

# **Predictors of Greek spelling in primary and secondary school children**

## **Greek-spelling predictors; an investigation of literacy- and cognitive-related factors**

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### **Abstract**

Greek spelling has been less explored than reading, and studies looking at predictors have primarily focused on phonological ability (PA) and rapid automatized naming (RAN). Few studies have been conducted on visual attention span (VAS), although there is growing acknowledgement that spelling involves processes other than phonological ones. We investigated single-word spelling accuracy cross-sectionally with 145 students attending Grades 1-to-7 in Greece. Regression analyses conducted found that only PA was a significant predictor for the beginner spellers after controlling for reading speed and chronological age. VAS and RAN were significant predictors in addition to PA for the advanced spellers. This suggests that phonological and visual processes are important as the children gain more spelling experience. Analyses of the effects on spelling accuracy of the item-related variables printed word frequency and phoneme-grapheme probability supported those obtained from the child-related analyses. The educational implications of the findings are discussed.

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In recent years there has been increasing awareness of the importance of carrying out research into the processes involved in literacy acquisition in a range of languages. For example, Joshi et al. (2021) wrote *'most studies and theoretical models of writing are based on the English language, and it is generally assumed that what is true for English is also true for other languages'* (p.1). Yet, English is an outlier language in terms of transparency (Share, 2008) compared to more transparent orthographic systems, like Greek, which was evaluated to be the second most transparent orthographic system for reading among several European languages (Seymour et al., 2003). The transparency of the Greek orthography makes the contribution of this study important. Also, we know much about the cognitive processes that underpin reading, but much less about those underlying spelling, and a lot less about spelling in transparent writing systems, such as Greek. The present study aimed to increase our understanding of spelling development in transparent Greek. We investigated, for the first time, apart from phonological ability (PA) and rapid automatized naming (RAN), visual attention span (VAS).

Although strong associations have been reported between children's reading and spelling ability (Georgiou et al., 2020), 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 addition, despite the relation between reading and spelling, spelling is not just the opposite of the same mechanism and often (in most orthographies) asymmetry in the skills and their relative development has been found (Fletcher-Flinn et al., 2004; Georgiou et al., 2020). In order to support children's spelling acquisition effectively, it is crucial to understand the processes involved and the cognitive skills that underpin those, after controlling for the impact of reading skill (Niolaki et al., 2020).

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### Spelling

Spelling is defined as the process of writing words by using letters conventionally (Treiman, 2017) and constitutes an integral component of literacy, which is essential for someone's academic and professional achievement (Galuschka et al., 2020). Several studies have indicated that reading and spelling are interdependent skills from early grades (Desimoni, Scalisi, & Orsolini, 2012) through the whole process of development (Ye et al., 2021) relying on similar linguistic skills. For example, the ability to perceive, store, and manipulate phonological information and letter-sound correspondence knowledge play critical roles in learning how to read and spell effectively in alphabetic orthographies (de Bree & van den Boer, 2019; Ehri, 2017). Young children need to acquire knowledge of the names of printed letters and their sounds in order to learn how to read and write (Treiman et al., 1998). Greek-speaking preschool children have a better understanding of the sounds rather than the names of letters of the alphabet, particularly with regard to lowercase letters (Georgiou et al., 2006; Tafa & Manolitsis, 2003). This might be because of the highly consistent relationship between Greek letters and their corresponding sounds (Tafa & Manolitsis, 2008).

Yet, spelling is more taxing than reading in Greek, as in other languages, as there are usually more ways to spell a phoneme than to read a grapheme (Kessler & Treiman, 2001). All phonemes are orthographically represented, although ambiguities and inconsistencies exist (Nunes et al., 2006) which can be overcome by knowing the spelling rules (Kotoulas, 2004). For example, some of the vowels can be spelled in multiple ways (e.g., /o/ can be spelled with <ο> or <ω>; /e/ can be spelled with <ε> or <αι>; /i/ can be spelled with <ι, η, υ, οι, ει, υι>) (Kuperman et al., 2021). All consonants are pronounced, in contrast to English where consonants may be disregarded in the

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pronunciation of some words (e.g., *island, hymn*) (Nikolopoulos et al., 2006). However, in Greek there are also inconsistencies in spelling certain classes of consonants (e.g., palatal consonants /γγ-γκ/ which both correspond to /g/). Another major linguistic feature of Greek is the simplicity of its phonological structure, with a predominance of open consonant–vowel (CV) syllables (Nikolopoulos et al., 2006).

Because of the high degree of transparency of the Greek writing system, Greek speaking young children are expected to pass through the first phases of literacy development more quickly than their counterparts who are learning to read in languages with deep orthographies (Seymour & Duncan, 2001; Niolaki et al., 2022). Tafa and Manolitsis (2008) found that Greek-speaking novice spellers, who were both precocious and non-precocious readers in kindergarten, used a phonological spelling strategy, but progressed to using orthographic spelling strategies by the end of grades 1 and 2 respectively, confirming previous research findings with Greek-speaking readers (Koutsouraki, 2004).

In the Greek language, non-phonological spelling errors (that deviate from letter-sound associations (e.g., <elph> for <elephant>) are relatively rare compared to phonological errors (e.g., <elefant> for <elephant>) (Niolaki et al., 2014; Protopapas et al., 2013). Phonological errors can be "grammatical" errors on inflections <πόλι> /poli/= city instead of <πόλη>= /poli/, as well as "orthographic" errors on stems <ώρα> /ora/ = time instead of <ώρα> /ora/. The correct spelling may be determined by grammatical type (for inflectional suffixes, e.g., female noun with article <η πόλη> /i poli/ = the city), word formation processes (for derivational morphemes, e.g., base: περνώ /perno'/ to pass = derived: πέρασμα /pe'razma/ passage), or arbitrary lexical convention (historical/etymological reasons; for word roots, e.g., τυρί, /tiri'/ cheese), causing difficulties in learning to spell (Kuperman et al., 2021). This is particularly

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evident in Greek-speaking children with literacy difficulties who exhibit lower spelling performance than typically developing peers (e.g., Diamanti et al., 2018; Parrila et al., 2020).

### **Literacy-related and cognitive predictors of Greek spelling**

Different theoretical frameworks have been used in exploring the cognitive and linguistic processing mechanisms that are associated with spelling, and how the patterns of association change with age. The dual-route (DR) models of spelling have been widely used and are employed in the present paper. DR models postulate two sets of processes that are used to spell words, lexical and sublexical. Sublexical processes are responsible for the production of nonwords (e.g., *barle*) and low-frequency regularly spelled words (e.g., *trombone*), and lexical processes are responsible for spelling unpredictable or irregular words (e.g., *yacht*), as well as familiar regularly spelled words (e.g., *mat*) (Ellis & Young, 2013). It is likely that both types of process will be used concurrently before skilled spelling is achieved. However, beginning spellers may predominantly use sublexical processes as many words will not yet be entries in the orthographic lexicon, and because of the phonics-focused instruction in Greek schools (Porpodas, 1999; see also similar results for English, Niolaki et al., 2022b). On the other hand, advanced spellers are expected to use predominantly lexical processes (Niolaki et al., 2014; see also similar results in English, Niolaki et al., 2020), which involves storing and using whole word orthographic forms (Castles et al., 2009; Perry et al., 2010).

Treiman and Kessler (2022), in their IMP model of learning to spell, emphasise the integration of multiple patterns, such that phonological, semantic and orthographic representations interact simultaneously not only among each other but also with the orthographic processing system (Smith et al., 2021). Treiman and Kessler refer to

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orthography as the formal patterns of language and phonology as the functional ones, suggesting that both patterns are important for spelling, but for some items (i.e., pseudowords), the functional elements will be the most important ones, and for others (i.e., irregular words) the formal ones. Correspondingly, addressed (lexical) and assembled (sublexical) spellings are also incorporated in the IMP framework (Stainthorp, 2019, p.9). The main difference between the DR and IMP models is that, according to the latter, individuals have a predisposition to detect patterns which means that the probability of occurrence of letters and letter patterns can lead to learning of the word's spelling. As a result, the IMP model considers lexical and sublexical processing as being on a continuum, rather than being distinct processes. Thus, both the DR and the IMP models are considered appropriate when interpreting the findings from the current investigation.

### **Reading**

Reading requires the transformation of letters to sounds and spelling the opposite, hence, it is evident that reading and spelling are highly interrelated, irrespective of the orthographic systems having similar underlying linguistic and cognitive skills (see more in Papadopoulou et al., 2020). For example, spelling depends on the quality of lexical representations (Niolaki et al., 2022), and it has been found that systematic teaching of spelling had a significant effect on young print readers in grades 1 to 7 (Graham & Hebert, 2011). Additionally, gradual improvements in children's phonological and orthographic knowledge have been shown to impact spelling development (Daffern, 2017). However, research has indicated an internal asymmetry between those skills in most orthographic systems. For instance, Greek is approximately 95% consistent in the reading direction and almost 80% in the spelling direction suggesting that Greek is easier to read than to spell (Protopapas & Vlahou,

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2009) and this unavoidably leads to delay in spelling development (Diamanti et al., 2018). In the current study we used reading as a control variable. We explored the effect of PA, RAN and VAS after controlling for the effect reading speed. It might be the case that due to the influence of reading on the literacy and cognitive correlates their impact on spelling is weakened or strengthened.

### **Phonological ability**

The important role of phonological ability (PA) in spelling development has been attested to by cross-sectional and longitudinal studies (e.g., Al-Otaiba et al., 2010; Caravolas et al., 2012; Harrison et al., 2016; Lervåg & Hulme, 2010; Moll et al., 2014; van den Boer et al., 2015; Nielsen & Juul, 2016). However, not all studies have found a significant contribution of PA to spelling (Georgiou et al., 2012). PA, especially phoneme awareness, is associated with sublexical processing because a necessary part of decoding is the ability to segment a lexical phonological form into component parts and associate phonemes with graphemes (deBree & van den Boer, 2019; Niolaki et al., 2020). Reports of a weak contribution of PA to spelling may be due to the time when the skill was assessed (PA is more likely to be a significant predictor in the case of younger students) or when the assessment involves individual phonemes rather than larger units (Georgiou et al., 2012).

Mouzaki, Protopapas, and Tsantoula (2008) conducted a longitudinal study with 55 Greek-speaking children who were first tested at the end of kindergarten, before formal literacy instruction began. The children were assessed again in the middle of first grade (soon after formal instruction began). The authors found a strong association between PA and spelling performance. In agreement with earlier findings of Porpodas (1999) with young Greek speakers, they found poorer spelling performance in children with weak phonemic awareness. In similar vein, Nikolopoulos et al. (2006), in a

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longitudinal study with Greek children, initially in Grades 2 and 4, found that PA was a predictor of spelling at both Time 1 (when the Grade 2 children were aged seven and the Grade 4 children were aged nine) and at Time 2 (when the children were eight- and ten-years-old). Additionally, they reported that PA was a more powerful predictor of spelling than reading skill, and this was justified because spelling is heavily dependent on an explicit translation of phonemes into graphemes (Nikolopoulos et al., 2006). A strong relationship between PA and reading and spelling was also reported by Kotoulas (2004) who conducted a study with 280 Greek-speaking pupils with and without learning difficulties attending Grade 1 to 6 and also in a more recent study with Greek children by Kargiotidis et al. (2021).

### **Rapid Automatised Naming (RAN)**

In RAN tasks participants are assessed for the speed with which they can name a series of visually presented familiar items, such as colors, objects, letters, or digits (Onochie-Quintanilla et al., 2019). Research has established the intimate connection between RAN and spelling ability (e.g., Landerl & Wimmer, 2008; Niolaki et al., 2020, 2022; van den Boer et al., 2015; Kargiotidis et al. 2021), however, the meta-analysis of Chen et al. (2021) indicated a moderate association between RAN and spelling. The meta-analysis also revealed that the relationship of RAN and spelling was stronger in opaque orthographies than in transparent or intermediate orthographies, was stronger in the case of real word spelling compared to pseudoword spelling, and was also stronger for RAN letters and digits, compared to RAN objects and colors.

Some of the evidence for the role of RAN in spelling comes from studies of poor spellers. For example, Savage et al. (2008) and Savage and Frederickson (2006) found that poor spellers could be discriminated by poor RAN digit performance, independently of phonological processing abilities. Stainthorp et al. (2013) reported

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that poor spellers had a RAN deficit (they assessed letter and digit RAN and used a composite of the two in their analyses) that was associated specifically with irregular word spelling. This indicated that RAN may be associated with the ability to establish good quality orthographic representations (Loveall et al., 2013). De Bree and van den Boer (2019) assessed Dutch speaking children in spelling and letter and digit RAN. The composite RAN score was associated with spelling for beginning (Grade 1) but not for more advanced (Grade 2) spellers. Since, as noted earlier, younger or less experienced spellers are expected to rely more on phonological processes for spelling, the finding indicates that RAN is associated with phonological processes rather than lexical ones. De Bree and van den Boer (2019) adopted Moll et al.'s (2009) interpretation of RAN. According to this explanation RAN involves visual-to-verbal conversion fluency – a phonological process. Similarly, Niolaki et al. (2020) found that RAN was associated with early spelling performance in younger compared to older English children. However, when the same researchers (Niolaki et al., 2022) used a more fine-grained spelling assessment comprising irregular words, regular words and pseudowords they found that RAN was a significant predictor of irregular word spelling in Year 5 and 6 children, and it was a significant predictor of regular word and pseudoword spelling in years 2 and 6. The findings indicate that RAN may be associated with both lexical and sublexical processes.

As for the Greek language, Nikolopoulos et al. (2006) failed to find that RAN was a longitudinal predictor of spelling performance with Greek speaking children, while, in contrast, Georgiou et al. (2012) found that RAN was a unique predictor of spelling in English- and Greek-speaking children, but not in Finnish-speaking children. This suggests an association of RAN with lexical processes, since English and Greek are less transparent for spelling compared to Finnish. Thus, it should be informative to

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investigate further the association between Greek spelling and RAN for beginning and advanced spellers, especially in an orthography that is considered to be rich in phonological, orthographic and morphological patterns.

### **Visual Attention Span**

Another cognitive process, whose role in spelling is under-researched till now, is visual attention span (VAS). VAS refers to the number of units, such as letters or clusters, that can be processed simultaneously in one glance (e.g., Valdois et al., 2004; Valdois et al., 2003). For consistency with previous studies that investigated VAS, we utilized the letter report task developed with English-speaking children (Bosse et al., 2007). Poor performance in reporting letters from briefly presented arrays has been interpreted as reflecting a restricted VAS. Bosse et al. (2007) and Bosse and Valdois (2009) reported findings indicating that VAS affects the establishment of orthographic representations in single word reading in typically developing readers and in dyslexic children. This has also been confirmed in a recent computational study which successfully demonstrated that VAS taps orthographic learning beyond the influence of phonological decoding (Ginestet et al., 2022).

Only a handful of studies have investigated VAS in relation to spelling. Van den Boer et al. (2015) assessed this relation in advanced spellers in fourth grade and found that VAS and PA were the most significant predictors of spelling in Dutch, followed by phonological short-term memory and RAN. In another study, de Bree and van den Boer (2019) assessed beginning and advanced spellers to address this issue and found an association only for the advanced but not for the beginning spellers which may indicate that VAS is more strongly linked to lexical/semantic than phonological processes.

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Niolaki et al. (2020) conducted a study with English-speaking beginning and advanced spellers. They found a strong influence of VAS for the advanced spellers. This finding agrees with an interpretation that VAS is primarily a visual task and therefore associations with literacy skills are due to the role of VAS in the access, retrieval and storage of orthographic information during reading and spelling (e.g., Valdois et al., 2004). In line with this interpretation, Zoubrinetzky et al. (2014) reported that children with only a VAS difficulty scored lower in real-word spelling but similarly to age-matched controls in pseudoword spelling.

Also, in Greek Niolaki and Materson (2013) reported a case study of an adolescent, RF, who had surface dyslexia, which was manifested by difficulty in spelling irregularly spelled words and slow reading. RF was found to have very poor performance in assessments of VAS, but no evidence of a phonological deficit. The researchers proposed that the results indicate that VAS is associated with orthographic rather than sublexical processes. This provides further support for the expectation that VAS could influence spelling performance in advanced but not beginning spellers, since for the latter group sublexical processing will be the predominant means for spelling.

### **Item characteristics**

In order to provide additional indication of the use of lexical and sublexical spelling processes we conducted item analyses. Spencer (1999; 2007) previously conducted item analyses with spelling accuracy data from a large cohort of children in Years 2 to 6. The stimulus-related variables included in the analyses were, among others, printed word frequency and least transparent phono-grapheme probability (LTPG). Phono-grapheme probability referred to the probability of a phoneme corresponding to a particular grapheme in the language (i.e., <e> or <ai> for /e/).

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Spencer found that both lexically-related variables (word frequency) and sublexically-related ones (LTPG probability) were significantly associated with the children's single word spelling accuracy. Niolaki and Masterson (2012) also found in a cross-linguistic study with (6- to 10-year-old children) that both variables were important for English and Greek single word spelling, however, the effect of word frequency was larger than the effect of LTPG probability for English speakers, while the opposite pattern was observed for spelling in Greek. It is therefore interesting to see in a larger sample with Greek-speaking participants if LTPG probability or word frequency are important influences for the children's single word spelling and whether there is a difference for beginning vs advanced speller groups.

### **The present study**

The current study aimed to explore in beginning and advanced spellers the role of PA, RAN and VAS. Although there are some studies that have looked at the association between spelling and PA and RAN, this research primarily involved younger spellers. In the current cross-sectional study, we wanted to explore if the associations differ as the children became more experienced spellers. Beginning spellers are expected to demonstrate greater influence of sublexically-related processes, because most of the words they initially encounter will be unfamiliar and/or lower in frequency compared with words encountered by advanced spellers (Barry, 1994). Whereas more advanced spellers would be expected to show greater influence of lexically-related variables rather than sublexically-related processes, as they have greater experience with a number of different words (high and low in frequency).

It is also the first study in Greek speaking children, as far as the authors are aware, to examine the relation of VAS with spelling of beginning and advanced spellers. We aimed to explore to what extent variables associated with lexical/semantic

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processes (i.e., VAS and perhaps RAN) and sublexical spelling processes (i.e., PA and perhaps RAN) would predict single word spelling ability after controlling for age and single word reading skill. We controlled for single word reading as we wanted to see if variables that are associated with both reading and spelling will still impact on spelling after controlling for the influence of reading.

Stainthorp et al. (2010) suggested that VAS seems to tap similar processes to RAN, i.e., production of verbal output in response to visually presented stimuli. Thus, we aimed to examine their unique contributions to single word spelling. For the Greek orthography, where both sublexical and lexical processes seem necessary for accurate spelling (e.g., Barry, 1994), 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 process, it should be associated more strongly with advanced spellers' performance.

We, therefore, expected:

- due to the transparency of the Greek orthography PA to be significantly associated with spelling for both beginner and advanced spellers;
- that if RAN taps both lexical/semantic and phonological processes (Chen et al., 2021; Niolaki et al., 2022), it should be associated with spelling skill for both advanced and beginner spellers;
- VAS as a variable associated with lexical/semantic processes should affect spelling only for the advanced spellers;
- for beginning spellers item analyses with the spelling accuracy scores should show more evidence of the influence of sublexical stimulus-related variables (LTPG probability), for advanced spellers the same analyses should reveal less evidence of the influence of sublexical stimulus-related variables.

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### Methods

#### Participants

The participants were 145 monolingual Greek-speaking children from Crete and Cyprus ( $N=107$  and 38, respectively), they all came from inner city schools, and they represent a typical student population from both islands. The children were recruited from private ( $N=26$ ; 12 were girls) and state schools, and 56 were girls in total. No exclusionary criteria were applied, all children who returned a consent form signed by their parents/guardians participated in the study. Their age ranged from 6;8 to 13;0 (mean=9.5,  $SD=1.5$ ).

The children were divided in two groups of beginning (Grades 1 to 3) and advanced spellers (Grades 4 to 7). The first group had 63 children (37 males, mean age 8 years 1 month ( $SD=.86$ )). The second group had 82 children (52 males, mean age 10 years 5 months ( $SD= 1.1$ )). Literacy instruction in the children's schools involved a phonics-based approach. For the older children (advanced speller group), the formal teaching of grammatical, syntactic and orthographic rules is reinforced. The children practice spelling almost every day from Grade 1 and they also have spelling homework daily. All children reported that their first language was Greek.

Beginning spellers attended Grades 1 to 3 and advanced spellers were from Grades 4 to 7. We selected this grouping as Loizidou-Ieridou et al. (2009) found a strong effect of grapheme-phoneme regularity in younger participants (6- to 7-year-old children). Similar results were reported by Porpodas (1999). Aidinis (1998) in a cross-sectional study conducted with 7- to 10-year-old children, found that a developmental sequence in spelling was observed similar to that found in English children. Initially

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children use a phonological strategy (choosing the most common vowel grapheme among the alternative graphemes), older children adopted the alternative vowel/s instead of the most common, and over-generalised, and only by Grade 5 children consistently spelled using the correct morphological rule. A similar trend was observed by Giannouli and Harris (1997) who found in a longitudinal study (following children from nursery to Grade 3) that Greek children after three years of formal schooling can master the basic morpho-syntactic rules. We based our age groupings for the analysis of results on this evidence.

### **Materials**

Single word reading speed and spelling, as well as PA, RAN and VAS, were assessed with the tasks described next.

### ***Literacy assessments***

**Single word spelling.** The stimuli from Masterson et al. (2008) were employed in a spelling to dictation task. A single randomized order was composed for presentation purposes. During testing, presentation of each target word was followed by a sentence incorporating the target for disambiguation. Data consisted of the number of items spelled correctly. The mean number of letters for the 60 words is  $m = 6.7$  ( $SD=1.9$ ). The items cover a wide range of psycholinguistic variables in Greek and incorporate simple and complex spelling rules and consonant clusters and singletons. In addition, the referents of the words are known concepts to most children from the age of 6 years. Word frequency values were obtained by Terzopoulos et al. (2016) and their mean frequency per million was  $m = 93.3$ ,  $SD= 145.7$ . The items differed in regularity, although grapheme-phoneme correspondences in Greek are straightforward, phoneme-grapheme correspondences are not, due to the different vowel choices (i.e., /e/ having

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two different grapheme choices <ε> and <αι>). Of the 60 words in the spelling list, 26 were regular words (with regularity defined in terms of use of the most frequent grapheme to represent a phoneme) and 34 irregular words. Regular and irregular words did not differ in number of phonemes ( $t(58)=1.7$   $p<.05$ ) or frequency ( $t(58)=.78$ ,  $p<.05$ ). The fact that the list includes a few more irregularly spelled items reduces the possibility of ceiling effects influencing the spelling accuracy in the older spellers. The reliability coefficient, based on the sample of children in the study, was high  $\alpha = .95$ .

**Single-word reading speed.** In the absence of an available standardized reading test for Greek at the time the research was conducted, the stimuli from Loizidou-Ieridou et al. (2009) were adopted. The time taken to read aloud the total set of items (i.e., words and nonwords) was calculated, as reading fluency is considered a better indicator than reading accuracy for children's reading performance, especially in a transparent orthography like Greek. The stimuli consist of 40 words and 40 nonwords. Half the items are short (two and three syllables in length) and half long (four and five syllables) in each category. Shorter items were presented first followed by longer ones and real words were followed by nonwords. Words and nonwords were tested separately. The reliability coefficients for accuracy were  $\alpha=.80$  for words and  $\alpha=.73$  for nonwords.

### ***Cognitive assessments***

**Phonological ability (PA).** The blending subtest from the Athena Test (Paraskevopoulos, Kalatzi-Azizi & Giannitsas, 1999) was used to assess PA. The child heard a series of phonemes they had to blend to make a real word. The discontinue criterion was three consecutive errors. One point was given for each correct correctly blended item, and the maximum correct score was 32.

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**Rapid automatised naming of digits and letters (RAN).** Children were asked to name the digits and letters from the Phonological Assessment Battery (Frederickson et al., 1997). The digits are presented on two cards, with 10 groups of five digits/letters on each card. Children are asked to name the items as quickly as possible. The time taken to name all the digits and letters (letter sounds) was recorded in seconds. The letters used in the task were six lowercase high frequency letters ( $\alpha$ ,  $\kappa$ ,  $\pi$ ,  $\lambda$ ,  $\epsilon$ ,  $\sigma$  /a, k, p, l, e, s, respectively) mean frequency = 6.97,  $sd = 2.9$ . The combined score from the two tasks was used in the analyses. Reliability coefficients reported by the test developer are  $\alpha=.85$  for RAN letters and  $\alpha=.87$  for RAN digits.

**Visual Attention Span (VAS).** The letter report task developed by Bosse et al. (2007) to assess simultaneous multi-character processing was used. The children were asked to report all the letters in the array (or as many as they could remember) on each trial ( $N=20$ ); items were presented in random order for each child. Since Greek letter names are not frequently used and they are of two syllables, and longer than English letter names, children were asked to respond with letter sounds. Nine uppercase letters were used ( $\Gamma$ ,  $\Delta$ ,  $\Theta$ ,  $\Lambda$ ,  $\Xi$ ,  $\Pi$ ,  $\Sigma$ ,  $\Phi$ ,  $\Psi$  /j,  $\delta$ , th, l, x, p, s, ps/). The letters were presented on the screen of a Dell Inspiron portable laptop with Windows 7, the video mode was 1366x768 at 60Hz. Arrays consisted of five consonant letters, in Consolas 14 font, with 57cm spacing between letters. The DMDX software developed by Forster and Forster (2003) was used to programme the task. At the beginning of each trial a blank screen appeared for 50 msecs, followed by a fixation point appearing in the centre of the screen for 1000 msecs, and finally the target array was presented for 200 msecs.

Consonants and not vowels were used in the task to avoid grapheme complexity and orthographic knowledge. The letters had mean frequency of occurrence 8,489,

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according to the count of Ktori et al. (2008), while the letters not included had a mean frequency of 12,309. The letter arrays did not correspond to the skeleton of any words. The total number of letters identified in the task was used in the analyses (maximum possible score = 100). The reliability coefficient of the task based on the sample was  $\alpha=.78$ .

### **Procedure**

Testing began once ethical approval was obtained from the Institute of Education, University College London Ethics Committee and after parents/guardians and school authorities consented. Children were seen in their school individually, or in small groups for assessment of spelling. This was completed in two group sessions; all items were administered to both cohorts. The one-to one tasks were administered to each child in a single testing session lasting approximately an hour in the spring (second) school term. There were several rest breaks between tasks.

### **Analysis of results**

We conducted correlational analyses, using SPSS 25, followed by stepwise regression analyses looking at the predictors of spelling after controlling for chronological age and word reading speed for the beginner and advanced spellers separately. All statistically significant scores are reported in bold, and they are either less than  $p<.05$  or  $p<.01$ ; in addition, effect sizes ( $d$ ) are reported to express the magnitude of effects found. The effect sizes were considered as small ( $d \leq 0.2$ ), medium ( $d \leq 0.5- 0.2$ ), and large ( $d \geq 0.8$ ) (Cohen, 1988).

## **Results**

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Prior to the analyses, inspection of the data was carried out. All variables apart from VAS were normally distributed based on visual inspection. A logarithmic transformation was applied for the VAS whole report scores; the transformed variable proved to be a better fit in the regression model, so all analyses were conducted with the transformed variable. We also checked the timed measures of RAN and reading for normality. The Kolmogorov-Smirnov statistic was not significant ( $p > .05$ ). The percentage of missing data was low (2%). Descriptive statistics are presented in Table 1.

Table 1 about here

The group effect was significant for all measures except blending and VAS. The effect size was large for reading speed, medium for RAN and small for spelling.

### *Interrelationships among variables*

Partial correlations were conducted, controlling for the effect of age. The results are presented in Table 2. For beginning spellers (lower orthogonal), reading speed, PA and RAN were significantly associated with spelling. For advanced spellers (upper orthogonal), all variables were significantly correlated with spelling accuracy.

Table 2 about here

### *Regression analyses*

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Stepwise regression analyses were carried out controlling for the effect of age and reading speed separately for each group (beginning and advanced spellers). The dependent variable was spelling accuracy in the 60-word list, and the predictors were age and reading, followed by PA, RAN and VAS. Age and reading speed were included in the first step and all other predictor variables were entered in the second step. ANOVAs were significant for both regression models, and for the beginning spellers and advanced spellers, the final model explained a total of 45% and 41% of variance, respectively. The results from the analyses are presented in Table 3.

Table 3 about here

For the beginning spellers, PA was the only significant predictor after controlling for the effect of reading speed and age. For the advanced spellers, after controlling for reading speed and age, PA, RAN and VAS were significant predictors. We also examined whether the relationships would remain the same after removing the effect of reading speed. The outcome was exactly the same for VAS and RAN, but for PA the beta coefficients were slightly increased for younger spellers from .28 to .35 and for the older spellers from .26 to .30. This indicates that for both age groups reading as a control variable mediates the PA-spelling relationship but not the RAN and spelling or the VAS and spelling relationship. We reflect on this further in the Discussion.

Finally, we conducted item-based analyses to see whether further evidence could be obtained for a difference in the use of spelling processes between the beginning and advanced spellers. We carried out separate regression analyses for the

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beginning and advanced spellers with item accuracy as the dependent variable and with predictor variables printed word frequency (log\_frequency counts taken from Helexkids, Terzopoulos et al., 2016) and least transparent phoneme-grapheme probability (LTPG, Spencer, 2007; scores calculated by Spencer, personal communication). The results are presented in Table 4.

Table 4 about here

The results revealed that for the beginning spellers, LTPG probability (a sublexically related variable) predicted spelling scores, while for the advanced spellers both LTPG probability and frequency predicted spelling. This result concurs with the significant influence of both sublexically- and lexically-related variables observed in the analysis of child-related variables for the advanced speller group presented earlier (see Table 3).

### **Discussion**

Most of the research on spelling has been conducted with English speakers, so we wanted to ascertain whether similar findings would be observed in the more transparent Greek orthography. We investigated predictors of spelling accuracy in Greek in beginning and more advanced spellers. We first looked for any developmental change in the measures employed: the advanced spellers (Grade 4 to 7) outperformed the beginning spellers (Grade 1 to 3) in all measures, and the effect sizes varied from small to large. The findings indicated a medium effect size for reading speed, which

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reaffirmed the importance of using reading speed rather than reading accuracy for transparent orthographies. This can be attributed predominantly to the high degree of transparency of the Greek orthography, which has consistent sound-letter correspondences (Protopapas & Vlahou, 2009), as well as the prevalent structure of consonant-vowel (Protopapas et al., 2012), which makes syllabic analysis much easier compared to the situation for English (Goswami, 2010).

There was also a significant difference between the two groups for spelling accuracy, revealing that spelling developed gradually and smoothly regardless of the rich morphological and etymological system of the Greek language (Fragkouli et al., 2021; Protopapas, 2017). The difference for blending was non-significant, with the scores indicating that both groups performed satisfactorily. This finding suggests that in this sample of children, phonological awareness is not greatly enhanced over time, and it seems to be almost entirely developed by the first school years. We could perhaps have employed a more difficult PA task, which might have produced a more pronounced difference between the groups. The group difference for VAS was also non-significant. This suggests perhaps that VAS is acquired satisfactorily from the first school years and remains efficient without being substantially affected by increased experience. In contrast to the results for PA and VAS, for RAN, the results revealed that the more experienced spellers significantly outperformed the beginner spellers, and the effect size was in the medium range.

The results of the regression analyses revealed that reading speed was a significant predictor of spelling accuracy for both beginner and advanced speller groups. The effect was larger in the beginner than the advanced spellers, however, for both groups, the effect was in the medium range. This finding confirms results from

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previous studies reporting robust effect sizes for predicting spelling by reading ability (Graham, 2020; Georgiou et al., 2019).

We explored whether the significant predictive effects that we detected for PA, RAN and VAS would still hold when we did not account for reading in the regression models. In these re-analyses, the strength of the effect of RAN and of VAS was not affected, but a change for PA was observed and this held for both speller groups. The Beta coefficients increased by .7 ( $d=.89$ ) and .4. ( $d=.67$ ) for the beginner and more experienced spellers, respectively. This could suggest that reading ability mediates the relationship between PA and spelling. This is perhaps not unexpected since Greek is so transparent for reading, and PA is strongly associated with sublexical processes.

### **PA, RAN and VAS as predictors of spelling accuracy**

In the full regression models, where reading speed and age were included as the first step, PA was a significant predictor of spelling accuracy, and the effect was equally as strong for the advanced spellers as it was for the beginner spellers. This result is in accord with the findings of Caravolas et al. (2005), who observed that PA was strongly associated with the spelling performance of both younger (Grade 2) and older (Grades 5 and 7) English-speaking children. Similarly, the results are in line with the findings from the longitudinal study of Kargiotidis et al. (2021) for Greek spellers which went up to Grade 2. However, the results differ from those obtained in two other studies: Nielsen and Juul (2016) reported that PA was associated with spelling accuracy in Danish children in Grade 2 but not in Grade 5, and Georgiou et al. (2012) reported that PA was not significantly associated with spelling accuracy in Greek-speaking second grade children. The discrepancy in findings across studies could be due to different tasks used (Nielsen & Juul used an elision task), as well as differences in the design (Georgiou et al.'s study was a longitudinal one), and/or the transparency of the

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orthography. Danish is an opaque orthography so for older learners orthographically-related processes might be more important for spelling (see also Niolaki et al. (2022) for English spelling predictors).

In the present study, as noted above, we found that the PA scores for the more advanced spellers were not significantly better than those of the beginner spellers, and PA was significantly associated with spelling accuracy in both groups. This finding could indicate that PA plays a critical role even in the later school years, although as a skill, depending on the task used, it seems to develop to a fairly high level in the first school years. The finding that PA was still a significant predictor of spelling accuracy for both groups of children, after reading ability and age were entered as earlier steps in our regression analyses, indicates that PA and spelling develop simultaneously and comprise an unbreakable link for Greek spellers enrolled in primary education (Grades 1-6) and the first class of the gymnasium (Grade 7).

The results of the regression analyses with regard to RAN revealed that it was a significant predictor of spelling only for the advanced spellers. This result runs counter to findings from some previous studies that examined the association in students enrolled in Grades 1 and 2 (indicatively de Bree & van den Boer, 2019; Georgiou et al., 2012; Caravolas et al., 2012; Niolaki et al., 2020). However, in de Bree and van den Boer's study, when reading was included in the regression model the significant effect of RAN mostly disappeared, supporting our finding for the younger spellers. Niolaki et al. (2020) reported no significant association between RAN and spelling accuracy for English students aged 8-10 years old (Grades 3-5). However, in the studies by Niolaki et al., Georgiou et al. and Caravolas et al. a measure of reading ability was not included, and this could be a potential reason for the different results, as well as the different designs used (the studies of Georgiou et al. and Caravolas et al.

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were longitudinal studies), and/or the different orthography in the case of the Caravolas et al. study.

The results for VAS revealed that it was also a significant predictor of spelling for the advanced spellers only. De Bree and van den Boer (2019) and Niolaki et al. (2020) reported a significant association between VAS and spelling only for advanced spellers, with Dutch and English participants, respectively. The authors inferred that VAS is more strongly linked to lexical/semantic than phonological processes. However, it should be mentioned that de Bree and van den Boer (2019) considered advanced spellers those enrolled in Grade 2 and Niolaki et al. (2020) those enrolled in Grades 3-5, whereas the advanced spellers in the current study were children in Grades 4 to 7. Consequently, our findings are more in line with those of Niolaki et al. (2020) concerning the association between VAS and spelling and extend the argument above to an older group. Similarly, van den Boer et al. (2015) found an association between fifth graders' spelling skill and VAS, which is in agreement with the current results. The result resonates with the modelling findings of Ginestet et al. (2021), who argue that visual attention is a core mechanism of orthographic learning. Evidence from individuals with surface dyslexia who have a VAS deficit but no difficulties in phonological processing, also support the view that VAS taps lexical-orthographic processes (Niolaki et al., 2014; Niolaki & Masterson, 2013).

### **Summary of findings from the regression analyses**

We found that after controlling for reading ability and age, PA was a significant predictor in the case of the beginner spellers, while PA, RAN and VAS were significant predictors in the case of the advanced spellers. This developmental difference suggests for the first time, at least to our knowledge, that RAN and VAS are both associated with

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lexical spelling processes (since the advanced spellers are assumed to be relying more on lexical than sublexical processes). Concerning the finding for RAN, this resonates with the observation of Chen et al. (2021) in a recent metaanalysis, that RAN is more strongly related to real word than pseudoword spelling and is thus a lexically-related variable. The association of RAN with lexical processes could be due to the retrieval from long-term memory of representations of familiar items under speeded conditions. Thus, it is expected that sublexical processes will be much less associated with RAN performance, since it involves the retrieval of familiar forms. However, due to the transparency of the Greek orthography, the influence of phonology underpinning the relationship between RAN and spelling cannot be totally excluded. This is something that can be explored in the future with a spelling test that investigates different word categories (i.e., irregular and regular words, and pseudowords). In that way more refined investigation of the role of variables that are not clearly linked to phonological or orthographic processes can be conducted.

### **Effects of item characteristics**

Finally, we conducted item-related regression analyses separately for the beginning and more advanced spellers, using as predictor variables printed word frequency and LTPG, which reflects the probability of a specific phoneme corresponding to a particular grapheme (Spencer, 2007). For the beginning spellers only LTPG predicted spelling accuracy, but for the advanced spellers both LTPG and frequency predicted spelling. Per Barry (1994), these results suggest that sublexical spelling processes prevail during the first three school years among the Greek spellers, because the achievement of phoneme-grapheme correspondences is the fundamental prerequisite for the gradual formation of orthographic representations. Over time, the

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acquisition of phoneme-grapheme correspondences and the gradual increase of the lexicon during the first years contributes to a transition to the use of advanced processes. This allows for the use of sublexical processes in the case of infrequent words or pseudowords and lexical processes in the case of frequently used words (Ellis & Young, 2013). For the Greek language, this transition seems to be feasible from the fourth grade onwards.

### **Limitations and future directions**

As with any research, the current study is not free of limitations. Firstly, we used a single measure to capture each of the predictors. The reason for this was that we considered that it is challenging for children and their precious school time to include multiple assessments, so we aimed to keep the testing as brief as possible. Although we found that early year's spelling was influenced by PA, and for more experienced spellers RAN and VAS, in addition to PA, still the amount of variance explained in the regression models was 45% and 41% respectively. These figures, although substantial, show that there is variance not explained by the measures targeted in the current study. Other important variables that have been explored in the past as influential for spelling were not included, such as morphological awareness (Chliounaki & Bryant, 2002; Kargiotidis et al., 2021). This is an avenue that could be explored in the future with beginning and advanced spellers, as well as longitudinal studies that can more strongly establish causal associations. Concerning the analyses, as we were interested in spelling performance in beginning and advanced spellers, thus, we did not conduct group comparison analyses as part of the regression model. This is something that could be taken into account in future studies.

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In addition, although children reported that their first language was Greek, we did not collect data on whether an additional language was spoken at home. Also, socioeconomic and other demographic data were not gathered. Future studies could also employ assessments that measure reading efficiency, the number of items correctly read in a specific amount of time, rather than reading speed. This can provide a better understanding of readers who struggle with literacy and take additional time when reading words. Reading efficiency could control for this more effectively than reading speed.

### ***Conclusions***

The findings suggest that sublexical processes are important for beginning spellers' single-word spelling. Then, with increasing literacy experience, lexically related variables such as RAN and VAS become equally important. This indicates that for Greek spelling specifically, where the incidence of phonologically inappropriate errors is low, phonics training is not enough to allow children to commit word spellings to memory. It should also be noted based on our findings that relationships between VAS and spelling and RAN and spelling are differently modulated by age and language characteristics. Our results highlight that although phonological processes are essential for beginning Greek spellers, as the children progress in their spelling knowledge and they encounter words many times in their writing, automatic processes that require speeded performance and fast retrieval of sequences, as reflected in performance in RAN and VAS tasks, become more important. This does not necessarily mean that RAN and VAS processes are similar; in RAN tasks, children need to name sequentially all the items presented. In contrast, in the letter report task used in the present study to assess VAS, children need to name the stimuli following very brief presentation, so the latter imitates a lot more the ability to integrate the parts of a whole into a coherent unit.

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This is exactly what skilled spellers do, and is perhaps why VAS becomes strongly associated with spelling later in life when the system becomes more mature. One could argue the same for the impact of memory, however, as retrieval is not constrained by the position of the item, performance in the letter report task is more visually- rather than memory-related (Cheng et al., 2021; Valdois, 2022). We hope that our research adds to our need to understand spelling in more transparent orthographies, such as Greek, and how spelling skill is affected by not only phonological but also visual processes.

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## Predictors of Greek spelling in primary and secondary school children

**Table 1**

*Mean scores and standard deviations per variable and group separately (standardised deviations are in parentheses)*

|   | Beginning<br>spellers | Advanced<br>spellers | <i>T-test</i>              | <i>d</i> |
|---|-----------------------|----------------------|----------------------------|----------|
| Spelling <sup>a</sup> (max.= 60)        | 33.1<br>(10.8)        | 38.2<br>(13)         | $t(114.6)=-2.3$<br>$p<.01$ | .42      |
| Reading speed <sup>b</sup><br>(seconds) | 216<br>(103)          | 147<br>(44)          | $t(85)=3.5$ $p<.001$       | .75      |
| Blending (max.=32)                      | 23.5<br>(5.9)         | 24.6<br>(6.7)        | $t(115)=-.95$ $p>.05$      | .17      |
| RAN composite <sup>c</sup><br>(secs)    | 745<br>(337)          | 462<br>(216)         | $t(135)=3.03$ $p<.01$      | .52      |
| VAS letters correct<br>(max.=100)       | 59<br>(17)            | 64<br>(16)           | $t(75)=.81$ $p>.05$        | .19      |

Note: <sup>a</sup>Masterson et al., 2008; <sup>b</sup>Loizidou et al., 2009, <sup>c</sup> Composite score for RAN digits and RAN letters

## Predictors of Greek spelling in primary and secondary school children

**Table 2**

*Partial Correlation controlling for age, associations between spelling accuracy and literacy and cognitive correlates (upper orthogonal advanced spellers – lower orthogonal beginning spellers)*

|                        | 1              | 2            | 3            | 4              | 5             |
|------------------------|----------------|--------------|--------------|----------------|---------------|
| 1. Spelling            | -              | <b>-.56*</b> | <b>.52**</b> | <b>-.80***</b> | <b>.57***</b> |
| 2. Reading speed       | <b>-.47***</b> | -            | -.21         | <b>-.72**</b>  | <b>.58*</b>   |
| 3. Blending            | <b>.44***</b>  | -.27         | -            | <b>-.61**</b>  | .23           |
| 4. RAN composite       | <b>-.54*</b>   | -.21         | -.36         | -              | -.31          |
| 5. VAS letters correct | .46            | .14          | .43          | -.43           | -             |

*Note:* Significant results are in bold  $p < .05^*$ ,  $p < .01^{**}$ ,  $p < .001^{***}$

## Predictors of Greek spelling in primary and secondary school children

**Table 3**

*Regression analyses, with accuracy in the 60-word spelling test as the dependent variable and predictors, age, reading, PA, RAN and VAS for each speller group (final model)*

|               | Beginning spellers |              |             | Advanced spellers |              |             |
|---------------|--------------------|--------------|-------------|-------------------|--------------|-------------|
|               | $\beta$            | $t$          | $d$         | $\beta$           | $t$          | $d$         |
| constant      |                    | -1.11        | -.27        |                   | -.83         | -.18        |
| <b>Step 1</b> |                    |              |             |                   |              |             |
| Age           | <b>.49</b>         | <b>5.28</b>  | <b>1.33</b> | .02               | .23          | .053        |
| Reading speed | <b>-.27</b>        | <b>-2.81</b> | <b>-.70</b> | <b>-.21</b>       | <b>-2.42</b> | <b>-.53</b> |
| <b>Step 2</b> |                    |              |             |                   |              |             |
| Blending      | <b>.28</b>         | <b>2.84</b>  | <b>.71</b>  | <b>.26</b>        | <b>2.69</b>  | <b>.59</b>  |
| RAN           | -.08               | -.79         | -.19        | <b>-.33</b>       | <b>-3.61</b> | <b>-.78</b> |
| VAS           | .06                | .62          | .15         | <b>.28</b>        | <b>3.28</b>  | <b>.72</b>  |

*Note: Significant results are in bold ( $p < .05$ ).*

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**Table 4**

*Regression analyses with item totals for spelling accuracy as the dependent variable and predictors log\_frequency and LTPG for the beginning and advanced speller groups*

|          | Beginning spellers (total explained variance 20%) |             |             | Advanced spellers (total explained variance 24%) |             |             |
|----------|---|-------------|-------------|--|-------------|-------------|
|          | $\beta$   | $t$         | $d$         | $\beta$  | $t$         | $d$         |
| constant | -   | 1.92        | .52         | -  | <b>4.37</b> | <b>1.18</b> |
| Log_freq | .15   | 1.27        | .35         | <b>.34</b>                                       | <b>2.85</b> | <b>.77</b>  |
| LTPG     | <b>.45</b>  | <b>3.72</b> | <b>1.01</b> | <b>.39</b>                                       | <b>3.33</b> | <b>.91</b>  |

*Note:* LTPG, least transparent phoneme-grapheme probability; significant results are in bold ( $p < .05$ ).