Reciprocal effects of morphological awareness, vocabulary knowledge, and word reading: A cross-lagged panel analysis in Chinese

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Abstract

There are strong correspondences among syllable, morpheme, and orthographic representations in Chinese. For this reason, bidirectional relationships have been hypothesized among morphological awareness, vocabulary knowledge, and word reading from an early age. Our study examined the reciprocity of these skills among Hong Kong Chinese primary school children. Data were collected from 160 first graders at two time points and were analyzed using a cross-lagged panel design with the three skills modeled simultaneously. No reciprocal pathways were demonstrated in the model; instead, unidirectional relationships emerged. Morphological awareness facilitated later word reading and word reading facilitated later vocabulary knowledge. Results are discussed in relation to a developmental account of learning to read in Chinese.

Keywords: cross-lagged panel model, morphological awareness, vocabulary knowledge, word reading, Chinese

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Bidirectional, rather than unidirectional, relationships have been hypothesized between morphological awareness and vocabulary knowledge (McBride-Chang et al., 2008) morphological awareness and word reading (Kuo & Anderson, 2006), and vocabulary knowledge and word reading (Liu et al., 2013), respectively. This idea is compelling to consider in Chinese, where the demands on semantic rather than phonological processing are salient due to the nature of the writing system (Yang et al., 2013). This paper investigated the reciprocal relationships of morphological awareness, vocabulary knowledge, and word reading in Hong Kong Chinese first graders using a cross-lagged panel design.

Interrelations among Literacy Skills in Chinese Reading Acquisition

In any writing system, learning to read engages the same functional architecture that links orthography, phonology, and semantic units together (Yang et al., 2013). However, writing systems vary in the cognitive demands they place on mapping print-to-sound and print-to-meaning relationships for succesful word recognition. Behavioral and computational modelling evidence suggest that Chinese places heavier demands on semantic processing than English does (McBride, 2016; Yang et al., 2013).

These heavy semantic processing demands can be attributed to features of the Chinese language and writing system. In Chinese, there are strong “one-to-one-to-one” (McBride, 2016, p. 534) correspondences among syllables, morphemes, and characters, e.g., the character 書 represents the morpheme ‘book’ and the syllable *syu* in Cantonese. However, there are many more characters (thousands in regular use) than there are possible syllables (hundreds) in Chinese and every syllable may contain multiple possible meanings (McBride, 2015). In contrast, English involves learning only 26 letters and allows for thousands of possible syllables to combine into word units; as such, there are fewer homophones to distinguish in spoken language. Furthermore, many commonly used Chinese words are formed by compounding two morphosyllables (McBride, 2016); for example, 書 (book) and 包 (pack) together make 書包 (schoolbag; *syu1 baau1*). Hence, Chinese readers must learn the principle of putting component morphemes into appropriate sequences to create meaningful words—a skill that is tapped using measures of lexical compounding.

Therefore, oral word reading in Chinese, especially for young readers, might involve retrieving knowledge of specific characters or character combinations from memory, using knowledge of morphemes that are shared across words, or even a level of guessing by connecting partial character knowledge to words familiar in oral vocabulary (McBride, 2016). As such, semantic skills such as vocabulary knowledge and morphological awareness are considered building blocks of Chinese reading development.

A consistent body of evidence has demonstrated that morphological structure awareness—usually assessed using lexical compounding measures—is significantly related to later Chinese reading skills based on longitudinal studies of kindergarten and early primary students (e.g., McBride-Chang et al., 2003; Wu et al., 2009). Studies of primary students up to grade 5 also found significant interrelations between morphological awareness and word reading when measured at concurrent time points (e.g., Liu et al., 2013; Shu et al., 1995; Tong et al., 2017). Vocabulary knowledge was similarly identified as a longitudinal predictor of later Chinese reading among kindergarten and early primary students (Hulme et al., 2019; McBride-Chang et al., 2003) and as a correlate of word reading among primary students up to grade 5 (Liu et al., 2013; Shu et al., 1995; Tong et al., 2017), though this association is not always significant (e.g., Mainland China sample; McBride-Chang et al., 2005).

In contrast to these ‘predictor studies’ are studies that examine reciprocal relations among these skills. Two studies found significant reciprocal longitudinal relationships between morphological awareness and vocabulary knowledge among kindergarten (McBride-Chang et al., 2008) and grade 1 children (Cheng et al., 2015). On the one hand, a larger vocabulary could enable children to access a wider range of instances wherein certain morphemes are used in words. An awareness of morphological structures, on the other hand, could give children clues about what unfamiliar words mean, enabling them to access more complex vocabulary words (Liu et al., 2013). This mutual bootstrapping relationship appears valuable in a morphosyllabic language such as Chinese, where one can disambiguate among competing homophones heard orally by connecting knowledge of component morphemes with known vocabulary words.

Likewise, researchers studying English-speaking children have proposed that while morphological awareness and vocabulary knowledge facilitate the development of word reading, exposure to print can also draw attention to the morphological structures of words (Kuo & Anderson, 2006), giving children the opportunity to encounter a larger, more diverse, and more difficult set of vocabulary words in written text as opposed to oral language (Nagy & Anderson, 1984). Similar proposals have been made by researchers studying Chinese children, including a suggestion that morphological awareness, vocabulary knowledge, and word reading are all bidirectionally associated by third grade (Liu et al., 2013). However, evidence is scarce to support these suggestions in Chinese samples. No studies to our knowledge have tested the three-way bidirectional relationship mentioned by Liu and colleagues. In contrast, two studies involving Mainland Chinese children have examined pairwise reciprocity of morphological awareness and word reading and of vocabulary knowledge and word reading. One study that tested the two pairs of variables in separate models found only a unidirectional influence of initial word reading skill on the growth of either morphological awareness or vocabulary knowledge between grades 1 to 3 (Hulme et al., 2019). In contrast, another study demonstrated reciprocal pathways between morphological awareness and word reading using concurrent measures when children were in grade 3, which authors interpreted as evidence for a "mutually supportive reciprocal causation" once children acquire reading skills (Wu et al., 2009, p. 49). The situation in Hong Kong could be different, as children are taught to read very early, around the age of 3.5 years old. Hence, Hong Kong Chinese children will have had almost 3 years of reading experience by the time they enter first grade, and the mutual reinforcement of these three skills might already be evident by then.

The Current Study

Hong Kong presents an interesting context in which to examine a potential three-way reciprocity among morphological awareness, vocabulary knowledge, and word reading. Specifically, we were interested in longitudinal rather than concurrent relations among the variables, with the motivation of identifying which literacy skills, if trained or supported, could benefit later performance in other skills. Given the tight link between semantic processing and word reading in Chinese, and the early onset of reading instruction in Hong Kong, we hypothesized that we would see a pattern of mutual reinforcement from Primary 1 to one year later. Alternatively, it is possible that children's skills have not yet reached a sufficient level to inform other literacy components later on; in this case, unidirectional rather than bidirectional pathways might be observed.

We used an analytic strategy that is designed to test directional influences among variables over time. Cross-lagged panel designs can achieve this by accounting for both the stability of constructs between two time points (i.e., accounting for autoregressive effects) and the cross-associations (i.e., examining the reciprocity of effects) among the variables (Kearney, 2017). These three intercorrelated skills were entered simultaneously in the same model to clarify whether the relationships were indeed reciprocal, or if not, which directional influences remained after statistically controlling for the other skills. The present study aimed to bridge the gap between theory and evidence in the notion of reciprocal longitudinal relationships among the variables in a Chinese context.

Material and Methods

Participants

A sub-sample of 160 Hong Kong Chinese children (56% female, M_{age} = 6.68 years) was selected from a longitudinal study of Chinese and English reading development among twins in Hong Kong. The original sample comprised 405 pairs of twins attending K3 or primary school at the beginning of the study. The sub-sample was created by applying the following filters to the dataset: IQ ≥ 80, no parent-reported learning disability, and is attending Primary 1 at a local primary school during Wave 1 of the study. To eliminate bias due to the non-independence of observations within families, one twin from each pair was randomly selected for the current study. Wave 2 assessments were conducted approximately 1 year after Wave 1 (*M* = 1.10 years, *SD* = 0.16, range = 0.58-1.75 months). The rate of sample attrition was 15.3% of the overall study sample and 8.1% of the sub-sample.

Measures

A selection of tasks in Chinese was analyzed from among a broader battery of tests in Chinese and in English. Children were tested on the main outcome measures during the two study waves: morphological awareness, vocabulary knowledge, and word reading. Covariates were age, IQ, and working memory. These were included to control for general cognitive factors with significant relations to literacy-related skills, similar to what was done in past studies (e.g., Cheng et al., 2015). Details of each task are described below.

Morphological awareness. The Chinese morphological awareness measure was adapted from past studies (e.g., McBride-Chang et al., 2003). Experimenters presented two statements orally. In the first statement, the experimenter described two morphemes that were combined into a single word. In the second statement, the experimenter asked the child to combine one of the morphemes in the first word with a different morpheme. For example, “A web made by a spider is called a spiderweb (蜘蛛網). What do we call a web made by an ant?”. The correct answer is “antweb” (螞蟻網). One point was given for each correct answer. In subsequent items, following previous research (e.g., Liu & McBride-Chang, 2013), children were presented with an open-ended question orally; for example, “What do we call a house that’s red?” The children had to answer “red house” (紅屋) in order to receive one point.

Vocabulary knowledge. Children’s vocabulary knowledge was assessed using vocabulary questions tapping receptive vocabulary and expressive vocabulary. We sought to capture broad and deep vocabulary knowledge by using this comprehensive measure. In the first ten items, experimenters said a word and children had to point to a picture that matched that word from a set of four pictures. The stimuli were selected from the Peabody Picture Vocabulary Test-Third Edition (PPVT-III; Dunn & Dunn, 1997). In the next 12 items, children were asked to name objects presented using a picture format orally. Such answers were typically one-word answers. In the final 26 items, experimenters asked for the definition of certain words, and children had to answer orally. In these final items, experimenters wrote children's answers verbatim and one marker subsequently scored the answers according to a marking scheme that awarded 0-2 points to each based on the quality of children's definitions. One example item on this task is: "What is 'apologize' (道歉)?". A response such as "saying sorry" received two points, a response such as "did something wrong and felt unhappy" received one point, and a response such as "you will be scolded by the teacher if you don't do so" received zero points. Testing was stopped when children got 5 consecutive errors.

Word reading. Word reading was measured using a word recognition task. A total of 150 two-character Chinese words were taken from the Chinese Word Reading subtest of the Hong Kong Test of Specific Learning Difficulties in Reading and Writing for Primary School Students-Second Edition (HKT-P[II]; Ho et al., 2007). Children were instructed to read each word aloud. The words were arranged according to an increasing difficulty level. Children received one point for every correct answer, with a maximum possible score of 150 and a stopping criterion of 15 consecutive errors.

IQ. IQ was measured using Ravens's Standard Progressive Matrices Parts A to C, with a total of 36 items (Raven, Court, & Raven, 1996). Children were instructed to complete a visual design by choosing the missing piece from among 6 to 8 options.

Backward digit span. A backward digit span task was adapted from WISC-3 (Wechsler, 1991). Children were presented orally with a series of numbers in Chinese with increasing lengths (between 2 to 9 digits) and were asked to repeat the numbers in reverse sequence. Testing was stopped when children answered two sequences of the same length incorrectly. One point was awarded for each correct response for a maximum possible total of 16 points.

Data Analysis

The data were analyzed using MPlus 7.11 (Muthén & Muthén, 1998-2013) using maximum likelihood estimation with robust standard errors. Path analysis was conducted to analyze the cross-lagged associations of the following measures in the two assessment waves: morphological awareness, vocabulary knowledge, and word reading. The model was designed to test pairwise longitudinal reciprocity between each pair of variables and had no mediational pathways specified. Age, IQ, and backward digit span served as covariates and were intercorrelated with Wave 1 measures and with one another. Furthermore, Wave 2 measures were regressed on the three covariates. This model specification resulted in a just-identified model; hence, the analysis is sufficient for the estimation of path coefficients but does not yield indices of model fit (Wang, Hefetz, & Liberman, 2017). This is expected in cross-lagged panel analyses for two-wave studies (Kearney, 2017; Kenny, 1975); moreover, we do not have sufficient theoretical justification to omit any correlations or pathways for purposes of overidentification. Boxplots identified 1 univariate outlier for Wave 1 vocabulary knowledge and 3 outliers for Wave 2 morphological awareness. No multivariate outliers were detected based on Mahalanobis distance computations. Separate analyses were conducted with outlier scores included and removed to assess model sensitivity to outlier effects.

Results

The means, reliabilities, and intercorrelations of measures in Wave 1 and Wave 2 are reported in Tables 1 and 2. Morphological awareness and vocabulary scores by item type are available in Appendix A. Paired *t*-test results revealed significant increases in children's performance in all measures between Wave 1 and Wave 2, $p < .001$. All outcome measures were significantly correlated with each other (*r*s = .37-.88).

Notably, 46% (74) of participants did not complete the morphological awareness task at Wave 2 due to sample attrition (13) and changes in assessment protocol (61). In the latter case, Wave 2 assessments fell within the extension phase of the twin study. Based on *t*-test results, children who completed the morphological awareness task at both study waves and those who did not were not significantly different in terms of age, IQ, digit span, vocabulary knowledge (both waves), word reading (both waves), and morphological awareness (Wave 1), $p > .05$. Results of Little's MCAR (Missing Completely at Random) test were not significant, $\chi^2(15) = 24.61$, $p = .055$, suggesting that missingness in the Wave 2 morphological awareness task was not conditional on children's scores on the other variables. Hence, the use of maximum likelihood estimation in the following analysis was justified.

The two models had nearly identical results except for the Wave 1 word reading → Wave 2 morphological awareness pathway which was significant in the model with outliers ($\beta = .17$) but was non-significant in the model without ($\beta = .08$). Results described below refer to the model without outliers as it represented a more stringent analysis of the dataset.

Model results are summarized in Figure 1 with standardized coefficients reported. Intercorrelations and path coefficients of covariates and study variables are reported in Appendix B. All literacy measures demonstrated stability over time (βs = .46-.83). Contrary to our hypothesis, the cross-loadings did not demonstrate reciprocal longitudinal effects between any pair of variables in the model. Nevertheless, Wave 1 morphological awareness predicted Wave 2 word reading ($\beta = .13$) and Wave 1 word reading predicted Wave 2 vocabulary knowledge ($\beta = .25$). Furthermore, concurrent relationships among all three variables were generally significant in Wave 1 and Wave 2 (*rs* = .20-.54); however, the vocabulary knowledge—word reading correlation was non-significant in Wave 2 ($r = .15$).

Discussion

Morphological awareness, vocabulary knowledge, and word reading demonstrated significant concurrent relationships when the children were in Primary 1 and around one year later, except for a non-significant relationship between Wave 2 vocabulary knowledge and word reading. While this indicates a general pattern of interrelatedness among the three variables, our study focuses on their longitudinal reciprocity, which is of theoretical and practical importance in Chinese.

Contrary to our hypothesis, no such reciprocal longitudinal relations emerged. In contrast, the following unidirectional relationships were supported by the results: morphological awareness predicted later word reading performance and word reading predicted later vocabulary knowledge. While an initial model revealed that Chinese word reading predicted later morphological awareness, this result was not robust to outlier effects.

Overall, the results were inconsistent with previous studies (of younger children) that found a reciprocal longitudinal relationship between vocabulary knowledge and morphological awareness (e.g., McBride-Chang et al., 2008) and a theoretical proposal for three-way reciprocity among the three main study variables. In contrast, the results were consistent with a large number of studies that have emphasized the importance of morphological awareness as a precursor for reading development. Children benefit from the ability to extract component morphemes within compound Chinese words and use these insights to read new words. The current results also align with the idea that word reading supports later vocabulary acquisition (Nagy & Anderson, 1984), a finding that few studies so far have reported in a Chinese context. Exposure to Chinese words in print may strengthen children's vocabulary development by introducing distinct visual symbols to represent meaningful spoken words, thus helping to disambiguate among multiple homophones in spoken language.

Reciprocity, as mentioned or tested in previous studies, covers multiple interpretations that can refer to either concurrent or longitudinal relationships and to unidirectional pathways that flow in both directions either simultaneously or at different time points. Hence, reciprocity may not always satisfy the relatively strict definition of the current study; that is, of longitudinal pathways that are simultaneously significant between pairs of variables at a particular age. Instead, a more realistic definition of reciprocity may refer to changing patterns of unidirectional relationships among interrelated variables as children move from novice to skilled reading.

Our goal is to understand how learning to read in Chinese involves a continuous interplay between word reading and its semantic processing components, given the characteristics of the writing system. What could be missing in the theoretical examination of reciprocity is a full and explicit account of the overall developmental trajectory of these interrelationships. For example, vocabulary knowledge and morphological awareness have been demonstrated to have simultaneous, bidirectional, and longitudinal relations among young children (Cheng et al., 2015; McBride-Chang et al., 2008). The current results could invite speculation that this reciprocal relationship weakens as word reading becomes more emphasized; however, we do not have a cross-sectional or longitudinal design with enough coverage to track these changes. Model construction in studies of older children further highlight the need for an exhaustive developmental account of these interrelated variables. In two studies involving 8- and 9-year-olds, morphological awareness and vocabulary knowledge were not given equal status in their respective relationships with word reading; instead, vocabulary knowledge was defined as a mediator of the relationship between the two other variables (Liu et al., 2013; Tong et al., 2017).

However, we note that the analyses in both papers focused on concurrent relationships. Whether or not this conceptualization holds in a longitudinal timeframe remains to be seen. Likewise, adopting a developmental perspective could be useful for studies examining the relationship between vocabulary knowledge and word reading, where evidence is sometimes mixed (e.g., grade 2; McBride-Chang et al., 2005) or scant in establishing pathways from word reading to vocabulary development (e.g., grades 1-3; Hulme et al., 2019).

A developmental account also fits the current results of the study wherein children who are already competent at utilizing lexical compounding rules have better word reading outcomes one year later. However, lexical compounding might have limited utility from a long-term horizon. Morphological awareness also involves the discrimination of homophones in Chinese (Liu et al., 2013); lexical compounding is relevant for homophone discrimination (e.g., *sun* as in *Sunday* but not as in *grandson*), but it is distinct. A cross-sectional study involving Hong Kong children in grades 2, 5, and 8 suggested that compounding awareness was more relevant for word reading in the lower grades as opposed to the higher grades, wherein homophone and homograph awareness were identified as significant correlates instead (Choi, Tong, Law, & Cain, 2018). At which point other indicators of morphological awareness could predict later reading is another interesting direction for future research. Going the other direction, the benefit of word reading on morphological awareness might emerge sometime between grades 1-3, as demonstrated among primary school students in Mainland China (Hulme et al., 2019; Wu et al., 2009); however, we did not observe this in our current set of results in Hong Kong. Contextual and instructional differences might also be a factor to consider when evaluating the results of the current study.

Methodologically, the current study is limited due to the small sample size relative to the number of parameters estimated in the model and missing data in Wave 2 morphological awareness scores. Both could introduce some bias in the estimation of model results. Furthermore, the lack of model fit indices hinders the evaluation of how well the model fit the data. This can be resolved in future studies that test models with data from three waves or more. Despite the limitations, this study is novel in explicitly testing for three-way reciprocity among morphological awareness, vocabulary knowledge, and word reading in Chinese, where there is a gap between theory and evidence for these assertions. The current study distinguishes between concurrent and longitudinal relations and between unidirectional and bidirectional pathways in examining these skills. The results of the current study suggest that Chinese readers (at least in the early grades) may benefit from explicit instruction on morphological structure to facilitate reading development, as well as an intervention to motivate children to read more to encourage vocabulary development. Future work should examine how longitudinal relationships among morphological awareness, vocabulary knowledge, and word reading change over the course of development, which could aid in identifying the best time windows to support particular aspects of reading development towards a particular educational goal.

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Table 1. Descriptive Statistics of Wave 1 Variables

Measures	n	α	*M*	*SD*	Min	Max	Skewness		Kurtosis	
							Statistic	Std. Error	Statistic	Std. Error
Wave 1										
Morphological Awareness Total	159	.84	19.01	5.02	5	31	-.29	.19	.39	.38
Vocabulary Knowledge Total	160	.81	25.73	7.13	10	52	.71	.19	.77	.38
Word Reading Total	159	.98	46.86	27.97	1	120	.54	.19	-.50	.38
Wave 2										
Morphological Awareness	86	.89	23.15	5.96	7	44	.51	.26	1.84	.51
Vocabulary Knowledge	143	.78	34.48	7.44	17	54	.23	.20	-.15	.40
Word Reading Total	147	.98	79.30	27.31	10	141	-.39	.20	-.48	.40
Covariates										
IQ: Raven's Progressive Matrices	160	-	111.97	12.80	80	135	.03	.19	-.53	.38
Backward Digit Span	159	-	4.19	1.59	1	9	.57	.19	.15	.38
Age	160	-	6.72	.42	6	8	.38	.19	.19	.38

Table 2. Intercorrelations Among Variables

	Covariates			Wave 1			Wave 2	
	Age	IQ	Backward Digit Span	Morphological Awareness	Vocabulary Knowledge	Word Reading	Morphological Awareness	Vocabulary Knowledge
Covariates								
IQ	.02	1						
Backward Digit Span	.12	.25**	1					
Wave 1								
Morphological Awareness	.23**	.26**	.19*	1				
Vocabulary Knowledge	.25**	.27***	.16*	.54***	1			
Word Reading	.24**	.29***	.26**	.46***	.49***	1		
Wave 2								
Morphological Awareness	.08	.50***	.14	.62***	.50***	.48***	1	
Vocabulary Knowledge	.07	.34***	.12	.37***	.58***	.48***	.42***	1
Word Reading	.11	.25**	.20*	.51***	.47***	.88***	.49***	.50***

Note. * p < .05, * p < .01, ** p < .001.

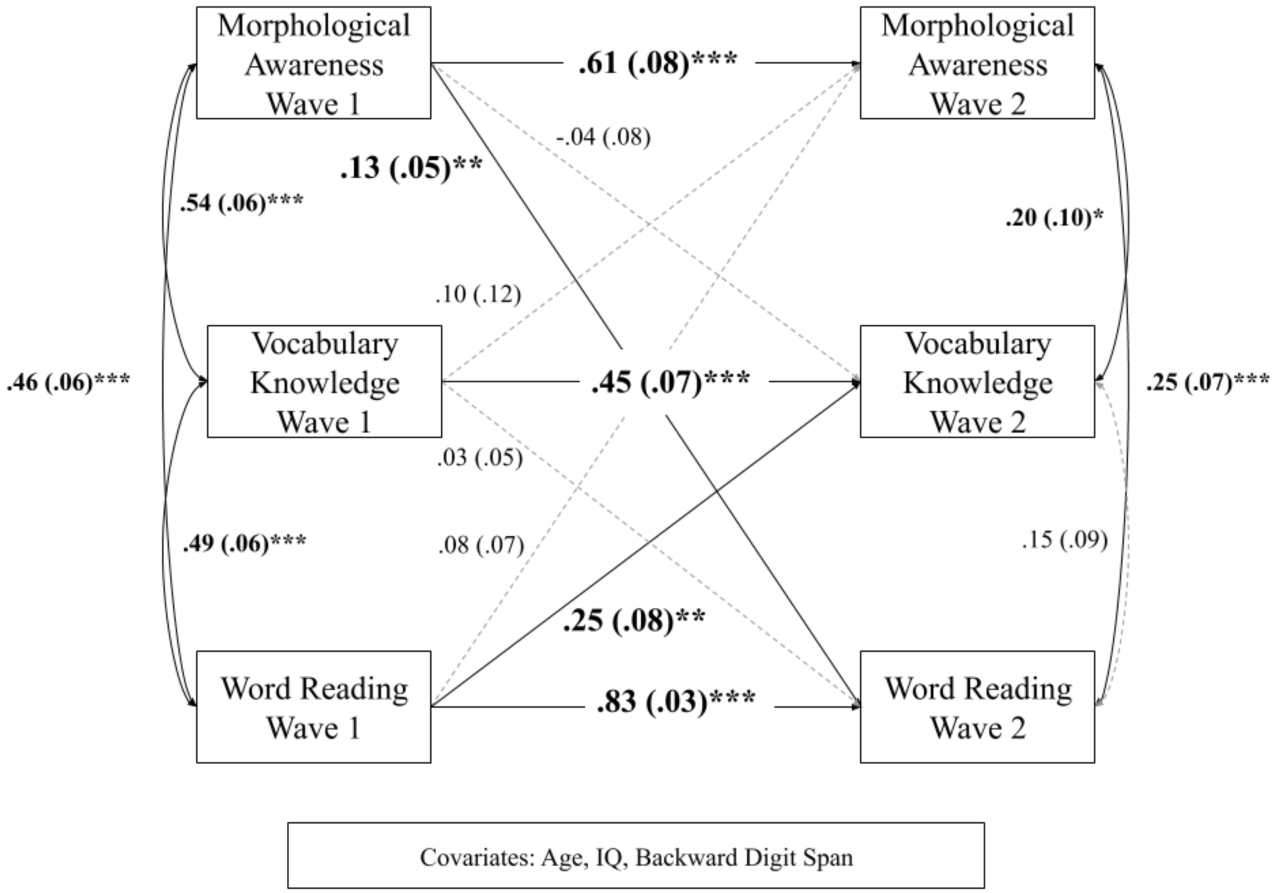

Figure 1. Cross-lagged associations among morphological awareness, vocabulary knowledge and word reading with covariates (4 univariate outlier scores removed). Solid lines represent significant pathways and dashed lines represent nonsignificant pathways. Significant coefficients are boldfaced. Intercorrelations and path coefficients of covariates and study variables are reported in Appendix B. * $p < .05$, ** $p < .01$, *** $p < .001$.

Appendix A

Table 3. Morphological Awareness and Vocabulary Knowledge Scores by Item Type

	Time 1					Time 2				
Measures	n	*M*	*SD*	Min	Max	n	*M*	*SD*	Min	Max
Morphological Awareness										
Morphological Construction	159	15.74	4.61	5	27	86	19.40	4.70	7	27
Compounding Production	149	1.09	1.70	0	8	81	2.59	3.25	0	17
Vocabulary Knowledge										
Receptive Vocabulary	160	8.41	1.29	5	10	147	9.28	0.99	6	10
Expressive Vocabulary	160	6.93	2.08	2	12	147	8.85	1.80	3	12
Vocabulary Definitions	160	10.39	5.34	0	31	143	16.31	6.14	4	33

Appendix B

Intercorrelations and Path Estimates of Covariates and Study Variables

Analysis	β	SE
Intercorrelations		
Age – Backward Digit Span	.12	.08
Age – IQ	.02	.08
Age – Wave 1 Morphological Awareness	.23**	.08
Age – Wave 1 Vocabulary Knowledge	.25**	.09
Age – Wave 1 Word Reading	.23**	.09
IQ – Backward Digit Span	.26***	.07
IQ – Wave 1 Morphological Awareness	.25***	.07
IQ – Wave 1 Vocabulary Knowledge	.26***	.08
IQ – Wave 1 Word Reading	.28***	.08
Backward Digit Span – Wave 1 Morphological Awareness	.19*	.07
Backward Digit Span – Wave 1 Vocabulary Knowledge	.17*	.08
Backward Digit Span – Wave 1 Word Reading	.25**	.08
Path Estimates		
Age → Wave 2 Morphological Awareness	-.08	.10
Age → Wave 2 Vocabulary Knowledge	-.07	.06
Age → Wave 2 Word Reading	-.11**	.04
IQ → Wave 2 Morphological Awareness	.20*	.09
IQ → Wave 2 Vocabulary Knowledge	.16*	.07
IQ → Wave 2 Word Reading	-.03	.04
Backward Digit Span → Wave 2 Morphological Awareness	.01	.08
Backward Digit Span → Wave 2 Vocabulary Knowledge	.00	.06
Backward Digit Span → Wave 2 Word Reading	.03	.04

* $p < .05$, ** $p < .01$, *** $p < .001$.