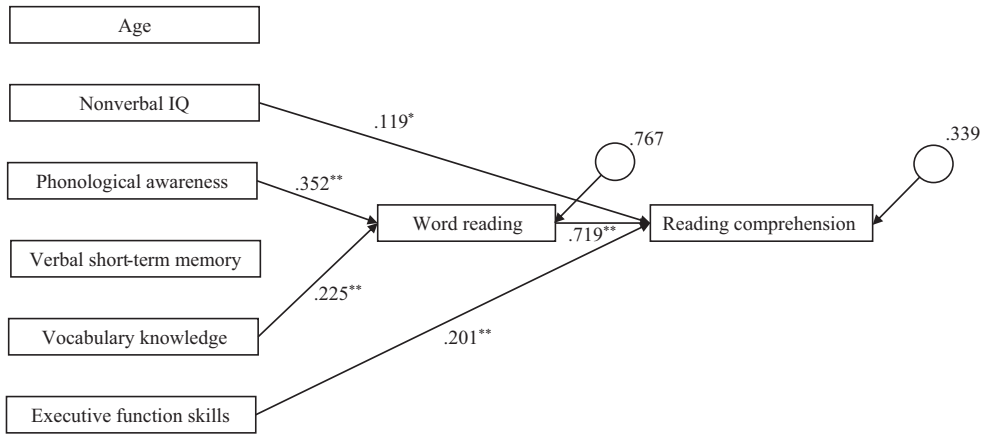

Figure 2. The proposed model to test the second explanation why linguistic comprehension skills were not significant in Figure 1. The correlations between predictors were not presented for the simplicity of presentation. *$p < .05$. **$p < .01$.

Discussion

The present study revealed the importance of EF skills in the reading comprehension of a group of Hong Kong kindergarteners. Importantly, the results add to our knowledge about the SVR framework of reading comprehension in the Hong Kong Chinese context. Different from other studies on English reading comprehension (e.g., Kendeou *et al.*, 2009), in Hong Kong, linguistic comprehension skills seem to be less important than word reading ability in reading comprehension. Consistent to the studies with Western samples (e.g., Christopher *et al.*, 2012; Chrysochoou, Bablekou, & Tsigilis, 2011), EF is an important component in the SVR framework. In addition, the present study tested word-level and phrase-level reading comprehension in kindergarteners, suggesting that EF was one of the predictors of reading comprehension from an early age.

Reading comprehension in Chinese kindergarteners

Together, the results here may reflect the variation of the SVR framework in reading comprehension in Hong Kong. The predictive power of word reading in reading comprehension found in the present study is consistent with previous studies with Western (Johnston & Kirby, 2006; Kirby & Savage, 2008) and Chinese samples (Yeung *et al.*, 2011; Zhang *et al.*, 2014). Good word reading abilities provide a basis for further word-to-text integration that occurs continuously through comprehension processes (Perfetti, Stafura, & Adlof, 2013). Previous studies have shown that, in elementary school students, distinct predictors were present for word reading and reading comprehension (Ouellette, 2006). The present study extended these findings to kindergarteners, suggesting that reading comprehension, even at word and sentence levels, requires additional skills beyond word reading (Fleisher, Jenkins, & Pany, 1979; Perfetti, 2007).

Linguistic comprehension skills were significantly correlated with reading comprehension, but their roles became non-significant when they were included in the regression model. These findings collaborate with Yeung *et al.* (2011)'s results that when word reading was controlled, oral vocabulary and listening comprehension did not contribute

any unique variance to Chinese reading comprehension in Cantonese-speaking children in Grade 1 in Hong Kong. As discussed, in Hong Kong, written language used in reading formal texts, such as books, newspapers, is distinct from oral language used in daily dialogue (Cantonese as the dialect). As a result, part of the vocabulary and syntax acquired through oral language comprehension cannot be directly applied to comprehending texts. Additionally, the results of the Figure 2 model offer an alternative possibility on how word reading and linguistic comprehension work together to facilitate Chinese reading comprehension and thus possible variation of the SVR framework in the Hong Kong context. However, more evidence is needed for reaching a solid conclusion of a revision of the SVR framework. Currently, we simply suited the results of Figure 2 as an explanation on how linguistic comprehension might work on reading comprehension in Hong Kong Chinese children.

EF skills and reading comprehension

The present study has merged two lines of research – reading comprehension and early childhood EF skills. The relationship between EF and reading comprehension has been well demonstrated in English-speaking populations as well as in children of upper-elementary graders and above (Arrington *et al.*, 2014; Cain *et al.*, 2004; Chrysochoou *et al.*, 2011; Conners, 2009). More recently, there has been evidence showing the importance of EF skills in children's learning in early childhood (Diamond, 2013; Foy & Mann, 2013; Kegel & Bus, 2014). Notably, not only is EF implicated in the comprehension of long expository text in upper graders (Seigneuric & Ehrlich, 2005), it is also implicated in the comprehension of words and sentences in kindergarteners.

Over development, the skills required for successful reading comprehension may change. Leong *et al.* (2008) tested Hong Kong third, fourth, and fifth graders' text comprehension and found that the role of verbal working memory accounted for significant variance of reading comprehension whereas pseudo-word reading was not that important. The contrast of the current findings with their findings may indicate the relative importance of word reading, linguistic comprehension, and EF skills in different stages of reading: kindergarteners versus elementary schools. In the early stage, for example, kindergarten years, children's word reading representing their lexical knowledge quality plays an important role in reading comprehension, while this role may decrease when word-level reading becomes relatively mature in the upper-elementary years (Ho *et al.*, 2003; Tilstra, McMaster, Van den Broek, Kendeou, & Rapp, 2009; Yin & McBride, 2015). Notably, the importance of EF skills has been found to be comparably important in reading comprehension across grades over development in Hong Kong.

In English comprehension, it is suggested that the role of EF skills is more about the coordination of the two components of the SVR framework(Cutting & Scarborough, 2012). Possibly, different mechanisms underlie the similar results regarding the role of EF skills in reading comprehension in Chinese and English studies. In English, although irregular words are not rare, children's word reading may not require EF skills as much as in Chinese reading does. Chinese is an opaque language with high visual–orthographic demands. For example, there is only about 40% of the compound characters share the exact same syllable with their phonetic radicals and the percentage drops to 26% when lexical tone is taken into consideration (e.g., Shu, Chen, Anderson, Wu, & Xuan, 2003). Additionally, learning to read Chinese requires precise discrimination of stroke patterns, for example, 己 (self) and 已 (already). Furthermore, the inconsistency between oral and written Chinese is a distinctive feature of Chinese in Hong Kong. EF skills probably not

only are heavily involved in coordinating word reading and linguistic comprehension, as argued by Scarborough (2001) and Cutting and Scarborough (2012), but also facilitate the processing of the two components of the SVR framework for Hong Kong kindergarteners (Chung & McBride-Chang, 2011).

Contributions, limitations, and implications

The present study has highlighted the importance of EF skills in reading comprehension in addition to word reading and linguistic comprehension skills in Hong Kong Chinese kindergartners. Two limitations of this study must be acknowledged. First, one should be cautious about generalizing the present results to societies with different education or linguistic background or children at different ages or reading levels. The current K3 children have accumulated 2 years of literacy experience since the age of three in Hong Kong. Second, the concurrent nature of the study prevents causal interpretations of the results. Further research is required to determine whether there is a causal relation between EF skills and reading comprehension in young children.

Practically, in addition to fostering children's decoding skills and listening comprehension, it is essential to cultivate EF skills in young children from early on. Some game-based training on either inhibitory control, working memory, or cognitive flexibility in general or in the specific area of reading could be beneficial to young children. It would be also practically helpful if there could be a summary of the systematic comparisons of the inconsistency of oral Cantonese and written Chinese specifically in Hong Kong and an attempt to make children explicitly aware of these differences. Another implication is that EF skills may be considered as a supporting construct for early identifications of children with reading comprehension difficulties, thus allowing for early intervention. Theoretically, as examined in Hong Kong Chinese kindergarteners, the study provided good evidence for the applications and variations of SVR in understanding the process of reading comprehension in an Asian non-alphabetic language at beginning readers.

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