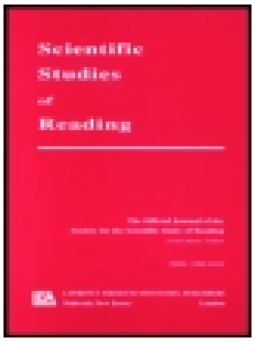

Scientific Studies of Reading

ISSN: 1088-8438 (Print) 1532-799X (Online) Journal homepage: http://www.tandfonline.com/loi/hssr20

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Wei Wei, George K. Georgiou & Ciping Deng

Scientific Studies of Reading, 00:1–10, 2015

ISSN: 1088-8438 print/1532-799X online
DOI: 10.1080/10888438.2015.1077447

Routledge
Taylor & Francis Group

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Wei Wei
East China Normal University

George K. Georgiou
University of Alberta

Ciping Deng
East China Normal University

The purpose of this 4-year longitudinal study was to specify the direction of the relationship between RAN and word reading (accuracy and fluency) in Chinese. This is important in light of arguments that the developmental relationships between RAN and reading can disclose changes in the reading processes underlying reading as development proceeds. One hundred thirty-five Mandarin-speaking Chinese children (65 boys, 70 girls; *M* age = 96.40 months) were assessed on RAN (digits), word-reading accuracy (Character Recognition), and word-reading fluency (One-Minute Reading). The children were assessed on the same measures when they were in Grades 3, 4, and 5. The results of path analysis indicated that the effects between RAN and word reading were unidirectional and subject to the type of reading outcome: Only RAN predicted word reading and only when word reading was operationalized with a reading fluency measure.

Several studies have established that rapid automatized naming (RAN), defined as the ability to name as fast as possible highly familiar visual stimuli (letters, digits, colors, and objects), is a strong predictor of word reading in different languages (e.g., Albuquerque, 2012; Bowey, McGuigan, & Ruschena, 2005; Cho & Chiu, in press; de Jong & van der Leij, 1999; Georgiou, Parrila, Cui, & Papadopoulos, 2013; Lervåg & Hulme, 2009; Liao, Georgiou, & Parrila, 2008; Moll, Fussenegger, Willburger, & Landerl, 2009; Parrila, Kirby, & McQuarrie, 2004; Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007; Savage & Frederickson, 2005), age groups (e.g., Di Filippo et al., 2005; Georgiou, Papadopoulos, & Kaizer, 2014; van den Bos, Zijlstra, & Spelberg, 2002), and reading ability levels (e.g., normal readers: Landerl & Wimmer, 2008; Parrila et al., 2004; poor readers: McBride-Chang & Manis, 1996; Scarborough, 1998). A common feature of these studies is that the relationship between RAN and word reading has been assumed to be unidirectional, namely, RAN was viewed as a predictor of word reading. However,

Correspondence should be sent to George K. Georgiou, Department of Educational Psychology, 6-102 Education North, University of Alberta, Edmonton-AB, T6G 2G5, Canada. E-mail: georgiou@ualberta.ca

it is equally possible that word reading predicts RAN or that their relationship is reciprocal (Compton, 2003). To date, there is paucity of research examining the cross-lagged relationships between RAN and word reading, particularly in upper grades and in nonalphabetic orthographies. Thus, the purpose of this study was to specify the direction of the relationship between RAN and word reading (accuracy and fluency) in Chinese following the same children from Grade 2 to Grade 5.

The few studies that have examined the developmental dynamics between RAN and word reading have provided mixed findings (e.g., Chow, McBride-Chang, & Burgess, 2005; Compton, 2000, 2003; Lervåg & Hulme, 2009; Verhagen, Aarnoutse, & Van Leeuwe, 2008; Wagner et al., 1997). For example, in their longitudinal study with Norwegian children followed from Grade 1 to Grade 4, Lervåg and Hulme (2009) showed that although RAN was predictive of both the intercept (initial status) and slope (growth) in reading fluency, reading fluency did not predict RAN. In contrast, in a study with English-speaking American children that were assessed seven times within Grade 1, Compton (2003) found a reciprocal relationship between RAN digits and word-reading accuracy.

The few longitudinal studies in Chinese that have examined the contribution of RAN to future reading ability after controlling for the effects of reading ability at an earlier point in time (known as *autoregressor*) have also provided mixed findings (see Chow et al., 2005; Liao et al., 2015; McBride-Chang, Chow, Zhong, Burgess, & Hayward, 2005; McBride-Chang & Ho, 2005; Pan et al., 2011). McBride-Chang and Ho (2005), for example, found that RAN (assessed in the 1st year of kindergarten with Object Naming) did not predict Character Recognition in the 3rd year of kindergarten, once the effects of the autoregressor (Character Recognition in the 1st year of kindergarten) were taken into account. In contrast, Pan et al. (2011) found that RAN (assessed at the age of 5 with Digit Naming) accounted for 1.3 to 4.6% of unique variance in Character Recognition (assessed at the age of 7, 8, 9, and 10), even after controlling for the effects of age, nonverbal IQ, vocabulary, and Character Recognition (assessed at the age of 5). Finally, in a longitudinal study that spanned Grades 2 to 5, Liao et al. (2015) found that RAN (assessed in Grade 2 with Digit Naming) did not account for unique variance in Character Recognition in Grades 3 and 5 once the effects of the autoregressor were taken into account but explained 4 to 6% of unique variance in reading fluency.

A better understanding of the cross-lagged relationships between RAN and word reading has important theoretical implications. Recently, Protopapas, Altani, and Georgiou (2013) argued that the relationship between RAN and word reading can be attributed to the fact that efficient performance in both requires simultaneous processing of multiple items (letters, digits, or words) that are presented in serial fashion. However, the ability to process multiple items depends on the characteristics of the items: The more automatic the naming of these items (see Segalowitz & Segalowitz, 1993, for a description of automaticity), the more efficient the parallel processing of multiple items will be. Because naming of RAN symbols (digits or letters) reaches automaticity earlier than naming of words (e.g., Georgiou & Stewart, 2013) and signifies the potential of an efficient system to process multiple items simultaneously, RAN should predict future word reading (particularly reading fluency). For as long as word reading does not reach the same level of automaticity as naming of RAN symbols (e.g., when naming multisyllabic, low-frequency words; see van den Boer, Georgiou, & De Jong, 2015), RAN will continue to predict future word reading, even after controlling for earlier levels of word reading. In contrast, word reading should not predict future RAN, as reading ability itself relies on efficient letter identification that is predicted by earlier levels of RAN (autoregressor). An exception to this could be the time between preschool and Grade 2 when children are still learning the letter names alongside word identification.

A related implication of this theoretical proposition is that orthographic characteristics as well as time when letter names and digits are introduced to children may impact the cross-lagged relationships between RAN and word reading. In regards to orthographic consistency, because in transparent orthographies (e.g., Finnish, German, Greek) each letter corresponds roughly to one sound, the feedback children get from correctly identifying these letters leads to phonological representations that are characterized by a high degree of specificity and distinctness (see Elbro, 1998). These early successes in letter identification result in greater automaticity in RAN (at least when RAN is operationalized with letter naming). Arguably, if RAN becomes automatic earlier in transparent orthographies, then a unidirectional relationship (RAN predicting future word reading) should be manifested earlier in transparent orthographies than in opaque orthographies. This may explain why Compton (2003) found a reciprocal relationship between RAN and word reading in Grade 1 in English (an opaque orthography), but Verhagen et al. (2008) found a unidirectional relationship in Grade 1 in Dutch (a relatively transparent orthography). In the context of Chinese, a language that is notorious for its low symbol-sound correspondences (see Shu, 2003, for a description of Chinese language), we would expect to see reciprocal relationships between RAN and word reading across the elementary school years.

However, equally important is the time when children are first introduced to letters and numbers. Because Chinese children go to kindergarten at the age of 3, they have much more exposure to digits than English-speaking children that start kindergarten at the age of 5. Chinese number system is also more transparent (e.g., 11 would be pronounced as "ten and one"). These factors should lead to greater automaticity in number naming among Chinese- than English-speaking children, which in turn should lead to unidirectional relationships between RAN (when operationalized by digit naming) and word reading. This may explain why Chow et al. (2005) found a unidirectional relationship between RAN digits and character recognition in Chinese.

THE PRESENT STUDY

The purpose of this study was to specify the direction of the relationship between RAN and word reading (accuracy and fluency) in a sample of Chinese children followed from Grade 2 to Grade 5. The following research questions were examined:

1. To what extent does children's RAN performance predict their subsequent word reading performance?
2. To what extent does children's word reading performance predict their subsequent RAN performance?

Chow et al.'s (2005) study on the same topic covered only a short developmental period before children had received any formal reading instruction (children were first assessed when they were on average 4.8 years old and then again 9 months later). Thus, we have an opportunity to examine if the relationship between RAN and word reading changes as a result of formal reading instruction. This is important in the context of Chinese because, in Grades 2 and 3, children in mainland China are introduced to 1,250 new characters (48.6% of the characters they are expected to learn in elementary school; Shu, Chen, Anderson, Wu, & Xuan, 2003). In addition, by following a group of older children we have an opportunity to assess not only their reading accuracy, but also their reading fluency.

METHOD

Participants

One hundred forty-five Grade 2 Mandarin-speaking Chinese children (69 boys, 76 girls; *M* age = 96.40 months, *SD* = 3.86 months) from Shanghai city participated in this study. The children were reassessed in Grades 3, 4, and 5, when they were 107.93 (*SD* = 3.72), 119.88 (*SD* = 3.80), and 127.93 (*SD* = 3.71) months old, respectively. Seven children withdrew from the study in Grade 4 and three more in Grade 5. Because the performance of these children on RAN and word reading in Grades 2 and 3 was not significantly different from those remaining in the sample (all ps $> .15$), we ran the analyses with the participants who had data at all measurement points ($n = 135$). The children were recruited on a voluntary basis from the general student population in three inner-city public schools serving families from middle to upper-middle socioeconomic backgrounds (based on the location of the schools). None of the children was diagnosed with any intellectual, behavioral, or sensory deficits. Parental consent was obtained prior to testing.

Materials

Rapid Automatized Naming

RAN was assessed with Digit Naming. Children were asked to name as fast as possible five numbers (1, 4, 5, 7, and 8; pronounced yi[1], si[4], wu[3], qi[1] and ba[1]; the number in brackets refers to the tone) that were repeated eight times each and arranged in semirandom order in five rows of eight. Prior to testing, the children were asked to name the digits in a practice trial to ensure familiarity. Each child named the digit matrix twice (in the second matrix, the digits were rearranged), and the children's time to name all stimuli in each matrix was noted. To children's score in RAN was the number of items named per second and was calculated by dividing the number of items by the average time in the two matrixes. The number of naming errors was negligible (mean number of errors was less than 1), and for this reason it was not considered further. Split-half reliability coefficient in our sample ranged from .82 to .92.

Reading Accuracy

Character Recognition, adapted from the Hong Kong Test of Specific Learning Difficulties in Reading and Writing (Ho, Chan, Tsang, & Lee, 2000), was used as a measure of word reading accuracy. The participants were asked to read aloud 150 Chinese two-character words that were arranged in terms of increasing difficulty. The task was discontinued after 15 consecutive errors.

A participant's score was the total number of correctly read Chinese words. Cronbach's alpha reliability in our sample ranged from .88 to .93.

Reading Fluency

One-Minute Reading, adapted from the Hong Kong Test of Specific Learning Difficulties in Reading and Writing (Ho et al., 2000), was used as a measure of word reading fluency. Children were asked to read aloud 140 Chinese two-character words as accurately and quickly as possible, and the number of words correctly read in 60 s was scored. An eight-word practice list was given to children prior to timed testing to ensure all children understood the instructions. A participant's score was the total number of correctly read words within the time limit. Split-half reliability coefficient in our sample ranged from .81 to .87.

Procedure

All children were individually tested in a quiet room in their school by trained graduate students, who received extensive training on test administration and scoring. Testing lasted approximately 20 min, and the tasks were given in the following order: RAN Digits, Character Recognition, and One-Minute Reading.

Statistical Analyses

To examine the cross-lagged relationships between RAN and word reading, we performed path analysis using AMOS 17. Separate models were constructed for Character Recognition and One-Minute Reading (see Figure 1). Because the models were saturated, no fit indexes could be estimated.

RESULTS

Descriptive statistics for the tasks used in the study are presented in Table 1. An examination of the distributional properties of the variables revealed that there were not any significant violations of normality. A one-way repeated measures analysis of variance showed that all measures developed significantly from Grade 2 to Grade 5. Table 2 shows the correlations between the measures. RAN correlated strongly with One-Minute Reading (*r*s ranged .43–.62) and weakly with Character Recognition (*r*s ranged .15–.29).

Next, we performed path analysis to examine the direction of the relationship between RAN and word-reading accuracy and fluency (see Figure 1). When Character Recognition was the reading outcome (Model A), neither RAN nor reading predicted each other. When One-Minute Reading was the reading outcome (Model B), RAN at each time point significantly predicted subsequent performance in word reading.

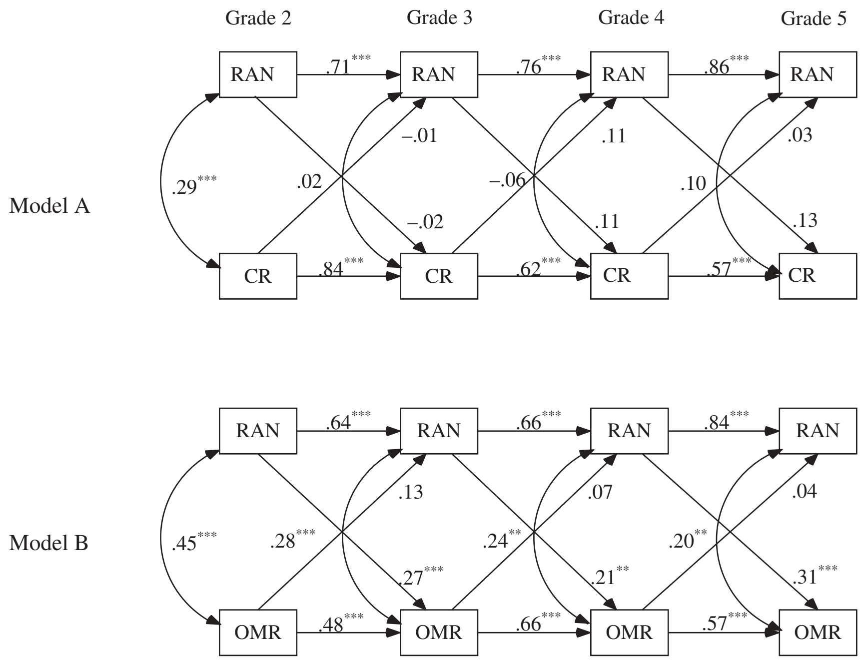

FIGURE 1 Cross-lagged relationships between rapid automatized naming (RAN) and character recognition (CR; Model A), and one-minute reading (OMR; Model B). *Note.* ** $p < .01$. *** $p < .001$.

TABLE 1
Descriptive Statistics for All the Tasks Used in the Study

	Grade 2		*Grade 3*		*Grade 4*		*Grade 5*		
	M	SD	M	SD	M	SD	M	SD	F*(1, 132)*
RAN[a]	2.14	.41	2.44	.48	2.77	.55	2.99	.59	226.50***
CR	104.37	19.19	126.26	13.95	138.63	7.04	142.87	6.94	255.66***
OMR	74.89	14.63	85.22	15.52	91.70	15.25	98.40	17.20	143.28***

Note. RAN = rapid automatized naming; CR = character recognition; OMR = One-Minute Reading.
[a]Number of items per second.
*** $p < .001$.

DISCUSSION

The purpose of this study was to examine the direction of the relationship between RAN and word reading (accuracy and fluency) from Grade 2 to Grade 5 in Chinese. In line with the findings of previous studies in alphabetic orthographies (e.g., Lervåg & Hulme, 2009; Verhagen et al., 2008; Wagner et al., 1997), the effects were unidirectional (RAN predicted word reading) and

TABLE 2
Correlations Between the Measures Used in the Study

		1.	*2.*	*3.*	*4.*	*5.*	*6.*	*7.*	*8.*	*9.*	*10.*	*11.*	*12.*
1.	RAN_G2												
2.	CR_G2	.29**											
3.	OMR_G2	.45**	.57**										
4.	RAN_G3	.70**	.19*	.42**									
5.	CR_G3	.22**	.84**	.56**	.18*								
6.	OMR_G3	.49**	.39**	.60**	.43**	.44**							
7.	RAN_G4	.76**	.17	.46**	.78**	.20*	.57**						
8.	CR_G4	.21*	.56**	.46**	.16	.63**	.30**	.24**					
9.	OMR_G4	.40**	.34**	.56**	.55**	.39**	.70**	.53**	.46**				
10.	RAN_G5	.76**	.18*	.52**	.76**	.21*	.56**	.87**	.19*	.52**			
11.	CR_G5	.25**	.64**	.55**	.14	.76**	.41**	.18*	.60**	.44**	.26**		
12.	OMR_G5	.50**	.37**	.64**	.51**	.44**	.69**	.62**	.43**	.74**	.62**	.51**	

Note. CR = character recognition; OMR = One-Minute Reading; G = grade.
$^*p < .05$. $^{**}p < .01$.

evident only when reading was operationalized with One-Minute Reading (an indicator of word-reading fluency). The strong connection between RAN and reading fluency has been documented in several previous studies in both alphabetic (e.g., de Jong & van der Leij, 1999; Landerl & Wimmer, 2008; Moll et al., 2014; Protopapas et al., 2013) and nonalphabetic orthographies (e.g., Cho & Chiu, in press; Liao et al., 2015; Liao et al., 2008; Pan & Shu, 2014). This does not mean that RAN is not important for Chinese reading accuracy but likely suggests that the effects of RAN on reading accuracy are overshadowed by the effects of reading accuracy at an earlier point. In addition, if we accept the argument that RAN and word reading are related because they reflect efficiency in simultaneous processing of multiple items (Protopapas et al., 2013), then this efficiency should matter for reading fluency more so than reading accuracy. Obviously, when the goal is to read accurately, there is less demand to simultaneously process multiple items (unless this processing refers to individual letters within a word). Finally, for a predictor variable to account for unexpected growth in a target skill, the predictor variable should be more strongly related to the target variable at the later point in time than concurrently (de Jong & van der Leij, 2002). This "strengthening of relationships" was true when RAN predicted One-Minute Reading but not when RAN predicted Character Recognition.

Our finding that word reading was not predictive of subsequent RAN performance is in contrast to Compton's (2003) finding. This may be due to the different levels of automaticity in RAN across the two studies. In China, children learn to identify numbers by the age of 3, when they start Kindergarten (Miller, Kelly, & Zhou, 2005; Stevenson, Chen, & Lee, 1993). By the age of 6, when they go to Grade 1, they already have a lot of exposure to, and instruction in, number naming. As a result, the ability to name numbers reaches an automatic level earlier than in North America, where most children are introduced to numbers at the age of 5. This may explain why Chow et al. (2005) found unidirectional relationships between RAN Digits and Character Recognition already in Kindergarten.

Some limitations of the present study are worth mentioning. First, we assessed only digit naming, and we do not know if the same pattern of relationships would be found if nonalphanumeric RAN tasks (e.g., colors, objects) were used. Previous studies in Chinese have shown that Object Naming is a unique predictor of Character Recognition (e.g., Ding, Richman, Yang, & Guo, 2010; Hu & Catts, 1998). Second, we did not administer other processing skills such as phonological awareness, orthographic processing, or speed of processing because we wanted to estimate only the direct effects (not mediated) of RAN to word reading, and vice versa. Finally, the children were in Grade 2 when we first assessed them. As a result, we do not know if the direction of the relationships would be different had we followed the same children from kindergarten.

To conclude, our findings add to those of previous longitudinal studies that examined the developmental dynamics between RAN and word reading (e.g., Chow et al., 2005; Compton, 2003; Lervåg & Hulme, 2009) suggesting that the relationship between RAN and word reading (assessed for the first time in Grade 2) is unidirectional and subject to the type of reading outcome. RAN predicted further growth only in word-reading fluency. Taken together, these findings suggest that RAN performance may serve as a marker of a child's ability to process in parallel multiple items presented in serial fashion, which in turn is fundamental for reading fluency. The observed differences in the predictive value of RAN across languages are likely due to the different levels of automaticity in RAN as a result of orthographic consistency and time when children are first introduced to letters and digits.

REFERENCES

Albuquerque, C. P. (2012). Rapid naming contributions to reading and writing acquisition of European Portuguese. *Reading and Writing*, *25*, 775–797. doi:10.1007/s11145-011-9299-6

Bowey, J. A., McGuigan, M., & Ruschena, A. (2005). On the association between serial naming speed for letters and digits and word-reading skill: Towards a developmental account. *Journal of Research in Reading*, *28*, 400–422. doi:10.1111/jrir.2005.28.issue-4

Cho, J. R., & Chiu, M. M. (in press). Rapid naming in relation to reading and writing in Korean (Hangul), Chinese (Hanja) and English among Korean children: A 1-year longitudinal study. *Journal of Research in Reading*.

Chow, B. W.-Y., McBride-Chang, C., & Burgess, S. (2005). Phonological processing skills and early reading abilities in Hong Kong Chinese kindergarteners learning to read English as a second language. *Journal of Educational Psychology*, *97*, 81–87. doi:10.1037/0022-0663.97.1.81

Compton, D. L. (2000). Modeling the growth of decoding skills in first-grade children. *Scientific Studies of Reading*, *4*, 219–259. doi:10.1207/S1532799XSSR0403_3

Compton, D. L. (2003). Modeling the relationship between growth in rapid naming speed and growth in decoding skill in first-grade children. *Journal of Educational Psychology*, *95*, 225–239. doi:10.1037/0022-0663.95.2.225

de Jong, P. F., & van der Leij, A. (1999). Specific contributions of phonological abilities to early reading acquisition: Results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology*, *91*, 450–476. doi:10.1037/0022-0663.91.3.450

de Jong, P. F., & van der Leij, A. (2002). Effects of phonological abilities and linguistic comprehension on the development of reading. *Scientific Studies of Reading*, *6*, 51–77. doi:10.1207/S1532799XSSR0601_03

Di Filippo, G., Brizzolara, D., Chilosi, A., De Luca, M., Judica, A., & Pecini, C., & Zoccolotti, P. (2005). Rapid naming, not cancellation speed or articulation rate, predicts reading in an orthographically regular language (Italian). *Child Neuropsychology*, *11*, 349–361. doi:10.1080/09297040490916947

Ding, Y., Richman, L. C., Yang, L. Y., & Guo, J. P. (2010). Rapid automatized naming and immediate memory functions in Chinese Mandarin-speaking elementary readers. *Journal of Learning Disabilities*, *43*, 48–61. doi:10.1177/0022219409345016

Elbro, C. (1998). When reading is "readn" or somthn. Distinctness of phonological representations of lexical items in normal and disabled readers. *Scandinavian Journal of Psychology*, *39*, 149–153. doi:10.1111/sjop.1998.39.issue-3

Georgiou, G. K., Papadopoulos, T. C., & Kaizer, E. L. (2014). Different RAN components relate to reading at different points in time. *Reading and Writing*, *27*, 1379–1394. doi:10.1007/s11145-014-9496-1

Georgiou, G. K., Parrila, R., Cui, Y., & Papadopoulos, T. C. (2013). Why is rapid automatized naming related to reading? *Journal of Experimental Child Psychology*, *115*, 218–225. doi:10.1016/j.jecp.2012.10.015

Georgiou, G., & Stewart, B. (2013). Is rapid automatized naming automatic? *Preschool and Primary Education*, *1*, 67–81. doi:10.12681/ppej.46

Ho, C.-S., Chan, D., Tsang, S.-M., & Lee, S.-H. (2000). *The Hong Kong test of specific learning difficulties in reading and writing*. Hong Kong: Hong Kong Specific Learning Difficulties Research Team.

Hu, C.-F., & Catts, H. W. (1998). The role of phonological processing in early reading ability: What we can learn from Chinese. *Scientific Studies of Reading*, *2*, 55–79. doi:10.1207/s1532799xssr0201_3

Landerl, K., & Wimmer, H. (2008). Development of word reading fluency and spelling in a consistent orthography: An 8-year follow-up. *Journal of Educational Psychology*, *100*, 150–161. doi:10.1037/0022-0663.100.1.150

Lervåg, A., & Hulme, C. (2009). Rapid automatized naming (RAN) taps a mechanism that places constraints on the development of early reading fluency. *Psychological Science*, *20*, 1040–1048. doi:10.1111/psci.2009.20.issue-8

Liao, C.-H., Deng, C., Hamilton, J., Lee, S.-C., Wei, W., & Georgiou, G. K. (2015). The role of rapid naming in reading development and dyslexia in Chinese. *Journal of Experimental Child Psychology*, *130*, 106–122. doi:10.1016/j.jecp.2014.10.002

Liao, C.-H., Georgiou, G. K., & Parrila, R. (2008). Rapid naming speed and Chinese character recognition. *Reading and Writing*, *21*, 231–253. doi:10.1007/s11145-007-9071-0

McBride-Chang, C., Chow, B. W., Zhong, Y., Burgess, S., & Hayward, W. G. (2005). Chinese character acquisition and visual skills in two Chinese scripts. *Reading and Writing*, *18*, 99–128. doi:10.1007/s11145-004-7343-5

McBride-Chang, C., & Ho, C.-S. (2005). Predictors of beginning reading in Chinese and English: A 2-year longitudinal study of Chinese kindergartners. *Scientific Studies of Reading*, *9*, 117–144. doi:10.1207/s1532799xssr0902_2

McBride-Chang, C., & Manis, F. R. (1996). Structural invariance in the associations of naming speed, phonological awareness, and verbal reasoning in good and poor readers: A test of the double deficit hypothesis. *Reading and Writing*, *8*, 323–339. doi:10.1007/BF00395112

Miller, K. F., Kelly, M., & Zhou, X. (2005). Learning mathematics in China and the United States. In J. I. D. Campbell (Ed.), *Handbook of mathematics cognition* (pp. 163–178). New York, NY: Psychology Press.

Moll, K., Fussenegger, B., Willburger, E., & Landerl, K. (2009). RAN is not a measure of orthographic processing. Evidence from the asymmetric German orthography. *Scientific Studies of Reading*, *13*, 1–25. doi:10.1080/10888430802631684

Moll, K., Ramus, F., Bartling, J., Bruder, J., Kunze, S., Neuhoff, N., & Landerl, K. (2014). Cognitive mechanisms underlying reading and spelling development in five European orthographies. *Learning and Instruction*, *29*, 65–77.

Pan, J., McBride-Chang, C., Shu, H., Liu, H., Zhang, Y., & Li, H. (2011). What is in the naming? A 5-year longitudinal study of early rapid naming and phonological sensitivity in relation to subsequent reading skills in both native Chinese and English as a second language. *Journal of Educational Psychology*, *103*, 897–908. doi:10.1037/a0024344

Pan, J., & Shu, H. (2014). Rapid automatized naming and its unique contribution to reading: Evidence from Chinese dyslexia. In X. Chen, Q. Wang, & Y. C. Luo (Eds.), *Reading development and difficulties in monolingual and bilingual Chinese children* (pp. 125–138). Dordrecht, the Netherlands: Springer.

Parrila, R., Kirby, J. R., & McQuarrie, L. (2004). Articulation rate, naming speed, verbal short-term memory, and phonological awareness: Longitudinal predictors of early reading development? *Scientific Studies of Reading*, *8*, 3–26. doi:10.1207/s1532799xssr0801_2

Powell, D., Stainthorp, R., Stuart, M., Garwood, H., & Quinlan, P. (2007). An experimental comparison between rival theories of rapid automatized naming performance and its relationship to reading. *Journal of Experimental Child Psychology*, *98*, 46–68. doi:10.1016/j.jecp.2007.04.003

Protopapas, A., Altani, A., & Georgiou, G. K. (2013). Development of serial processing in reading and rapid naming. *Journal of Experimental Child Psychology*, *116*, 914–929. doi:10.1016/j.jecp.2013.08.004

Savage, R., & Frederickson, N. (2005). Evidence of a highly specific relationship between rapid automatic naming of digits and text-reading speed. *Brain and Language*, *93*, 152–159. doi:10.1016/j.bandl.2004.09.005

Scarborough, H. S. (1998). Predicting the future achievement of second graders with reading disabilities: Contributions of phonemic awareness, verbal memory, rapid naming, and IQ. *Annals of Dyslexia*, *48*, 115–136. doi:10.1007/s11881-998-0006-5

Segalowitz, N. S., & Segalowitz, S. J. (1993). Skilled performance, practice, and the differentiation of speed-up from automatization effects: Evidence from second language word recognition. *Applied Psycholinguistics*, *14*, 369–385. doi:10.1017/S0142716400010845

Shu, H. (2003). Chinese writing system and learning to read. *International Journal of Psychology*, *38*, 274–285. doi:10.1080/00207590344000060

Shu, H., Chen, X., Anderson, R. C., Wu, N., & Xuan, Y. (2003). Properties of school Chinese: Implications for learning to read. *Child Development*, *74*, 27–47. doi:10.1111/cdev.2003.74.issue-1

Stevenson, H. W., Chen, C., & Lee, S. Y. (1993). Mathematics achievement of Chinese, Japanese, and American children: Ten years later. *Science*, *259*, 53–58. doi:10.1126/science.8418494

van den Boer, M., Georgiou, G., & de Jong, P. (2015, July). *The relation of serial and discrete RAN with word and nonword reading in two languages varying in orthographic consistency*. Paper presented at the 22nd annual meeting of the Society for the Scientific Studies of Reading, The Big Island, Hawaii.

van den Bos, K. P., Zijlstra, B. J., & Spelberg, H. C. (2002). Life-span data on continuous-naming speeds of numbers, letters, colors, and pictured objects, and word-reading speed. *Scientific Studies of Reading*, *6*, 25–49. doi:10.1207/S1532799XSSR0601_02

Verhagen, W., Aarnoutse, C., & Van Leeuwe, J. (2008). Phonological awareness and naming speed in the prediction of Dutch children's word recognition. *Scientific Studies of Reading*, *12*, 301–324. doi:10.1080/10888430802132030

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., & Burgess, S. R., . . . Garon, T. (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: A 5-year longitudinal study. *Developmental Psychology*, *33*, 468–479. doi:10.1037/0012-1649.33.3.468