Journal of Research in Reading, ISSN 0141-0423 *DOI:10.1111/1467-9817.12330*
Volume 43, Issue 4, 2020, pp 577–596

Predictors of single word spelling in English speaking children: a cross sectional study

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Background: The study aimed to explore to what extent variables associated with lexical and sublexical spelling processes predicted single word spelling ability and whether patterns of lexical and sublexical processes were different across ages.
Methods: Beginning (mean age 7 years, $N = 144$) and advanced (mean age 9 years, $N = 114$) English-speaking spellers completed tasks associated with sublexical processing (phonological ability and phonological short-term memory), lexical processing (visual short-term memory and visual attention span) and factors known to predict spelling (e.g., rapid automatised naming).
Results: Phonological ability, rapid automatised naming, visual short-term memory and visual attention span were significant predictors of spelling accuracy for beginning spellers, while for more advanced spellers, only visual attention span was a significant predictor.
Conclusions: The findings suggested that for beginning spellers, both lexical and sublexical processes are important for single word spelling, but with increasing

literacy experience, lexically related variables are more important.

Keywords: spelling, phonological ability (PA), rapid automatised naming (RAN), visual attention span processing (VAS), visual short-term memory (VSTM)

Highlights

What is already known about this topic

- Research in the past has investigated predictors of single word spelling.
- An association between phonological ability and spelling performance has been established.
- Some studies have established an association between visual short-term memory and spelling, but others failed.

What this paper adds

- For the beginning spellers, phonological ability, visual short-term memory, visual attention span (VAS) and rapid automatised naming digits predicted variance in spelling after controlling for age and nonverbal reasoning.
- For the more advanced spellers, when VAS was included in the final regression analysis step, all other variables became nonsignificant, and VAS was the unique significant predictor.

Implications for theory, policy or practice

- The present study increased the clarity of our theoretical understanding of spelling development.
- Activities targeting both sublexical and lexical skills are important to enhance children's spelling performance in the early stages.
- Supporting only sublexical skills could lead to a reliance on sublexical processes, which is not optimal for spelling in English.

There has been much less research into the cognitive processes involved in the development of spelling than reading (Keilty & Harrison, 2015). Proficient spelling is not just a by-product of learning to read; it is important in its own right; children's early spelling attempts give insight into the cognitive and linguistic skills involved in literacy acquisition (e.g., Treiman, 2017), and spelling is positively associated with writing performance (Department for Education, 2012; Kim, Al Otaiba, Wanzek, & Gatlin, 2015). Competent writing entails automatic and fluent retrieval of words for transcription (e.g., Berninger et al., 2002). Paying conscious attention to spelling can cause a bottleneck for working memory, which may hamper important writing processes such as composition, editing and drafting (Berninger, 1999). Although there is a strong association between children's reading and spelling (Georgiou et al., 2019), the processes that have been found to make a significant contribution to reading have been less explored for spelling, and it is important to understand the underlying cognitive predictors of spelling beyond reading ability. In order to support children's spelling acquisition effectively, it is crucial to understand the processes involved and the cognitive skills that underpin them. Existing studies of beginning spellers vary widely in the variables examined, the tasks used (not only for cognitive correlates but also for the assessment of spelling) and the characteristics of the children sampled. These differences have made it difficult to identify the best predictors of spelling ability, how this can inform theory, and to develop appropriate strategies to support children's spelling effectively. The current study aims to increase our knowledge of the pattern of predictors of spelling in beginning and advanced spellers. We specifically focus our attention on visual short-term memory (VSTM) and visual attention span (VAS) (de Bree & van den Boer, 2019; van den Boer, van Bergen, & de Jong, 2015).

Differences between spelling and reading, such as the distinction between production versus perception, as well as the complexity of the task (phoneme–grapheme correspondences are more equivocal than grapheme–phoneme correspondences) may affect how and which cognitive processes are associated with spelling, for example, rapid automatised naming (RAN) (Georgiou, Torppa, Manolitsis, Lyytinen, & Parrila, 2012; Stainthorp, Powell, & Stuart, 2013). Thus, we know much about the cognitive correlates of reading, but much less about the cognitive correlates of spelling and how they may vary as a function of competence. To interpret the cognitive correlates associated with spelling and how the pattern of associations between them and spelling change with age, we turn to dual-route (DR) models of spelling (Barry, 1994; Ellis & Young, 2013; Houghton & Zorzi, 2003; Tainturier & Rapp, 2001) and the lexical quality hypothesis (LQH) (Perfetti, 1992; Perfetti & Hart, 2002) as theoretical frameworks. These approaches assume that distinct processes – sublexical and lexical – are involved in spelling. We form our hypotheses on the basis of the differential contributions these processes may make for beginning and advanced spellers.

According to the LQH, well-established lexical representations will be mirrored in idealised spelling. By 'idealised', Perfetti (1992, p. 152) proposes that cognitive processes such as sequencing, memory and pattern confirmation underpin spelling skill. If any of these processes goes awry, then the item will be imperfectly represented in the lexicon. Therefore, our exploration of the cognitive correlates that underpin idealised spelling, such as phonological ability (PA), VSTM and VAS, might be critical in order to establish the skills that teachers and researchers need to facilitate in order to support competent spelling. Skilled spelling involves having accurate orthographic concepts, phonological information from spoken language and semantic information, as well as clear links between the three (Perfetti, 1992; Perfetti & Hart, 2002). As lexical quality increases, higher precision across all levels of representation should be achieved, and advanced spellers' focus should be on building high-quality orthographic representations. We, therefore, expect advanced spellers to demonstrate greater reliance on lexically rather than sublexically related processes, because of the number and quality of lexical entries they have in comparison with those of beginning spellers.

Dual-route models of spelling postulate two sets of processes to spell words, lexical and sublexical (e.g., Barry, 1994; Ellis & Young, 2013). Sublexical processes are responsible for the production of nonwords and low-frequency regularly spelled words, and lexical processes are responsible for spelling unpredictable or irregular words (e.g., *mortgage*) as well as familiar regularly spelled words. Much of the evidence to support the existence of the two processes comes from adult studies and research in cognitive neuropsychology. Here, we find cases of surface dysgraphia, where regular/nonwords are more likely to be spelled correctly than irregular words (Beauvois & Dérouesné, 1981) and conversely, phonological dysgraphia where nonwords are spelled incorrectly (Shallice, 1981). We, therefore, expect beginning spellers to demonstrate greater reliance on sublexically rather than lexically related processes, because relatively speaking, most of the words they initially encounter will be unfamiliar and/or lower in frequency and regular, compared with words encountered by older, more advanced spellers.

According to the LQH and DR model, we may see that children rely on lexical and sublexical skills differentially during the course of spelling acquisition. It is likely that both types of process will be used concurrently before skilled spelling is achieved. However, beginning spellers might be influenced by cognitive processes associated mainly with sublexical processes, not only because many words will be unfamiliar and relatively lower in frequency but also because of the strong influence of phonology in early spelling from phonics-focused instruction in UK schools. Phonologically appropriate responses (e.g., *cough* COF) are frequently observed in novice spellers (Treiman, 2017). For advanced spellers, we might expect spelling to be more strongly influenced by cognitive processes associated with lexical processing. The reasons for this include spellers' developing knowledge of the high level of inconsistency in English orthography, less emphasis and/or reliance on phonics in instruction, and a greater familiarity with known words.

Phonological ability (the skill to identify and manipulate individual speech sounds) and phonological short-term memory (PSTM) are often measured by tasks such as phoneme deletion and nonword repetition, respectively. Research indicates that phonological processing ability plays an important role in spelling development for English (Caravolas, Hulme, & Snowling, 2001; Ehri et al., 2001; Furnes & Samuelsson, 2011; Stuart & Masterson, 1992; Treiman, 2017), for other more transparent alphabetic orthographies (Caravolas et al., 2012; Caravolas, Volin, & Hume, 2005; Niolaki & Masterson, 2012) and for atypical spellers (Bradley & Bryant, 1983; Niolaki, Terzopoulos, & Masterson, 2014). As for reading, much of the evidence for the link between PA and spelling comes from emergent spellers, with less known about its role in later development. It is difficult to disentangle PA from PSTM, but there is some evidence that when compared with PA, PSTM contributes more to nonword spelling than PA does (Passenger, Stuart, & Terrell, 2000). Savage et al. (2005) found that PSTM could discriminate poor from average spellers even after controlling for the effect of RAN and PA. PA, especially phoneme awareness, is associated with sublexical processing because a necessary part of (sublexical) decoding is the ability to segment a lexical phonological form into component parts and translate each sound into the corresponding letter(s). Thus, PA and PSTM are expected to be cognitive correlates of spelling tapping sublexical skills, and their association with spelling should be more pronounced for beginning spellers than for more advanced spellers.

Rapid automatised naming has also been found to predict reading and spelling skill. It is measured by counting how many objects/digits/letters can be named in a restricted timed period. This skill, the speedy processing of sound–symbol associations, is thought to be important for both reading and spelling because both rely on knowledge of how letters/words map to sounds and vice versa. Despite research indicating that RAN predicts reading ability independently from PA (e.g., Hagiliassis, Pratt, & Johnston, 2006; Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007; Stainthorp, Powell, Stuart, Quinlan, & Garwood, 2010; Swanson, Trainin, Necoechea, & Hammill, 2003), there is little agreement as to what the underlying cognitive skill determining this relationship is, or whether indeed RAN is entirely independent of PA (de Jong, 2011; Protopapas, Katopodi, Altani, &

Georgiou, 2018). When it comes to spelling, though, the evidence is even less clear-cut than for reading.

Evidence that RAN plays a role in spelling comes from studies of poor spellers, where poor spellers can be discriminated by poor RAN digits (Savage et al., 2005; Savage & Frederickson, 2006), independently of phonological processes. Further evidence suggests that poor spellers may have a RAN (letters and digits composite score) deficit specifically associated with irregular word spelling (Stainthorp et al., 2013), suggesting that RAN may be associated with a child's ability to establish good quality orthographic representations (Loveall, Channell, Phillips, & Conners, 2013). For Dutch spelling (de Bree & van den Boer, 2019), RAN (letters and digits composite score) was associated with spelling for beginning but not for advanced spellers, suggesting that RAN taps phonological processes rather than lexical ones. de Bree and van den Boer (2019) adopted Moll, Fussenegger, Willburger, and Landerl's (2009) interpretation of RAN (digit and object naming task) suggesting a possible visual-to-verbal conversion fluency association – a phonological process. Different findings have been reported depending on the diverse RAN measures used. Thus, results seem to be inconclusive.

The cognitive skills underlying RAN are not well understood. Recent studies suggest RAN might be tapping orthographic skills, but evidence here is scant and even more so for spelling. We, therefore, considered RAN as a likely predictor of spelling, but its alliance with sublexical or lexical processing might be determined by spelling skill. If RAN and spelling are correlated because both rely on visual serial processing and phonological representations (de Bree & van den Boer, 2019; de Jong, 2011; Moll et al., 2009; Protopapas et al., 2018), then RAN should be more important for beginning spellers. However, if the association is determined by the ability to establish orthographic representations (Bar-Kochva & Nevo, 2019; Stainthorp et al., 2013), one should expect that the association between RAN and spelling will be stronger for more advanced spellers. Here, we utilised RAN digits as well as RAN objects in line with previous spelling studies (de Bree & van den Boer, 2019; Moll et al., 2009; Savage et al., 2005; Stainthorp et al., 2013). The former seems to be a better predictor of spelling than RAN objects/colours and letters (Savage et al., 2005; Stainthorp et al., 2013; van den Boer et al., 2015).

There is less research relating literacy skills to VSTM than to PA and RAN. VSTM, often measured by tasks that require participants to reproduce a sequence of abstract shapes after a delay, measures the extent to which visual information can be retained accurately in memory for a short period of time. This would be associated with establishing lexical representations because it focuses on memory of the whole word's orthographic form. Several studies on adults with impaired spelling ability have reported a selective deficit in VSTM for sequences (Goulandris & Snowling, 1991; Romani, Ward, & Olson, 1999). If VSTM is associated with establishing orthographic representations, then it should be associated more strongly with advanced spellers' performance.

VAS is a relatively recently investigated process, although it has been explored more in relation to reading than spelling (Bosse, Tainturier, & Valdois, 2007; Bosse & Valdois, 2009). VAS corresponds to the elements an individual can process simultaneously in a single percept (Zoubrinetzky, Bielle, & Valdois, 2014). Usually, VAS is measured using letters, but some researchers also use digits; this variance in tasks can affect the interpretation and findings. Poor performance in reporting letters from briefly presented arrays has been interpreted as reflecting a restricted VAS. Bosse et al. (2007, 2009) demonstrated that this affects the establishment of orthographic representations in typical and dyslexic children. However, this research focused on reading, not spelling.

Only a handful of studies have investigated VAS in relation to spelling. In Dutch children, van den Boer et al. (2015) found that VAS (a combined task of digits and letters) and PA were the most significant predictors of spelling, followed by PSTM and RAN. They suggested that the strong association between VAS and spelling reflected simultaneous activation of phonological units, reflecting greater sublexical rather than lexical/visual processing. One should note that in that study, only advanced spellers were assessed (fourth graders). However, de Bree and van den Boer (2019) assessed beginning and advanced spellers to address this issue and found no association between VAS and spelling for beginning spellers, although they found an association for the advanced group. Based on this, they suggested that VAS is more strongly linked to lexical/visual processes than phonological processes. For the inconsistent English orthography, where both sublexical and lexical processes seem necessary for accurate spelling (e.g., Perfetti, 1992), one could hypothesise that if VAS is associated with sublexical processes, it should be more strongly associated with spelling in beginning than advanced spellers. However, if it is a lexically related skill, it should be associated more strongly with advanced spellers' performance. Stainthorp et al. (2010) also noted that VAS and its relationship with RAN have not been explored. Consequently, we also aimed to identify the relative contributions of the two variables to spelling, because they seem to involve similar processes, such as articulation of visually presented stimuli. For consistency with previous studies that investigated VAS, we utilised the letter report task developed with English-speaking children (Bosse et al., 2007).

The present study

The overall aim of the study was to examine cognitive variables associated with single word spelling and to investigate differences between beginning and advanced spellers that might inform theoretical models. This aspect of spelling development is rarely captured in existing studies (de Bree & van den Boer, 2019, for a study in Dutch) and less so in English. Hence, it is still unclear whether sublexical and lexical processing is differentially employed over time, as suggested by both the LQH and DR model. According to DR models and the LQH, both sublexical and lexical skills are required for competent spelling. Sublexical skills might be more important for beginning spellers who have yet to develop established lexical representations. Lexically related processes should show stronger relationships with spelling for more advanced spellers. We consequently aimed to extend previous research by including in the present study PA, PSTM, RAN and VSTM, which have been found to be associated with reading. However, there is less evidence that these factors are consistently associated with spelling. We also examined the association between spelling and VAS, something that has not been explored in English-speaking children. Previous research has focused more on the performance of beginning spellers, yet spelling seems to be a harder skill to develop in comparison with reading (Niolaki et al., 2019). Thus, we explore what affects more advanced spelling as well.

For sublexical skills, phonological processing ability seems to be important. Therefore, we expect PA and PSTM to exert a greater influence on the spelling ability of beginning spellers than advanced spellers, as early spelling is primarily a phonological skill (Ehri, 2017). For lexical skills, VSTM is implicated in establishing orthographic representations, so we expect it to influence mainly the spelling performance of the advanced spellers. If RAN and VAS are linked to sublexical processes, then we anticipate that they will be associated more with beginning than advanced spellers' ability. However, if they are related to lexical processing, we anticipate that they should be more strongly associated with the spelling performance of the advanced spellers. This is because a shift from sublexical to lexical processing can be expected as part of normal spelling development: lexical representations become more established with age and experience, and use of phonological (sublexical) processes becomes less efficient than the use of high-quality lexical representations.

Method

Participants

The children ($N = 258$; 150 girls) were recruited from four year-groups in schools in two UK cities and were divided into beginning and advanced spellers by year group. Literacy instruction in the schools involved a phonics-based approach and look–say–cover–spell methods for the advanced spellers. The beginning speller group had 144 children (mean age 7.05, range 6.04–7.90, 69 girls), and the advanced speller group had 114 children (mean age 9.02, range 8.00–10.50, 68 girls).

Materials

Scores were collected for background assessments of nonverbal reasoning, using the *Matrix Analogies Test* (Naglieri, 1985), and reading, using the *Diagnostic Test of Word Reading Processes* (Forum for Research in Language and Literacy, 2012). Spelling was assessed using the *Wechsler Individual Attainment Test* – second edition (WIAT-II) Teachers' Edition (Wechsler, 2005), which assessed spelling of both individual graphemes (e.g., <m>) and words. Administration involved presentation of the spoken target grapheme(s), for example, <m> (or word), followed by a word (or sentence) incorporating the target for disambiguation. The WIAT-II begins with grapheme/s and progresses to words. The total correct possible score is 53.

Phonological ability was measured with the full spoonerisms subtest from the Phonological Assessment Battery (Frederickson, Frith, & Reason, 1997). PSTM was assessed with the digit span subtest from the Athena Test (Paraskevopoulos, Kalantzi-Azizi, & Giannitsas, 1999). RAN for objects was measured using the Comprehensive Test of Phonological Processes (Wagner, Torgesen, & Rashotte, 1999), and RAN for digits was measured using the Phonological Assessment Battery (Frederickson et al., 1997). We assessed VSTM using the Memory for Designs subtest from the Athena Test (Paraskevopoulos et al., 1999).

Visual attention span was assessed using the procedure of Bosse and Valdois (2009). The letters report task involved presentation of an array of five consonant letters on each trial using DMDX software (Forster & Forster, 2003). Strings appeared in uppercase on a laptop screen for 200 ms. Ten uppercase letters were used (B, D, F, M, L, T, P, H, S, and R), and each appeared the same number of times in each array position. Children were asked to name the letters in each array. The number of letters and number of arrays correctly reported were recorded, irrespective of whether letters were reported in the correct order or not. Cronbach's α estimates of reliability for the arrays ($\alpha = .89$ for the beginning spellers; $\alpha = .85$ for the advanced spellers) and total number of correct letters ($\alpha = .77$ for the beginning spellers; $\alpha = .79$ for the advanced spellers) were high.

A summary of participant characteristics, reading ability and spelling ability for the beginning and advanced spellers is given in Table 1. One-way ANOVAs revealed that for both groups, there was no significant effect of school for nonverbal ability, spelling or reading.

Procedure

Ethical approval was obtained from the University's Ethics Committee. Children were tested individually for reading, PA, PSTM, RAN, VSTM and VAS and in small groups for spelling and nonverbal ability in spring by trained research assistants.

Results

This study aimed to examine differences between beginning and advanced spellers in the patterns of association between spelling accuracy and cognitive variables PA, PSTM, RAN, VSTM and VAS. We present correlational analyses, conducted separately for each spelling group, followed by multiple regression analyses to understand which cognitive variables predict beginning and advanced spelling. Raw scores were used for spelling because standard scores were not available for the experimental tasks.

Visual attention span correct arrays and RAN digit scores were not normally distributed. However, results with transformed and untransformed variables were the same, and so the analyses presented are based on untransformed variables. A summary of the scores for PA, PSTM, RAN, VSTM and VAS for the beginning and advanced spellers is given in Table 2. The measures for VAS are correct arrays and total correct letters. There is statistically significant improvement in the performance of all the measures as the children progress in age.

Table 1. Chronological age, and raw and standardised scores in assessments of nonverbal reasoning, spelling and reading for beginning and advanced spellers.

	Beginning spellers		Advanced spellers		
	M	*SD*	*M*	*SD*	*F*
Age (years)	7.05	0.42	9.02	0.74	(1,257) 712.65***
Nonverbal reasoning: SS[a]	102.5	19.4	109.1	11.6	(1,238) 8.81***
Nonverbal reasoning: raw score (max = 34)	19.03	8.2	19.93	6.6	(1,238) 0.82***
WIAT-II Spelling SS	105.1	11.9	106.3	12.5	(1,257) 0.65
WIAT-II Spelling raw score (max = 53)	22.2	5.7	31.8	6.5	(1,257) 156.8***
DTWRP Reading SS	113	13.7	113	12.3	(1,146) 0.004
DTWRP Reading raw score (max = 90)	65.04	16.2	75.1	11.1	(1,146) 18.63***

DTWRP, *Diagnostic Test of Word Reading Processes*; WIAT-II, *Wechsler Individual Attainment Test* – second edition.
[a]SS = age-based standardised score (mean 100).
*$p < .05$.
**$p < .01$.
***$p < .001$.

Table 2. Mean scores for measures of PA, PSTM, RAN, VSTM and VAS for the two groups.

	Beginning spellers		Advanced spellers		
	Mean	*SD*	*Mean*	*SD*	*F*
PA Spoonerisms (max = 20)	8.15[a]	6.14	13.05	5.11	(1,190) 36.05***
PSTM (max = 32)	23.10	5.61	25.11	4.95	(1,188) 6.8**
RAN Digits (s)	33.92	13.61	26.77	7.62	(1,156) 15.69***
RAN Objects (s)	73.71	32.56	50.05	11.83	(1,204) 50.75***
VSTM (max = 32)	12.40	6.14	18.59	4.96	(1,188) 58.00***
VAS Correct arrays (max = 20)	1.47	2.59	5.67	5.14	(1,247) 69.15***
VAS Correct letters (max = 100)	48.18	19.06	74.6	14.38	(1,247) 146.05***

PA, phonological ability; PSTM, phonological short-term memory; RAN, rapid automatised naming; VAS, visual attention span; VSTM, visual short-term memory.
[a]All scores reported are raw scores.
*$p < .05$.
**$p < .01$.
***$p < .001$.

Correlation analyses

Partial correlations controlling for age (due to strong associations between the variables and age) are presented in Table 3 for the beginning (lower orthogonal) and advanced spellers (upper orthogonal).

As expected, spelling correlated strongly with reading for both beginning and more advanced spellers. Scores for spoonerisms were more strongly correlated with spelling than PSTM. For RAN, RAN digits were more strongly associated with spelling than RAN objects, and for VAS, correct arrays was more strongly associated with spelling than total correct letters. VAS scores were not significantly related to RAN measures, VSTM or PSTM for the beginning spellers, but there was a weak association with PA scores. For the advanced spellers, VAS scores were weakly associated with RAN digits but not RAN objects.

Regression analyses

Hierarchical regression analysis was conducted with WIAT-II spelling raw scores as the outcome variable. The predictor variables were selected from each group of measures that were most strongly correlated with spelling (Table 3). As a result, we included scores for spoonerisms but not PSTM, RAN digits but not RAN objects, and VAS correct arrays but not VAS total correct letters. Reading was not included as a predictor variable because it was the highest correlate for spelling for both beginning and advanced spellers and is therefore likely to share many underlying processes with spelling. Including a process that is so similar to the process of interest (i.e., spelling) is likely to obscure the underlying processes that we are interested in evaluating.

Variables were included in an order based on the findings of past research highlighting the importance of PA and RAN for spelling[1] (Caravolas et al., 2001; Stainthorp et al., 2013). In addition, we wished to examine whether VAS accounted for unique variance in spelling scores after controlling for well-established predictors of spelling. Finally,

Table 3. Partial correlations for spelling accuracy and scores on the other assessments for the two groups controlling for age (lower orthogonal – beginning spellers; upper orthogonal – advanced spellers).

	1	2	3	4	5	6	7	8	9	10
1. Nonverbal reasoning	—	.32**	.09	−.21	−.40***	.26*	−.05	−.01	.26*	.29**
2. PA Spoonerisms	.27**	—	.31**	−.42***	−.30**	.21*	.07	.09	.38***	.39***
3. PSTM	.08	.44***	—	−.10	−.02	.19	−.01	−.04	.16	.21*
4. RAN Digits	.04	−.02	−.08	—	.47***	−.29*	−.31*	−.31*	−.38**	−.40***
5. RAN Objects	−.05	.04	.05	.04	—	−.27**	−.05	−.08	−.13	−24*
6. VSTM	.03	.17	.35***	−.03	−.26*	—	.05	−.00	.07	.18
7. VAS Correct arrays	.14	.26*	.13	−.09	−.13	.02	—	.83***	.39***	.36***
8. VAS Correct letters	.12	.24*	.16	−.03	−.15	.15	.67***	—	.37***	.33***
9. Reading: DTWRP	.43**	.63***	.62***	−.16	.07	.25	.32*	.22	—	.63***
10. Spelling: WIAT-II	.25**	.52***	.39***	−.27*	−.12	.31**	.29**	.28**	.76***	—

DTWRP, *Diagnostic Test of Word Reading Processes*; PA, phonological ability; PSTM, phonological short-term memory; RAN, rapid automatised naming; VAS, visual attention span; VSTM, visual short-term memory; WIAT-II, *Wechsler Individual Attainment Test* – second edition.

*$p < .05$.

**$p < .01$.

***$p < .001$.

we were interested in the role of VSTM because of past contradictory findings. Residual and scatter plots suggested that the assumptions of normality, linearity and homoscedasticity were all met (Field, 2013).

Beginning spellers

The hierarchical regression models at steps 1 to 5 were all significant (*F*s $p < .001$). At step 1, age was the only significant contributor. Each variable, added at subsequent steps (PA, RAN, VSTM and VAS), was significant and resulted in a significant final model (Table 4), accounting for 56% of the variance in spelling.

Advanced spellers

The hierarchical regression models were significant (*F*s $p < .001$) at every step. At step 1, age was the only significant contributor. After the addition of each variable at steps 2 to 4 (PA, RAN and VSTM), only RAN was significant. However, at step 5, VAS was the only significant predictor, resulting in a significant final model (Table 5), accounting for 49% of the variance in spelling.

Discussion

This study aimed to investigate predictors of spelling ability in beginning (7-year-old) and more advanced (9-year-old) spellers. Specifically, we aimed to investigate the associations between spelling and known correlates, PA, PSTM and RAN, as well as lesser known ones: VSTM and VAS. Our findings highlighted that the pattern of associations between spelling and the targeted variables differed according to the age of the children. We anticipated, based on the DR models of spelling (Barry, 1994; Ellis & Young, 2013; Houghton & Zorzi, 2003; Tainturier & Rapp, 2001) and the LQH (Perfetti, 1992; Perfetti & Hart, 2002), that although beginning spellers might use both lexical and sublexical

Table 4. Hierarchical regression analyses with spelling as the outcome for beginning spellers (final model).

Predictor	*b*	*SE*	*β*	*t*	Adjusted R^2
Intercept	10.2	7.52		1.35	
1. Age	1.4	1.01	.12	1.36	
Nonverbal reasoning	0.05	0.05	.08	0.99	
2. PA Spoonerisms	0.32	0.07	.37	4.3***	
3. RAN Digits	−0.14	0.0	−.25	−3.1**	
4. VSTM	0.22	0.08	.22	2.6*	
5. VAS Correct arrays	0.37	0.16	.20	2.3*	
					.56

PA, phonological ability; RAN, rapid automatised naming; VAS, visual attention span; VSTM, visual short-term memory.
*$p < .05$.
**$p < .01$.
***$p < .001$.

Table 5. Hierarchical regression analyses with spelling as the outcome for advanced spellers (final model).

Predictor	*b*	*SE*	*β*	*t*	Adjusted R^2
Intercept	6.88	11.29		.61	
1. Age	2.3	1.19	.24	1.96	
Nonverbal reasoning	0.09	0.14	.08	0.69	
2. PA Spoonerisms	0.14	0.15	.11	0.95	
3. RAN Digits	−0.17	0.11	−.19	−1.64	
4. VSTM	0.07	0.14	.06	0.55	
5. VAS Correct arrays	0.58	0.16	.41	3.7***	
					.49

PA, phonological ability; RAN, rapid automatised naming; VAS, visual attention span; VSTM, visual short-term memory.
*$p < .05$.
**$p < .01$.
***$p < .001$.

processes, the influence of phonological/sublexical processes at the earlier stages would be stronger because of the emphasis on phonics instruction and high reliance on phonological processes in early spelling. Accordingly, we expected that PA and PSTM would exert a strong influence on spelling accuracy in the beginning spellers group. We hypothesised that if RAN, VSTM and VAS are sublexically related variables, they should be more influential for beginning spellers, whereas if they are lexically related, they should be more influential for advanced spellers.

In accordance with previous findings, the advanced spellers were more accurate than the beginning spellers (also de Bree & van den Boer, 2019, for Dutch children). Also, we found strong associations between reading and spelling, which confirm previous findings (de Bree & van den Boer, 2019; Georgiou et al., 2019). Spelling skill for both beginning and more advanced spellers was strongly associated with all the cognitive correlates apart from RAN objects for the beginning spellers and VSTM for the advanced spellers. The results of the regression analyses revealed that for the beginning spellers, PA, VSTM, VAS and RAN digits predicted variance in spelling after controlling for age and nonverbal reasoning, confirming our first hypothesis that these variables are sublexically related variables.

Rapid automatised naming digits remained a strong predictor even when age, nonverbal reasoning and PA were controlled and even when VSTM was inserted in the fourth step (consistent with de Bree & van den Boer, 2019; Georgiou et al., 2012; Savage et al., 2005; Savage & Frederickson, 2006). De Bree and van den Boer (2019) also reported an association between RAN digits and spelling in beginning spellers and therefore suggested that RAN is more aligned towards phonological (de Bree & van den Boer, 2019; De Jong, 2011; Moll et al., 2009; Protopapas et al., 2018) rather than orthographic processing (Bar-Kochva & Nevo, 2019; Stainthorp et al., 2013). Our findings here, with English-speaking children, corroborate the results from the transparent Dutch orthography. We did not find a strong association between RAN digits and spelling for the more advanced spellers, indicating that RAN and spelling are correlates due to visual serial processing of phonological representations; however, as the children gain stronger spelling knowledge, RAN's contribution to spelling weakens. This could be because RAN as a fluency task is less important for the more advanced spellers where the major success factor is not time but accurate and precise orthographic representations (van den Boer et al., 2015).

We also found that VAS was a strong predictor of English spelling for the beginning spellers. De Bree and van den Boer (2019) failed to find such an association and suggested that VAS is a lexically related variable rather than a sublexical one. A possible explanation for the different findings could be due to differences in the transparency between the two orthographies, English and Dutch. Dutch is a transparent orthography; therefore, children can rely on sublexical processes at the early stages of spelling acquisition (hence manifestations of the effect of PA and RAN and no contribution of VAS). Because English is an opaque orthography, although beginning spellers will rely heavily on sublexical processes, they will also use lexical processes. Thus, effects of both lexically and sublexically related variables will be important for single word spelling, in accordance with both the DR model and the LQH.

For the more advanced spellers, results from the regression analyses revealed that PA and RAN digits were not significant predictors of spelling accuracy, suggesting less reliance on sublexical processes for spelling, in line with predictions from DR models and the LQH. In the final model, VAS was the only significant predictor. This confirms our second hypothesis that advanced spellers with more experience in reading and spelling will rely on lexically related processes. Our results are consistent with previous studies (de Bree & van den Boer, 2019; van den Boer et al., 2015) in finding VAS as a unique predictor of single word spelling after controlling for PA and RAN, but not for beginning spellers (de Bree & van den Boer, 2019). These studies, and others (Marinelli, Zoccolotti, & Romani, 2020; Zoubrinetzky et al., 2014), also interpret VAS as tapping lexical processes.

In the current study, we found that VAS was weakly associated with PA for the beginning spellers and weakly associated with RAN for the advanced spellers, similar to previous research (Bosse et al., 2007; Bosse & Valdois, 2009). Bosse and Valdois suggested that some of the processes might be shared between the constructs, such as memory, articulation and visual scanning, but it also seems that VAS might be involved in the memorisation of lexical orthographic knowledge. Our regression analyses show VAS contributes uniquely to both beginning and advanced spelling. Thus, once shared components are accounted for, the unique aspect of VAS that does not overlap with other phonologically related processes and could be attributed to lexical processes predicts both beginning and advanced spelling. Although we predicted that beginning spellers will rely heavily on sublexical processes, because of the inconsistent English orthography, they will need to recruit lexical processes, maybe early on, in the learning process. Our sample of beginning spellers had already received 2 years of formal literacy instruction; thus, it could be that they were starting to use lexical processes for spelling. Consistent with this interpretation, the relative weight of VAS in predicting spelling is much greater for the advanced spellers than for the beginning spellers.

The results indicate a role for variables related to both lexical and sublexical processes for the beginning spellers and more reliance on lexical processes for the advanced spellers. The findings suggest further support for the LQH (Perfetti, 1992; Perfetti & Hart, 2002), which emphasises the importance of well-specified lexical representations with increasing literacy experience. Evidence from single-case treatment studies also supports the hypothesis because, for example, Kohnen, Nickels, Coltheart, and Brunsdon (2008) reported that the pretreatment quality of lexical representations, defined by the similarity of pretreatment errors to target spellings, was a significant component of success of the intervention. Thus, if a student has weak or degraded orthographic representations, this will have a detrimental impact on spelling.

Additionally, our results suggest that beginning spellers must have in place both sublexical and lexical skills to become good spellers, which is consistent with Niolaki and Masterson (2012) who found that both PA and VSTM were predictors of spelling in 7-year-old English-speaking children. Caravolas et al. (2001) did not find a significant association between VSTM and spelling in a longitudinal study with 4- to 8-year-old children. This could be because of the low VSTM scores in that study or to differences in the age of participants and tasks used. However, if VSTM taps lexically related processes, then it can be expected to predict spelling for the advanced spellers. Current findings speak against that; a possible explanation could be that VSTM with unfamiliar designs is important for the beginning spellers, who use VSTM as a process towards the establishment of detailed orthographic representations (i.e., memorising graphemic information, which maps onto phonological markers), but not for the advanced spellers, who have more detailed lexical representations.

Ehri and Wilce (1979), with beginning readers, demonstrated the importance of seeing and imaging spellings for the development of accurate orthographic and phonological representations. Similarly, Stuart and Coltheart (1988) suggested that beginning readers and spellers with no prior phonological skills will perform a reading or spelling task as one of committing visual strings to memory. Beginning spellers with weak or developing phonological skills will perform the spelling task in a similar way as they commit a string of unfamiliar visual tiles to memory; this skill seems to be tapped by the VSTM task used in the current study. This does not suggest that memory is absent from the encoding process of the advanced spellers; on the contrary, it suggests that as the children have created reliable orthographic entries, this skill ceases to be central.

In past research, PA has been found to be a robust predictor of spelling in young children (e.g., Caravolas et al., 2005; Caravolas et al., 2012; Ehri et al., 2001; Stuart & Masterson, 1992), and our study is consistent with this. However, for the more advanced spellers, we found that only VAS was a significant predictor – after controlling for age, nonverbal reasoning, PA, RAN and VSTM – which indicates strong reliance on lexical processes. The outcome remained the same when the order of the variables was reversed in the regression analysis, with PA added last and VAS correct arrays added first. Thus, our findings are consistent with studies suggesting that at least for more advanced spellers, PA and RAN do not make a significant contribution to spelling over and above the contribution of VAS (de Bree & van den Boer, 2019; van den Boer et al., 2015).

Limitations and future directions

To move beyond correlational designs that cannot easily establish causation (Nickels, Kohnen, & Biedermann, 2010), longitudinal designs or single-case experimental designs that can explore further associations and dissociations between variables (Nickels et al., 2010) should be considered. Alternative predictors of spelling performance, such as orthographic knowledge, morphological awareness, vocabulary and home literacy activities, were not included in the current investigation (Apel, 2011; Kim, Apel, & Al Otaiba, 2013). Thus, future studies should also include these variables. Furthermore, the cognitive variables we investigated in the current study have been primarily found to be associated with reading. De Bree and van den Boer (2019) found that including reading in their statistical model substantially reduced the strength of the cognitive correlates, reinforcing the suggestion that reading and spelling are likely to share many underlying processes. We took a parsimonious approach to understanding the pattern of processes involved in spelling by examining factors that are directly and theoretically implicated in spelling. We did not include more complex factors (e.g., reading) that might overlap considerably with spelling and therefore obscure the underlying processes. However, the inclusion of different measures and age groups in comparison with previous studies may have resulted in weaker associations.

Rapid automatised naming digits were found to be more strongly associated with spelling than RAN objects (which were not associated with beginning spelling and were only weakly associated with advanced spelling). Similar findings were reported by Donker, Kroesbergen, Slot, Van Viersen, and De Bree (2016). Additionally, the VAS array-report variable was close to floor for beginning spellers; however, this is not unexpected as the children's VAS capacity should increase with reading and spelling experience. With this in mind, we used this variable in the analysis as it was more significantly associated with spelling than VAS correct letters and a more appropriate measure of the attention window at a single glance. In terms of measuring spelling, it is important not to treat spelling ability as a single construct, as in the current study. Future research should include assessment of irregular, regular and nonword spelling to provide a more detailed account of the spelling correlates and their association with lexical and sublexical skills (Niolaki et al., 2019).

Educational implications and conclusion

The emphasis here has been on understanding cognitive factors in spelling, but our findings are of value to those in education. English orthography is highly inconsistent for spelling, so a focus on activities targeting both sublexical and lexical skills is important to enhance children's spelling performance in the early stages. Supporting only sublexical skill could lead to over-reliance on sublexical processes, which is not optimum for spelling in English, where selecting correct graphemes for phonemes and close attention to the exact sequence of letters is important. This is consistent with Perfetti and Hart (2002) and Ehri (1992) who argue that orthographic representations should become autonomous (with no need for sublexical or semantic feedback to achieve accuracy). Orthographic representations should be precise to indicate that the orthographic characteristics of the words have been amalgamated with phonological and semantic elements (Ehri, 1992). Thus, instruction should focus not only on sublexical processes in spelling but also on processes that facilitate the autonomous representation of orthography. We hope that this research may provide an incentive for further work focusing on spelling, the neglected counterpart of literacy.

Acknowledgements

The research was supported in part by a Central Research Fund Grant, European Scholarship, Onassis Foundation, Leventis Foundation and Wingate Scholarships awarded to the first author. The authors are grateful to Ravinder Johal for her help in data collection and to the teachers, parents and children of the participating schools.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available owing to privacy or ethical restrictions.

Note

1. PSTM was not included because it was highly correlated with PA (spoonerisms) and was not a significant predictor for both groups. (If included the outcome was the same.)

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Professor Jackie Masterson's main research interests are in the areas of literacy development and literacy difficulties. She has used models of skilled reading in order to provide a context for thinking about the set of cognitive processes that are required for competent reading and spelling. She has investigated potential sensory difficulties as underlying causes of literacy problems and has looked at relationships with verbal memory processes. Jackie's research interests are in literacy development and difficulties, cross-linguistic investigations of reading and spelling, and object and action naming.

Received 2 November 2018; revised version received 5 August 2020.

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