MACQUARIE
University

Macquarie University PURE Research
Management System

This is the Accepted Manuscript version of the following article:

Georgiou, G. K., & Parrila, R. (2020). What mechanism underlies the rapid automatized naming–reading relation?. *Journal of experimental child psychology*, Vol. 194, 104840

which has been published in final form at:
https://doi.org/10.1016/j.jecp.2020.104840

© 2020. This manuscript version is made available under the CC-BY-NC-ND 4.0 license http://creativecommons.org/licenses/by-nc-nd/4.0/

What Mechanism Underlies the RAN–Reading Relation?

George K. Georgiou

University of Alberta, Canada

Rauno Parrila

Macquarie University, Australia

IN PRESS

JOURNAL OF EXPERIMENTAL CHILD PSYCHOLOGY

Abstract

We examined why RAN is related to reading by manipulating one aspect of the RAN task at a time and by inspecting the changes occurring to the RAN–reading relation. One hundred thirty-six Grade 2 English–speaking children and 121 university students were assessed on serial and discrete RAN, Cancellation, Yes/No naming, as well as on oral and silent reading fluency. The results of regression analyses indicated that seriality, access to phonological representations, and articulation play an important role in the RAN–reading relation. However, their effects were not equal for the two age groups or across the two reading outcomes.

Keywords: articulation, discrete naming, rapid automatized naming, reading, serial processing.

What Mechanism Underlies the RAN–Reading Relation?

Rapid automatized naming (RAN), defined as the ability of an individual to name as fast as possible highly familiar stimuli such as letters, digits, colors, and objects, is a strong predictor of reading (see Kirby, Georgiou, Martinussen, & Parrila, 2010, for a review), but the reason why it is related to reading remains unclear. Thus, the purpose of this study was to examine why RAN relates to reading by manipulating one aspect of the RAN task at a time and inspecting the changes occurring to the RAN–reading relation.

The Mechanism Underlying the RAN-Reading Relation

Researchers have employed three different approaches to study the mechanism behind the RAN–reading relation. First, they have examined the contribution of RAN to reading after controlling for the effects of the presumed mediator. The assumption is that if processing skill X is responsible for the RAN–reading relation, then controlling for X should eliminate RAN's contribution to reading. These studies have shown that RAN continues to predict word reading after controlling for several proposed mediators, such as speed of processing (e.g., Bowey, McGuigan, & Ruschena, 2005), phonological awareness (e.g., Manis, Doi, & Bhadha, 2000), paired–associate learning (e.g., Warmington & Hulme, 2012), orthographic knowledge (e.g., Georgiou, Parrila, & Kirby, 2009), or a combination of these (e.g., Georgiou, Aro, Liao, & Parrila, 2016; Poulsen, Juul, & Elbro, 2015).

Second, researchers have partitioned RAN total time into articulation time (the mean articulation length of all correctly articulated RAN stimuli) and pause time (the mean length of the time intervals between the correctly articulated stimuli), and examined how each component relates to reading. As Neuhaus and Swank (2002) noted, RAN total time fails to provide the precision needed to adequately determine the nature of the RAN tasks and therefore is not informative of the process(es) driving the RAN–reading relation. Georgiou and colleagues (2006, 2008, 2009; see also Clarke et al., 2005; Cobbold et al., 2003) reported that pause time was more strongly related to word reading than articulation time (particularly in young children). However, because pause time involves several sub-processes (e.g., conceptual and perceptual processing, access to phonological representations, motor planning) and cannot be further decomposed, we cannot draw firm conclusions on the role of each of these sub-processes in the RAN–reading relation.

Third, researchers have manipulated different aspects of the RAN tasks and examined how this affects the RAN–reading relation (e.g., Compton, 2003; Di Filippo et al., 2005; Georgiou et al., 2013; Jones, Branigan, & Kelly, 2009; Protopapas, Altani, & Georgiou, 2013a; Scarborough & Domgaard, 1998). The assumption is that, everything else being equal, if X is the processing skill that is responsible for the RAN–reading relation, then increasing or decreasing the demands of X should result in an increase or decrease in the RAN–reading relation.[1]

The first studies of this kind manipulated the format of the RAN tasks (i.e., serial versus discrete naming). If RAN and reading are related because both involve naming stimuli serially, then serial RAN (i.e., when all stimuli are presented simultaneously in an array) should produce stronger correlations with reading than discrete naming (i.e., when stimuli are presented one at-a-time); this assumption was verified in multiple studies (see Logan & Schatschneider, 2014, for a meta-analysis). However, more recent studies (e.g., Altani, Protopapas, & Georgiou, 2018; de Jong, 2011; Protopapas, Altani, & Georgiou, 2013b; van

---

[1] This is not to defy that many processes can be involved in RAN and that these processes may interact with each other during naming. However, the researchers in this group of studies manipulated only one process at a time.

den Boer & de Jong, 2015) indicate that the format of the reading task also matters: discrete naming is a stronger correlate of discrete word reading than serial RAN, at least in more advanced readers.

More recently, Georgiou et al. (2013) manipulated processes at all stages of RAN's production (input, processing, and output)[2] with a sample of Grade 2 (*n*=65) and 6 (*n*=65) Greek-speaking children. At the input stage, Georgiou et al. compared the effects of serial and discrete naming. At the processing stage, they compared the effects of set size (i.e., the number of stimuli that must be retrieved from long-term memory; 2 items repeated 25 times each [2X25], 5 items repeated 10 times each [5X10], and 10 items repeated 5 times each [10X5]). Finally, at the output stage, they compared the effects of traditional RAN tasks (5 items repeated 10 times) against two modified RAN tasks in which participants were asked to cancel out or say Yes/No in response to a specific stimulus. Their results indicated that (a) serial RAN dominated the prediction of reading fluency over discrete naming, (b) increasing the set size did not appreciably increase the correlations between RAN and reading fluency, and (c) only RAN tasks requiring overt articulation correlated with reading fluency. Georgiou et al. (2013) concluded that RAN is related to reading because it requires serial processing and overt articulation of items accessed in long-term memory.

The Present Study

We aimed to replicate and expand Georgiou et al.'s (2013) study with English-speaking second graders and university students. We asked the following questions:

1. Does seriality contribute to the RAN–reading relation? We know that serial RAN is a better predictor of reading fluency in Grades 2 and 6 in Greek (Georgiou et al., 2013).

---

[2] We borrow Klein's (2002) conceptualization of RAN as a task involving input, processing, and output stages.

However, we also know that Greek children master decoding by the end of Grade 1 (e.g., Seymour, Aro, & Erskine, 2003), which means that they can devote more resources to parallel processing (which then justifies why serial RAN was the only significant predictor of reading fluency). Because decoding automaticity is less developed among English-speaking second graders, we expect both serial and discrete naming to contribute to reading fluency. In contrast, because decoding is more automatic in adulthood, serial RAN should dominate the prediction of reading fluency.

2. Does set size contribute to the RAN–reading relation? Assuming larger set sizes place higher demands on retrieval of phonological representations from long-term memory, then a stronger relation with reading should be observed when naming 25 stimuli repeated 2 times (25X2) than when naming 5 stimuli repeated 10 times, or 2 stimuli repeated 25 times. This should be particularly evident among beginning readers (Grade 2).
3. Does articulation contribute to the RAN–reading relation? If yes, then (a) the traditional RAN task (5 items repeated 10 times) that requires overt articulation of the stimuli should be more strongly related to reading fluency than a task requiring ‘Yes/No’ articulation or crossing out of a target stimulus, and (b) the traditional RAN task should correlate more strongly with oral reading fluency than with silent reading fluency.

The findings of this study are expected to make three important contributions to the literature. First, we conducted our study in English (an opaque orthography). Assuming the relations between RAN and reading fluency provide an insight into the underlying reading processes (e.g., Protopapas et al., 2018) and that there is more reliance on larger orthographic units in word reading as orthographic transparency decreases (e.g., Marinelli, Romani, Burani, McGowan, & Zoccolotti, 2016; Schmalz, Beyersmann, Cavalli, & Marinus, 2016), we should observe some differences from Georgiou et al.'s (2013) findings in Greek (a transparent orthography) particularly in relation to the role of discrete naming in oral reading fluency (see Question 1). Second, because Georgiou et al. used RAN digits as one of the RAN tasks, they were confined to a pool of 10 digits (0 to 9) to develop the RAN task with the large set size. However, going from 5 items repeated 10 times to 10 items repeated 5 times may not substantially increase the retrieval demands of the task, which, in turn, reduces the chances of finding significant effects. To address this gap, we used RAN letters that allows us to draw from a pool of 26 letters. Finally, we contrast here the results of beginning readers (Grade 2) to those of advanced readers (university students). Typically, adults attempt to read the last 10-15 items in reading fluency tasks that comprise longer and more difficult words/nonwords. Reading these words/nonwords requires much more phonological recoding than what is needed when reading single syllable items (the first 30-40 items that young children encounter in the same fluency tasks). If this is true, then RAN (25X2) may play a more prominent role in young adults in our study that Georgiou et al. (2013) could not detect because they only assessed children.

Method

Participants

We assessed 137 Grade 2 (62 females, 75 males; M_{age} = 7.49 years, *SD* = .48) and 121 university (85 females, 36 males; M_{age} = 21.64 years, *SD* = 2.61) students. The second graders were recruited from seven public schools in Edmonton (Canada) that were located in different parts of the city to allow greater representation of different demographics in our study. 96% of the children were Caucasian, 3% East Asian, and 1% First Nations, Métis, and Inuit. The university students were recruited from the Subjects Pool program in the Faculty of Education at the University of Alberta. 98% of them reported being Caucasian and 2% East Asian. All participants were fluent speakers of English and had no documented intellectual, sensory, or behavioural difficulties. Parental consent was obtained for the Grade 2 participants and written consent was obtained from the adults. The university students received 5% credit towards one of their undergraduate courses for their participation.

Measures

Serial RAN. The participants were asked to name as fast as possible recurring letters that were arranged semi-randomly in five rows of ten. Three conditions were developed for this study: (1) five letters (o, a, s, d, p) repeated 10 times [hereafter called RAN (5X10)], (2) two letters (a, d) repeated 25 times [hereafter called RAN (2X25)], and (3) 25 letters (all letters of the alphabet except [w]) repeated 2 times [hereafter called RAN (25X2)]. A participant's score in each condition was the total time to name all the stimuli. Test-retest reliability was assessed with a sub-sample of Grade 2 (n=22) and adult (n=27) participants and ranged from .75 to .82.

Discrete naming. The five letters used in Condition 1 of serial RAN were used to assess discrete naming. Each stimulus was presented individually in the center of a computer screen, with a brief (500 ms) blank screen in between presentations. Stimuli were presented in random order, and each was presented ten times for a total of 50 trials. The time between the presentation of each stimulus and the onset of the vocal response was measured with voice onset reaction time, and the average latency was calculated across all 50 presentations. Articulations across all the stimuli were recorded and manually analyzed with a sound editing software (Goldwave 5.23). A participant's score was the sum of his/her average voice onset response times and average articulation times. Test-retest reliability (assessed as above) was .80 and .88, respectively.

Cancellation. The participants viewed a card similar to that of Condition 1 in serial RAN (the items were rearranged) and were asked to cross out row by row and as quickly as possible the target stimulus <p>. A participant’s score was the total time to cancel out all the target stimuli. Test-retest reliability (assessed as above) was .89 and .88, respectively.

Yes/No naming. The participants viewed a card similar to that of Condition 1 in serial RAN (the items were rearranged) and were asked to say ‘Yes’ every time they came across <a> and ‘No’ for all other letters. A participant’s score was the total time to respond to all stimuli. Test-retest reliability (assessed as above) was .91 and .88, respectively.

Reading fluency. Oral reading fluency was assessed with the Word Reading Efficiency (WRE) and Phonemic Decoding Efficiency (PDE) tasks from Test of Word Reading Efficiency (Torgesen, Wagner, & Rashotte, 1999). The participants were asked to read aloud and as fast as possible a list of increasingly more difficult words (max = 104) or pseudowords (max = 63). The score was the number of correct words/pseudowords read in 45 seconds. Test-retest reliability with a sub-sample of our Grade 2 participants was .86 for WRE and .90 for PDE. In our sub-sample of adults, test-retest reliability was .89 for WRE and .84 for PDE.

Silent reading fluency was assessed with the Test of Silent Reading Efficiency and Comprehension (Wagner, Torgesen, Rashotte, & Pearson, 2010) in Grade 2 and with the Reading Fluency task (Woodcock et al., 2001) in adults. In both tasks, the participants were asked to read silently simple sentences (max = 60 in Grade 2 and max = 98 in adults) and to indicate if the meaning of each sentence was true or false by circling Y (for Yes) or N (for

No) printed at the end of each sentence (e.g., *A cow is an animal*. Y - N). The participants were given 3 minutes to read the sentences and their score was the number of correct responses minus the number of incorrect responses. Test-retest reliability (assessed as above) was .79 and .82, respectively.

Procedure

All participants were individually tested by graduate students in a quiet room at their school (Grade 2) or at the university (adults). Testing took approximately 40 minutes and test order was counterbalanced. To calculate test-retest reliabilities, we retested a sub-sample of our participants approximately three weeks after their initial assessment.

Results

Preliminary Analyses

The descriptive statistics of our measures are presented in Table 1. The distributions of the three serial RAN tasks were positively skewed due to the presence of some outliers (1 in Grade 2 and 2 in adults). To normalize their distributions, the scores of the outliers were winsorized to the next non-outlier's score plus one. Before running any further analyses, we also created a composite score for oral reading fluency by averaging the z scores of Word Reading Efficiency and Phonemic Decoding Efficiency.

The results of correlational analyses are also presented in Table 1. The three serial RAN tasks correlated strongly with each other (*r*s ranged from .54 to .73 in Grade 2 and from .78 to .84 in adults) and with oral reading fluency (*r*s ranged from -.45 to -.56 in Grade 2 and from -.58 to -.63 in adults). In all instances, the correlations with silent reading fluency were lower than the corresponding ones with oral reading fluency.

Regression Analyses

We performed three sets of standard multiple regression analyses (see Models 1-3 in Table 2), separately for the two groups. Model 1 examined the effects of serial RAN (5X10) and discrete RAN on oral and silent reading fluency. Model 2 examined the effects of set size by comparing the effects of RAN (2X25), RAN (5X10), and RAN (25X2) on reading fluency. Finally, Model 3 examined the role of articulation by comparing the effects of RAN (5X10), Cancellation, and Yes/No naming. Standardized beta coefficients, significance levels, and total amount of variance explained by each model are presented in Table 2.

The results of Model 1 show that both serial RAN (5X10) and discrete naming predicted significantly the reading outcomes in Grade 2 (βs ranged from -.230 to -.465), but only serial RAN predicted significantly the two reading outcomes in adults (βs were -.595 and -.313, respectively). The results of Model 2 show that, in Grade 2, both RAN (5X10) and RAN (25X2) accounted for unique variance in oral reading fluency. In turn, only RAN (25X2) predicted significantly oral reading fluency in adults ($\beta = -.364$). Finally, the results of Model 3 show that RAN (5X10) was the only significant predictor of oral reading fluency in both groups (βs were -.579 in Grade 2 and -.520 in adults), and of silent reading fluency in Grade 2 ($\beta = -.442$).

Discussion

The purpose of this study was to examine the reasons why RAN relates to reading by manipulating one aspect of the RAN task at a time and inspecting the resulting changes to the RAN–reading relation. This is important because the question “why is RAN related to reading” is now more than 40 years old and because of recent arguments that the correlations between RAN and reading fluency can shed light on the underlying processes in reading words (e.g., Altani, Protopapas, & Georgiou, 2018; de Jong, 2011; Protopapas et al., 2018).

First, at the input stage, we observed differences between our two groups. Whereas in Grade 2 both discrete naming and serial RAN predicted reading, only serial RAN predicted reading for adults. This concurs with recent evidence from English (Altani et al., 2018) and Dutch (van den Boer & de Jong, 2015) showing that in beginning readers both naming tasks contribute to serial reading while in fluent readers only serial RAN predicts serial reading. Assuming these relations reveal underlying processes in reading words (de Jong, 2011), this implies that in early grades children process words in reading fluency tasks one at a time (as in discrete naming) and for this reason discrete naming predicts reading. Serial naming is important irrespective of grade level because it involves processes specific to the sequential nature of the task (e.g., eye-movement control), beyond the automaticity of name retrieval (tapped by discrete naming). In serial naming and reading fluency, individuals are exposed to multiple items presented simultaneously and are required to move from one item to the next in a sequential manner regardless of the grade level or how individuals process each item within the array. In other words, serial naming and reading fluency tasks require individuals to coordinate processing stages across successive items, while scheduling their eye-movements and verbal processes. Among more advanced readers, the contribution of individual item processing diminishes and serial naming dominates oral reading fluency, as efficiency in serial tasks is associated with greater coordination of processing stages across successive items (e.g., Altani, Protopapas, Katopodi, & Georgiou, 2020; Gordon & Hoedemaker, 2016; Protopapas et al., 2018).

From a theoretical point of view, the above findings suggest that reading fluency requires not only quick word recognition, but also efficient processing of words that appear in sequence (as in oral reading fluency tasks or in passage reading; see Altani et al., 2020). This skill is missing from the definitions of reading fluency (e.g., Kuhn & Stahl, 2003) as well as from the theoretical models of fluency development (e.g., Hudson, Pullen, Lane, & Torgesen, 2009).

Second, at the processing stage, we found that both RAN (5X10) and RAN (25X2) accounted for unique variance in oral reading fluency in Grade 2. This may be expected given that most words in the reading tasks would be unknown to Grade 2 children and they would need quick access to phonological representations of graphemes to facilitate decoding. This is clearly independent of a task (i.e., RAN 5X10) that requires maintaining the names of a small set of stimuli active in short-term memory (Amtmann, Berninger, & Abbott, 2007) as well as independent of a task (i.e., RAN 2X25) that requires serial processing of a highly repetitious set of stimuli. This explanation is further supported by the results with adults. Because the last 10-15 items in Word Reading Efficiency and Phonemic Decoding Efficiency that created the variability in our group comprised words that are relatively infrequent (e.g., *boisterous*) or have complex grapheme-phoneme correspondences (e.g., *darlankert*), this increased the demand for phonological encoding, which then led RAN (25X2) to be a unique predictor of oral reading fluency.

Finally, in line with our expectation as well as with the findings of previous studies (Di Filippo et al., 2005; Georgiou et al., 2013; Scarborough & Domgaard, 1998), we found that neither Cancellation nor Yes/No naming predicted reading. In addition, RAN and the other measures accounted for a substantially lower amount of variance in silent reading fluency than in oral reading fluency. Taken together, this suggests that articulation in both RAN and reading is partly responsible for their relation.

Some limitations of our study are worth noting. First, we assessed only RAN letters. A future study should examine if the results replicate with a non-alphanumeric RAN task (e.g., Object Naming). Second, our silent reading fluency task required some comprehension, and this may have added variance to the task that is unrelated to the distinction between oral and silent reading fluency. Finally, we did not control for the effects of other processing skills (e.g., intelligence, phonological awareness) before examining the role of different RAN tasks in reading. We decided against this in order to generate results that are directly comparable to those of Georgiou et al. (2013) whose study we tried to replicate.

To conclude, our findings extend those of previous studies in transparent orthographies (e.g., de Jong, 2011; Di Filippo et al., 2005; Georgiou et al., 2013) suggesting that RAN is related to reading fluency in English because both involve serial processing, quick access to and retrieval of phonological representations, and articulation. However, the reasons behind this relation seem to change depending on individuals' age and the type of reading outcome used.

References

Altani, A., Protopapas, A., & Georgiou, G. (2018). Using serial and discrete digit naming to unravel word reading processes. *Frontiers in Psychology*, *9*: 524. doi:10.3389/fpsyg.2018.00524

Altani, A., Protopapas, A., Katopodi, K., & Georgiou, G. (2020). From individual word recognition to word list and text reading fluency. *Journal of Educational Psychology, 112*, 22-39.

Amtmann, D., Abbott, R. D., & Berninger, V.W. (2007). Mixture growth models of RAN and RAS row by row: Insight into the reading system at work over time. *Reading and Writing: An Interdisciplinary Journal, 20,* 785–813. doi:10.1007/s11145-006-9041-y

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.

Clarke, P., Hulme, C., & Snowling, M. (2005). Individual differences in RAN and reading: A response timing analysis. *Journal of Research in Reading, 28,* 73-86.

Cobbold, S., Passenger, T., & Terrell, C. (2003). Serial naming speed and the component elements of speech time and pause time: Relationships with the development of word-level reading in children aged four to five years. *Journal of Research in Reading, 26*, 165-176.

Compton, D. L., (2003). The influence of item composition on RAN letter performance in first-grade children. *The Journal of Special Education, 37*, 81-94.

de Jong, P. F. (2011). What discrete and serial rapid automatized naming (RAN) can reveal about reading. *Scientific Studies of Reading, 15,* 314-337.

Di Filippo, G., Brizzolara, D., Chilosi, A., De Luca, M., Judica, A., Pecini, C., et al. (2005). Rapid naming, not cancellation speed or articulation rate, predicts reading in an orthographically regular language (Italian). *Child Neuropsychology, 11*, 349-361.

Georgiou, G. K., Aro, M., Liao, C. H., & Parrila, R. (2016). Modeling the relationship between rapid automatized naming and literacy skills across languages varying in orthographic consistency. *Journal of Experimental Child Psychology, 143*, 48–64. https://doi.org/10.1016/j.jecp.2015.10.017

Georgiou, G. K., Parrila, R. K., Cui, Y., & Papadopoulos, T. C. (2013). Why is rapid automatized naming related to reading? *Journal of Experimental Child Psychology, 115*, 218-225.

Georgiou, G. K., Parrila, R., & Kirby, J. (2006). Rapid naming speed components and early reading acquisition. *Scientific Studies of Learning, 10*, 199-220.

Georgiou, G. K., Parrila, R., & Kirby, J. (2009). RAN components and reading development from Grade 3 to Grade 5: What underlies the relationship? *Scientific Studies of Reading, 13*, 508-534.

Georgiou, G. K., Parrila, R., Kirby, J., & Stephenson, K. (2008). Rapid naming components and their relationship with phonological awareness, orthographic knowledge, speed of processing and different reading outcomes. *Scientific Studies of Reading, 12*, 325-350.

Gordon, P. C., & Hoedemaker, R. S. (2016). Effective scheduling of looking and talking during rapid automatized naming. *Journal of Experimental Psychology: Human Perception and Performance, 42*, 742–760.

Hudson, R. F., Pullen, P. C., Lane, H. B., & Torgesen, J. K. (2009). The complex nature of reading fluency: A multidimensional view. *Reading & Writing Quarterly, 25*, 4-32.

Jones, M. W., Branigan, H. P., & Kelly, M. L. (2009). Dyslexic and nondyslexic reading fluency: Rapid automatized naming and the importance of continuous lists. *Psychonomic Bulletin & Review, 16*, 567-572.

Kirby, R., Georgiou, G., Martinussen, R., & Parrila, R. (2010). Naming speed and reading: A review of the empirical and theoretical literature. *Reading Research Quarterly, 45,* 341-362.

Klein, R. M. (2002). Observations on the temporal correlates of reading failure. *Reading and Writing: An Interdisciplinary Journal, 15*, 207-232.

Kuhn, M. R., & Stahl, S. A. (2003). Fluency: A review of developmental and remedial practices. *Journal of Educational Psychology, 95,* 3-21.

Logan, J. A., & Schatschneider, C. (2014). Component processes in reading: Shared and unique variance in serial and isolated naming speed. *Reading and Writing, 27,* 905-922.

Manis, F. R., Doi, L. M., & Bhadha, B. (2000). Naming speed, phonological awareness, and orthographic knowledge in second graders. *Journal of Learning Disabilities, 33,* 325-333.

Marinelli, C. V., Romani, C., Burani, C., McGowan, V. A., & Zoccolotti, P. (2016). Costs and benefits of orthographic inconsistency in reading: Evidence from a cross-linguistic comparison. *PloS One, 11*(6), e0157457.

Neuhaus, G., & Swank, P. (2002). Understanding the relations between RAN letter subtest components and word reading in first-grade students. *Journal of Learning Disabilities, 35*, 158-174.

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.

Poulsen, M., Juul, H., & Elbro, C. (2015). Multiple mediation analysis of the relationship between rapid naming and reading. *Journal of Research in Reading, 38*, 124-140.

Protopapas, A., Altani, A., & Georgiou, G. (2013a). RAN backwards: A test of the visual scanning hypothesis. *Scientific Studies of Reading, 17,* 453-461.

Protopapas, A., Altani, A., & Georgiou, G. (2013b). Development of serial processing in reading and rapid naming. *Journal of Experimental Child Psychology, 116*, 914-929.

Protopapas, A., Katopodi, K., Altani, A., & Georgiou, G. (2018). Word reading fluency as a serial naming task. *Scientific Studies of Reading, 22*, 248-263*.*

Scarborough, H. S., & Domgaard, R. M. (1998, April). *An exploration of the relationship between reading and serial naming speed.* Paper presented at the Society for the Scientific Studies of Reading, San Diego.

Schmalz, X., Beyersmann, E., Cavalli, E., & Marinus, E. (2016). Unpredictability and complexity of print-to-speech correspondences increase reliance on lexical processes: More evidence for the orthographic depth hypothesis. *Journal of Cognitive Psychology, 28*, 658–672. https://doi.org/10.1080/20445911.2016.1182172

Seymour, P. H., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94,* 143-174.

Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (1999). *Test of Word Reading Efficiency (TOWRE)*. Austin, TX: PRO-ED.

van den Boer, M., & de Jong, P. F. (2015). Parallel and serial reading processes in children's word and nonword reading. *Journal of Educational Psychology, 107*, 141-151.

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., & Pearson, N. A. (2010). *Test of Silent Reading Efficiency and Comprehension (TOSREC) examiner's manual*. Austin, TX: Pro-Ed.

Warmington, M., & Hulme, C. (2012). Phoneme awareness, visual-verbal paired-associate learning, and rapid automatized naming as predictors of individual differences in reading ability. *Scientific Studies of Reading, 16,* 45–62.

Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology, 91*, 415-438.

Wolf, M., & Denckla, M. B. (2005). *Rapid automatized naming and rapid alternating stimulus tests (RAN/RAS).* Austin, TX: PRO-ED.

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock–Johnson III Tests of Achievement*. Itasca, IL: Riverside.

Table 1

Descriptive Statistics and Correlations between Our Measures (top half for our adult participants and bottom half for our Grade 2 participants)

		1.	2.	3.	4.	5.	6.	7.	8.	*M*	*SD*
1.	RAN-L (2X25)^a		.78**	.79**	.39**	.36**	.54**	-.58**	-.22**	16.23	2.29
2.	RAN-L (5X10)^a	.63**		.84**	.35**	.49**	.60**	-.60**	-.21**	16.78	2.90
3.	RAN-L (25X2)^a	.54**	.73**		.37**	.45**	.52**	-.63**	-.29**	19.18	2.85
4.	RAN-L Discrete^b	.22**	.23**	.33**		.26**	.45**	-.16	-.03	528.79	80.01
5.	Cancellation^a	.14	.10	.12	-.17*		.39**	-.36**	-.11	11.01	2.49
6.	Yes/No naming^a	.44**	.38**	.20*	.11	.38**		-.43**	-.15	18.05	3.11
7.	ORF^c	-.45**	-.56**	-.53**	-.44**	.10	-.14		.46**		
8.	SRF	-.36**	-.40**	-.38**	-.31**	.00	-.06	.68**		89.02	6.25
M		31.27	34.89	42.11	754.22	19.44	34.55		23.22		
SD		5.25	7.53	10.59	179.05	5.70	6.99		8.62		

Note. ^{a}. Measured in seconds. ^{b}. Measured in milliseconds. ^{c}. This is a composite score and that is why no descriptive statistics are presented.
RAN-L = Letter Naming; ORF = Oral Reading Efficiency; SRF = Silent Reading Fluency.
* $p < .05$; ** $p < .01$.

Table 2

Results of Standard Multiple Regression Analyses (top half for our Grade 2 participants and bottom half for our adult participants)

		Oral Reading Fluency		Silent Reading Fluency	
Model	Variables	*β*	R^2	*β*	R^2
		Grade 2			
Input Stage					
1.	RAN-L (5X10)	-.465***	.40	-.336***	.19
	RAN-L discrete	-.334***		-.230***	
Processing Stage					
2.	RAN-L (2X25)	-.129	.35	-.155	.17
	RAN-L (5X10)	-.303**		-.185	
	RAN-L (25X2)	-.235*		-.162	
Output Stage					
3.	RAN-L (5X10)	-.579***	.33	-.442***	.17
	Cancellation	.151		.005	
	Yes/No naming	.026		.107	
		Adults			
Input Stage					
1.	RAN-L (5X10)	-.595***	.34	-.313***	.09
	RAN-L discrete	.031		.070	
Processing Stage					
2.	RAN-L (2X25)	-.210	.42	-.007	.11
	RAN-L (5X10)	-.111		.179	
	RAN-L (25X2)	-.364*		-.331	
Output Stage					
3.	RAN-L (5X10)	-.520***	.37	-.228	.05
	Cancellation	-.078		-.005	
	Yes/No naming	-.066		.023	

Note. RAN-L = Letter Naming.
* $p < .05$; ** $p < .01$; *** $p < .001$.

View publication stats