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Stability of Visual Attention Span Performance and Its Relation With Reading Over Time

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ABSTRACT
Visual attention span (VAS) predicts reading performance over and above phonological skills. Given the growing number of studies that include VAS, it is surprising that indications of the stability of VAS performance and its relation with reading over time have not yet been reported. The current study addressed these important issues. Participants were 180 third graders, 131 of whom were reassessed in Grade 4. Results indicated that VAS (whole report for letters) accounts for variance in reading over and above phoneme awareness and rapid automatized naming. VAS performance was highly stable over time, and VAS and reading were related both concurrently and longitudinally. However, controlling for autoregressive effects, the effects of Grade 3 VAS on Grade 4 reading, and vice versa, were not significant. These findings encourage including VAS in future studies but indicate that there is as of yet little evidence for VAS being *causally* related to reading performance.

Introduction

There is general consensus on the importance of phonological processing skills for reading development (e.g., Ramus et al., 2003; Saksida et al., 2016; Vellutino, Fletcher, Snowling, & Scanlon, 2004). However, it has also been suggested that visual processing skills affect reading development instead of or in addition to phonological processing skills (Saksida et al., 2016; Vidyasagar & Pammer, 2010). Prominent among visual theories is the visual attention span (VAS) hypothesis (Valdois, Bosse, & Tainturier, 2004), stating that the number of orthographic units (i.e., letters, letter clusters, syllables) that can be processed in parallel (i.e., in one glance) is an important skill underlying reading performance. Whereas a large VAS allows words to be processed in parallel (i.e., through sight word reading), a small VAS requires visual attention to be focused on sublexical units, resulting in serial processing (i.e., word decoding; Ans, Carbonnel, & Valdois, 1998). VAS, most often measured as the ability to report back briefly presented letter strings, has been shown to relate to word reading (WR) performance over and above phonological skills in children with and without dyslexia in various languages (Bosse et al., 2007; Bosse & Valdois, 2009; Germano, Reilhac, Capellini, & Valdois, 2014; Valdois et al., 2003; van den Boer, de Jong, & Haentjens-van Meeteren, 2013; Zoubrinetzky, Bielle, & Valdois, 2014; Zoubrinetzky, Collet, Serniclaes, Nguyen-Morel, & Valdois, 2016). In addition, VAS was found to relate to other literacy skills, including text reading (TR; Lobier, Dubois, & Valdois, 2013; Prado, Dubois, & Valdois, 2007; van den Boer, van Bergen, & de Jong, 2014) and spelling (van den Boer, van Bergen, & de Jong, 2015).

It is surprising that there are as of yet no longitudinal studies including VAS. Consequently, two important issues concerning VAS have thus far not been addressed. First, it is unclear how stable

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individual differences in VAS performance are over time. Given the growing number of studies that include a measure of VAS, it is important that the stability of performance on the task is examined.

Furthermore, Goswami (2015a, 2015b) indicated that a deficit in VAS, as well as other sensory deficits proposed to underlie dyslexia, might not play a causal role in reading development but rather result from the effects of reduced reading experience on brain development. Lobier and Valdois (2015) responded with a number of findings indicating that it is highly unlikely that VAS performance mostly reflects reading experience. However, as a second issue, there is a lack of knowledge about the developmental relation between VAS and reading.

In the current study the relation between VAS and reading performance was examined from Grade 3 to Grade 4. The focus was on Grades 3 and 4 because previous studies indicating a relation between VAS and reading also focused on this age group (e.g., Bosse & Valdois, 2009; van den Boer et al., 2015), and it is thus important to know whether this established relation can be interpreted as causal. First, we examined in Grade 3 the relation between VAS and reading performance (i.e., WR, pseudoword reading [PWR], and TR) while controlling for phonological skills. More specifically, we included phoneme awareness (PA), the ability to distinguish and manipulate sounds in spoken words, and rapid automatized naming (RAN), the ability to quickly name a set of familiar symbols (i.e., letters and digits). These two skills have been shown to be strongly related to reading performance (e.g., Kirby, Georgiou, Martinussen, & Parrila, 2010; Melby-Lervåg, Lyster, & Hulme, 2012). The aim of these analyses was to ensure that the relations among these variables are in line with those reported in previous studies. VAS is expected to contribute to reading performance over and above PA and RAN.

The main aim, however, was to provide estimates of the stability of VAS as well as its relation with reading over time. Both VAS and reading skills were assessed in Grades 3 and 4. The stability of VAS performance across grades is reported, and we present the longitudinal relation of VAS with WR and PWR.

Method

Participants

Participants were 180 children (50.6% girls, *M* age = 8 years 11 months, *SD* = 5.40 months) attending third grade of mainstream primary education at one of five participating schools. Dutch was the dominant language for all children, although 16.7% of the children also spoke another language at home. Of this sample, 131 children (48.9% girls, *M* age = 10 years 1 month, *SD* = 5.69 months) were tested again in Grade 4. Twenty-seven children could not be tested in Grade 4 because one school was unable to participate. Another 22 children could not be tested again for various reasons. Most of them had changed schools, some were absent at the time of testing, and a few repeated a grade.

Materials and procedure

In Grade 3, five tasks were administered individually: visual attention span, WR, PWR, phoneme awareness, and rapid automatized naming. TR was administered in a classroom session. In Grade 4 visual attention span, WR, and PWR were assessed again. The study was conducted in accordance with the guidelines of the institution's ethics committee.

Grades 3 and 4

Visual attention span

VAS was measured with a whole report task (Valdois et al., 2003). Participants were presented with 20 five-letter strings (e.g., R H S D M) composed of 10 consonants (B, D, F, H, L, M, P, R, S, T) appearing twice in each letter position. The task was programmed in E-prime (Schneider, Eschman, & Zuccolotto, 2002). A plus sign was presented (1,000 ms) to focus attention, followed by a letter string (200 ms) in 24-point Arial font with two spaces between the letters. Children were asked to name as many letters as possible in the correct order. The score consisted of the number of letters repeated correctly in the correct position (maximum = 100). Split-half reliability for the current sample was .91 in Grade 3 and .87 in Grade 4.

Word reading

WR fluency was assessed with the standardized Eén Minuut test (Brus & Voeten, 1995; r = .89–.92). Children read aloud a list of 116 words of increasing difficulty as quickly and accurately as possible. The score was the number of words read correctly in 1 min.

Pseudoword reading

PWR fluency was assessed with the standardized Klepel (van den Bos, Lutje Spelberg, Scheepstra, & de Vries, 1994; r = .91). Children read aloud a list of 116 pseudowords of increasing difficulty as quickly and accurately as possible for 2 min. The score was the number of items read correctly.

Grade 3 only

Text reading

TR fluency was assessed with a maze task consisting of two age-appropriate texts (Muijselaar, de Bree, Steenbeek-Planting, & de Jong, 2017). The title and headings of the texts were intact, as well as the first sentence. After that, every 11th word was omitted. Children were asked to read the texts and choose from among three alternatives the words that were omitted (e.g., *heter/meter/beter* [hotter, meter, better]). The alternatives were similar in spelling but not in meaning. Identifying the correct alternative thus mainly required decoding rather than comprehension skills (Muijselaar, Kendeou, de Jong, & van den Broek, 2017). The texts consisted of 410 words and 35 choices, and 372 words and 32 choices, respectively, and they were preceded by an example text of 43 words including two choices. A time limit of 2 min per text was imposed to ensure that children could not read the entire text, thus capturing individual differences in reading fluency. The score consisted of the total number of omitted words identified correctly.

Phoneme awareness

PA was assessed with a phoneme deletion task (de Jong & van der Leij, 2003). An experimenter read aloud a pseudoword that participants were asked to repeat. Next, the pseudoword was presented again, and participants were asked to delete one phoneme (e.g., *tesp* without *p*). Children were presented with 12 items in three sets. The first four items were monosyllabic pseudowords, the next four items were bisyllabic pseudowords, and the last items were bisyllabic pseudowords in which the phoneme to be deleted was included twice (e.g., *stisnalt* without *t*). The task was discontinued when all items within a set were incorrect. Three practice items preceded the first item, and another two were presented before the final four items. The score consisted of the number of correct answers. Internal consistency was .77 in the current sample, and split-half reliability was .80.

Rapid automatized naming

RAN was assessed with digits (2, 4, 5, 7, 9) and letters (A, D, O, P, S) presented eight times each in five lines of eight items. Participants were asked to name all 40 items as quickly and accurately as possible. The score consisted of the average number of digits and letters named correctly per second.

Results

Data were first checked for missing values, outliers (i.e., scores more than 3 *SD* from the group mean) and score distributions. Scores on all tasks were normally distributed. One outlier each was identified for TR and Grade 4 WR. These scores were coded as missing. In addition, some scores were missing for the variables assessed in Grade 3 because children missed the classroom session, or because of errors in task administration. The exact total sample size for each of the tasks is presented in Table 1 with the descriptive statistics and correlations for all Grade 3 and Grade 4 measures.

The correlations indicated that VAS as well as PA and RAN each correlated significantly with all reading tasks. With hierarchical regression analyses it was examined whether VAS explained variance in reading skills over and above PA and RAN. For word reading, PA and RAN explained 32.0% of the variance, $F(2, 175) = 41.265$, $p < .001$, and VAS explained an additional 5.0%, $F(1, 174) = 13.789$, $p < .001$. Standardized betas of the complete model indicated that RAN ($\beta = .428$, $p < .001$) and VAS ($\beta = .253$, $p < .001$) were significant predictors of WR, whereas PA ($\beta = .090$, $p = .191$) was not. For pseudoword reading, PA and RAN explained 40.1% of the variance, $F(2, 176) = 58.912$, $p < .001$, and VAS explained an additional 6.3%, $F(1, 175) = 20.534$, $p < .001$. RAN ($\beta = .435$, $p < .001$), VAS ($\beta = .286$, $p < .001$), and PA ($\beta = .153$, $p = .017$) were all significant predictors of PWR. Finally, for text reading, PA and RAN explained 14.6% of the variance, $F(2, 156) = 13.333$, $p < .001$, and VAS explained an additional 5.9%, $F(1, 155) = 11.413$, $p = .001$. RAN ($\beta = .222$, $p = .005$) and VAS ($\beta = .274$, $p = .001$) were significant predictors of TR, whereas PA ($\beta = .087$, $p = .286$) was not. Taken together, VAS explained an additional 5%–6% of the variance in reading after PA and RAN were taken into account. Important to note, *t* tests showed that children who dropped out of the study did not differ from those who were reassessed in Grade 4 on any of the variables in the study, and regression results did not change when only the children who were reassessed in Grade 4 were included.

Next, the stability of VAS performance across grades was examined. VAS performance was significantly higher in Grade 4 ($M = 73.27$, $SD = 13.56$) than in Grade 3 ($M = 66.92$, $SD = 14.17$), $t(130) = 8.567$, $p < .001$, $d = .457$, indicating overall growth in VAS skills. In addition, the correlation between VAS performance in Grade 3 and Grade 4 was high ($r = .814$, $p < .001$), indicating that individual differences in VAS performance were highly stable over time.

Finally, we examined the longitudinal relation between VAS, WR, and PWR. VAS, WR, and PWR were found to correlate both concurrently and longitudinally. We specified a cross-lagged structural equation model to examine whether Grade 3 VAS predicted Grade 4 reading, after controlling for Grade 3 reading. Similarly, we examined whether Grade 3 reading predicted Grade 4 VAS, controlling for the autoregressive effect. We specified a factor structure in which WR and PWR loaded on one reading factor in both grades. To create a latent variable for VAS, separate scores were calculated for the odd and even items. VAS odd is the number of letters correct over the odd items of the task, whereas VAS even reflects performance on the even items. These two scores loaded on one VAS factor in both grades. Measurement invariance was assumed by constraining factor loadings and

Table 1. Descriptive Statistics and Correlations for all Grade 3 and Grade 4 Measures.

	Grade 3						Grade 4		
	WR	PWR	TR	VAS	PA	RAN	WR	PWR	VAS
Grade 3									
WR	—								
PWR	.859	—							
TR	.648	.538	—						
VAS	.434	.504	.383	—					
PA	.351	.435	.271	.444	—				
RAN	.540	.586	.340	.340	.349	—			
Grade 4									
WR	.916	.806	.662	.354	.379	.525	—		
PWR	.849	.852	.577	.402	.419	.572	.881	—	
VAS	.404	.423	.427	.814	.435	.205	.430	.470	—
N	179	180	160	180	180	179	131	132	131
M	58.20	50.91	18.66	66.78	7.06	1.81	65.81	60.57	73.27
SD	13.86	17.50	6.52	14.29	2.88	.32	13.67	18.97	13.56
Min.	28	13	2	34	0	.88	37	13	41
Max.	97	96	38	98	12	2.69	96	105	100

Note. All correlations are significant at $p < .05$. WR = word reading; PWR = pseudoword reading; TR = text reading; VAS = visual attention span; PA = phoneme awareness; RAN = rapid automatized naming.

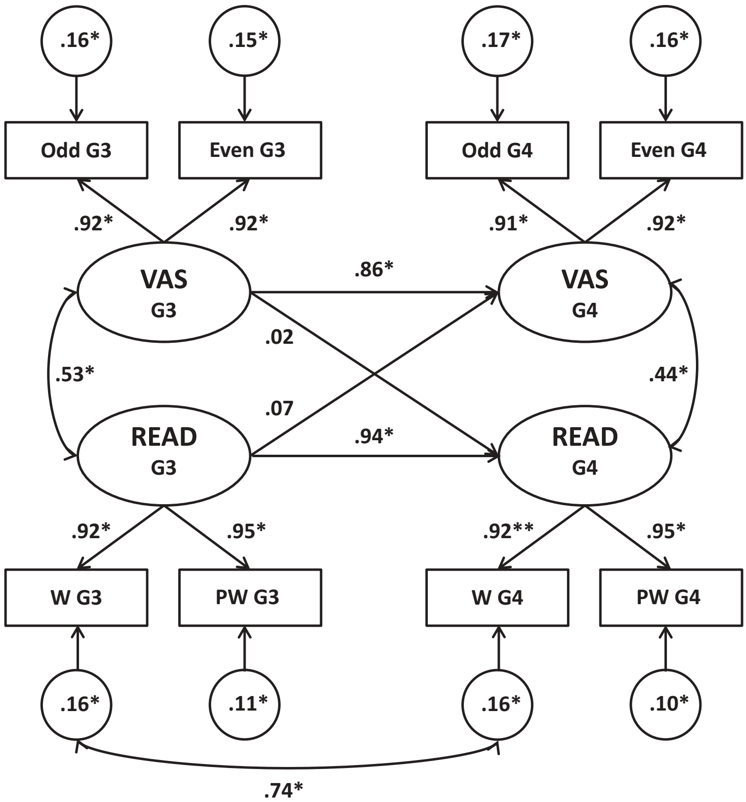

Figure 1. Cross-lagged relations between visual attention span (VAS) and reading (word reading [W] and pseudoword reading [PW]) in Grades (G) 3 and 4. *p <. 05.

residual variances of all observed variables to be equal across grades. All available data were included, but results were the same when only children who participated in Grades 3 *and* 4 were included. The model was estimated with Mplus version 7.11 (Muthén & Muthén, 1998–2013) using full-information maximum likelihood to account for missing data.

The model provided a poor fit to the data, $\chi^2(20) = 58.334$, $p < .001$, root mean square error of approximation = .10, 90% confidence interval [.07, .14], comparative fit index = .97, standardized root mean square residual = .05. WR was found to be slightly more stable over time than PWR. With an added correlation between the residuals of WR in Grades 3 and 4, the model provided a good fit to the data,[1] $\chi^2(19) = 27.960$, $p = .0844$, root mean square error of approximation = .05, 90% confidence interval [.00, .09], comparative fit index = .99, standardized root mean square residual = .04. The model and standardized parameter estimates are presented in Figure 1. The findings indicate that both reading and VAS are highly stable over time. Over and above these autoregressive effects, VAS did not have a significant effect on reading 1 year later, nor did reading ability affect later VAS.

Discussion

In the current study we examined two important issues concerning VAS that have thus far not been addressed: the stability of VAS performance and its relation with reading over time. VAS,

[1]The estimate of this correlation was .74, but note that the residuals are very low and therefore the residual correlation captures only a very small part of the observed correlation of .916 between Grade 3 and Grade 4 WR. The estimated autoregressive effect for WR in the models with or without the correlated residual was highly similar.

WR, and PWR were assessed in an unselected sample in Grades 3 and 4. First, we showed that VAS is related to reading performance in Grade 3, over and above PA and RAN. A relation was found for VAS with WR but also for PWR and TR. These findings fit nicely with the growing body of literature on VAS as a correlate of literacy skills (e.g., Bosse & Valdois, 2009; Germano et al., 2014; van den Boer et al., 2013, 2015).

Of interest, VAS accounted for differences in reading skills over and above RAN, particularly RAN letters. Rather than visual processing skills, VAS has been suggested to mainly tap coding abilities, either verbal coding of letter names or coding of letter positions (e.g., Collis, Kohnen, & Kinoshita, 2013; Hawelka & Wimmer, 2008; Ziegler, Pech-Georgel, Dufau, & Grainger, 2010). As RAN also included letters as stimuli and required verbal coding to name the letters, performance on the VAS task is unlikely to reflect only verbal coding. Different from RAN, where the stimuli remain visible and are processed sequentially, we propose that VAS also reflects fast *parallel* processing of multiple (verbal) elements (see also van den Boer et al., 2015).

Concerns about what VAS performance reflects particularly apply to the full report task with letters, as used in this study. It can be regarded as a limitation that no VAS task was included with less strong verbal output demands, such as partial report or VAS with symbols. Nevertheless, the current study clearly indicates that full report VAS is relevant to reading as it contributes to reading over and above PA and RAN. Moreover, its contribution is not specific to WR but applies to PWR and TR as well. These findings indicate that VAS not only determines whether individual words can be identified in parallel (i.e., through sight word reading) but also relates to the size of sublexical units processed during nonword reading, as well as the amount of text processed (parafoveally) during text reading.

It should be mentioned that only a limited number of variables were included in this study. Skills suggested to (partly) explain the relation between VAS and reading, such as single letter identification, intelligence or verbal short-term memory, were not assessed. An indication of single letter identification, however, is the naming accuracy of the first letter within the string on the VAS task, which was almost at ceiling (95.3% in Grade 3, and 96.3% in Grade 4). Furthermore, previous studies including children of a similar age have controlled for nonverbal intelligence and verbal short-term memory and showed that VAS still explained additional variance in reading skills (Bosse & Valdois, 2009; van den Boer et al., 2013, 2015).

Our main finding was that individual differences in VAS are highly stable over time. The stability of VAS performance was higher than stability estimates reported for phonological skills (e.g., Nation & Hulme, 2011; Wagner, Torgesen, & Rashotte, 1994). Notably, the stability in VAS performance was even close to the exceptionally high stability in reading performance reported in this study and others (e.g., van Viersen et al., 2018). Another main finding concerns the absence of crosslagged effects of VAS on reading, and vice versa. Both VAS and reading performance increased by approximately half a standard deviation from third to fourth grade, and performance on the tasks was related both concurrently and longitudinally. The absence of crosslagged effects thus indicates that the development of VAS and reading ability during this period was largely independent.

Our findings do not support a causal interpretation of the VAS–reading relation, at least not from Grade 3 onward. Nevertheless, VAS might causally affect early reading development, that is, before third grade, or the early VAS–reading relation could be reciprocal. Evidently, there is a need for longitudinal studies on the relation between VAS and reading in the early grades, using a wider range of measures to assess VAS skills. It also seems important to study this relation across orthographies. Although we showed that VAS is an important correlate of reading in a relatively transparent orthography, it has been found that VAS contributes more strongly to reading in deep rather than shallow orthographies (e.g., Lallier & Carreiras, 2017).

In conclusion, we found that VAS is remarkably stable over time and relates to reading ability both concurrently and longitudinally. However, the current results provide little support for VAS being *causally* related to reading performance.

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References

Ans, B., Carbonnel, S., & Valdois, S. (1998). A connectionist multiple-trace memory model for polysyllabic word reading. *Psychological Review*, *105*, 678–723. doi:10.1037/0033-295X.105.4.678-723

Bosse, M. L., Tainturier, M. J., & Valdois, S. (2007). Developmental dyslexia: The visual attention span deficit hypothesis. *Cognition*, *104*, 198–230. doi:10.1016/j.cognition.2006.05.009

Bosse, M. L., & Valdois, S. (2009). Influence of the visual attention span on child reading performance: A cross-sectional study. *Journal of Research in Reading*, *32*, 230–253. doi:10.1111/j.1467-9817.2008.01387.x

Brus, B., & Voeten, B. (1995). *Eén minuut test vorm A en B. Verantwoording en handleiding [one-minute-test manual]*. Lisse, The Netherlands: Swets & Zeitlinger.

Collis, N. L., Kohnen, S., & Kinoshita, S. (2013). The role of visual spatial attention in adult developmental dyslexia. *The Quarterly Journal of Experimental Psychology*, *66*, 245–260. doi:10.1080/17470218.2012.705305

de Jong, P. F., & van der Leij, A. (2003). Developmental changes in the manifestation of a phonological deficit in dyslexic children learning to read a regular orthography. *Journal of Educational Psychology*, *95*, 22–40. doi:10.1037/0022-0663.95.1.22

Germano, G. D., Reilhac, C., Capellini, S. A., & Valdois, S. (2014). The phonological and visual basis of developmental dyslexia in Brazilian Portuguese reading children. *Frontiers in Psychology*, *5*, 1169. doi:10.3389/fpsyg.2014.01169

Goswami, U. (2015a). Sensory theories of developmental dyslexia: Three challenges for research. *Nature Reviews Neuroscience*, *16*, 43–54. doi:10.1038/nrn3836

Goswami, U. (2015b). Visual attention span deficits and assessing causality in developmental dyslexia. *Nature Reviews Neuroscience*, *16*, 225–226. doi:10.1038/nrn3836-c2

Hawelka, S., & Wimmer, H. (2008). Visual target detection is not impaired in dyslexic readers. *Vision Research*, *48*, 850–852. doi:10.1016/j.visres.2007.11.003

Kirby, J. R., Georgiou, G. K., Martinussen, R., & Parrila, R. (2010). Naming speed and reading: From prediction to instruction. *Reading Research Quarterly*, *45*, 341–362. doi:10.1598/RRQ.45.3.4

Lallier, M., & Carreiras, M. (2017). Cross-linguistic transfer in bilinguals reading in two alphabetic orthographies: The grain size accommodation hypothesis. *Psychonomic Bulletin & Review*, *25*, 386–401. doi:10.3758/s13423-017-1273-0

Lobier, M., Dubois, M., & Valdois, S. (2013). The role of visual processing speed in reading speed development. *PLoS ONE*, *8*, e58097. doi:10.1371/journal.pone.0058097

Lobier, M., & Valdois, S. (2015). Visual attention deficits in developmental dyslexia cannot be ascribed solely to poor reading experience. *Nature Reviews Neuroscience*, *16*, 225. doi:10.1038/nrn3836-c1

Melby-Lervåg, M., Lyster, S. A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin*, *138*, 322–352. doi:10.1037/a0026744

Muijselaar, M. M. L., de Bree, E. H., Steenbeek-Planting, E. G., & de Jong, P. F. (2017). Is de cloze-toets een betrouwbare en valide maat voor begrijpend lezen? [Is the cloze test a reliabe and valid measure of reading comprehension?] *Pedagogische Studiën*, *94*, 418–435.

Muijselaar, M. M. L., Kendeou, P., de Jong, P. F., & van den Broek, P. W. (2017). What does the CBM-Maze test measure? *Scientific Studies of Reading*, *21*, 120–132. doi:10.1080/10888438.2016.1263994

Muthén, L. K., & Muthén, B. O. (1998–2013). *Mplus (version 7.11) [Computer software]*. Los Angeles, CA: Muthén & Muthén.

Nation, K., & Hulme, C. (2011). Learning to read changes children's phonological skills: Evidence from a latent variable longitudinal study of reading and nonword repetition. *Developmental Science*, *14*, 649–659. doi:10.1111/j.1467-7687.2010.01008.x

Prado, C., Dubois, M., & Valdois, S. (2007). The eye movements of dyslexic children during reading and visual search: Impact of the visual attention span. *Vision Research*, *47*, 2521–2530. doi:10.1016/j.visres.2007.06.001

Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., & Frith, U. (2003). Theories of developmental dyslexia: Insights from a multiple case study of dyslexic adults. *Brain*, *126*, 841–865. doi:10.1093/brain/awg076

Saksida, A., Iannuzzi, S., Bogliotti, C., Chaix, Y., Démonet, J. F., Bricout, L., … Ramus, F. (2016). Phonological skills, visual attention span, and visual stress in developmental dyslexia. *Developmental Psychology*, *52*, 1503–1516. doi:10.1037/dev0000184

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-prime: User's guide*. Pittsburgh, PA: Psychology Software Inc.

Valdois, S., Bosse, M. L., Ans, B., Carbonnel, S., Zorman, M., David, D., & Pellat, J. (2003). Phonological and visual processing deficits can dissociate in developmental dyslexia: Evidence from two case studies. *Reading and Writing: An Interdisciplinary Journal*, *16*, 541–572. doi:10.1023/A:1025501406971

Valdois, S., Bosse, M. L., & Tainturier, M. J. (2004). The cognitive deficits responsible for developmental dyslexia: Review of evidence for a selective visual attentional disorder. *Dyslexia*, *10*, 339–363. doi:10.1002/dys.284

van den Boer, M., de Jong, P. F., & Haentjens-van Meeteren, M. M. (2013). Modeling the length effect: Specifying the relation with visual and phonological correlates of reading. *Scientific Studies of Reading*, *17*, 243–256. doi:10.1080/10888438.2012.683222

van den Boer, M., van Bergen, E., & de Jong, P. F. (2014). Underlying skills of oral and silent reading. *Journal of Experimental Child Psychology*, *128*, 138–151. doi:10.1016/j.jecp.2014.07.008

van den Boer, M., van Bergen, E., & de Jong, P. F. (2015). The specific relation of visual attention span with reading and spelling. *Learning and Individual Differences*, *39*, 141–149. doi:10.1016/j.lindif.2015.03.017

van den Bos, K. P., Lutje Spelberg, H. C., Scheepstra, A. J. M., & de Vries, J. R. (1994). *De Klepel: Een test voor de leesvaardigheid van pseudowoorden [Klepel manual]*. Lisse, The Netherlands: Swets & Zeitlinger.

van Viersen, S., de Bree, E. H., Zee, M., Maassen, B., van der Leij, A., & de Jong, P. F. (2018). Pathways into literacy: The role of early oral language abilities and family risk for dyslexia. *Psychological Science*, *29*, 418–428. doi:10.1177/0956797617736886

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry*, *45*, 2–40. doi:10.1046/j.0021-9630.2003.00305.x

Vidyasagar, T. R., & Pammer, K. (2010). Dyslexia: A deficit in visuo-spatial attention, not in phonological processing. *Trends in Cognitive Sciences*, *14*, 57–63. doi:10.1016/j.tics.2009.12.003

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1994). Development of reading-related phonological processing abilities: New evidence of bidirectional causality from a latent variable longitudinal study. *Developmental Psychology*, *30*, 73–87. doi:10.1037/0012-1649.30.1.73

Ziegler, J. C., Pech-Georgel, C., Dufau, S., & Grainger, J. (2010). Rapid processing of letters, digits, and symbols: What purely visual-attentional deficit in developmental dyslexia? *Developmental Science*, *13*, F8–F14. doi:10.1111/j.1467-7687.2010.00983.x

Zoubrinetzky, R., Bielle, F., & Valdois, S. (2014). New insights on developmental dyslexia subtypes: Heterogeneity of mixed reading profiles. *PloS ONE*, *9*, e99337. doi:10.1371/journal.pone.0151015

Zoubrinetzky, R., Collet, G., Serniclaes, W., Nguyen-Morel, M. A., & Valdois, S. (2016). Relationships between categorical perception of phonemes, phoneme awareness, and visual attention span in developmental dyslexia. *PloS ONE*, *11*, e0151015. doi:10.1371/journal.pone.0151015