The Spanish Journal of Psychology (2021), **24**, e3, 1–16.
© Universidad Complutense de Madrid and Colegio Oficial de Psicólogos de Madrid 2021
doi:10.1017/SJP.2021.3

CAMBRIDGE UNIVERSITY PRESS

Orthographic Knowledge, and Reading and Spelling: A Longitudinal Study in an Intermediate Depth Orthography

Luís Querido, Sandra Fernandes and Arlette Verhaeghe

Universidade de Lisboa, Faculdade de Psicologia (Portugal)

Abstract. Orthographic knowledge is an important contributor to reading and spelling. However, empirical research is unclear about its long-lasting influence along with literacy development. We examined whether reading and spelling benefitted from an independent contribution of lexical and sublexical orthographic knowledge in European Portuguese, an intermediate depth orthography. This was investigated longitudinally from Grade 2 to 5 with two cohorts of Portuguese children, using common measures of orthographic knowledge, and word and pseudoword reading and spelling tasks. Regression analyses showed that lexical orthographic knowledge assessed at the beginning of Grade 2 predicted word reading at the beginning of Grade 3 ($p < .05$, variance explained = 6%), word spelling at the end of Grade 2 ($p < .05$, variance explained = 6%) and pseudoword spelling at the beginning of Grade 3 ($p < .05$, variance explained = 8%). They also revealed that lexical orthographic knowledge assessed at the beginning of Grade 4 predicted word spelling at the end of Grade 4 ($p < .001$, variance explained = 21%). Differently, sublexical orthographic knowledge evaluated at the beginning of Grade 2 and of Grade 4 only contributed to pseudoword spelling at the beginning of Grade 3 ($p < .01$, variance explained = 12%), and to pseudoword reading at the end of Grade 5 ($p < .01$, variance explained = 9%), respectively. Therefore, orthographic knowledge predicted spelling more often and earlier than reading. Furthermore, the results suggest that the influence of orthographic knowledge may vary during literacy development and, along with findings from other studies, that this influence at the lexical level may depend on orthographic consistency.

Received 11 December 2019; Revised 20 December 2020; Accepted 18 December 2020

Keywords: lexical, orthographic knowledge, reading, spelling, sublexical

The Orthography of a language is defined as "the manner in which spoken language is represented in print" (Apel, 2009, p. 43). Its knowledge has been recognized as having a crucial role in literacy development (e.g., Conrad et al., 2013; Ise et al., 2014; Rothe et al., 2014), beyond phonological awareness, letter knowledge, vocabulary, and verbal short-term memory.

The aim of the present study was examining the long-lasting influence of the components of orthographic knowledge on reading and spelling skills, from early phases of literacy development to more advanced ones, in European Portuguese, an orthography of intermediate depth in the orthographic consistency continuum (Fernandes et al., 2008; Lima & Castro, 2010; Querido et al., 2020; Sucena et al., 2009).

Components of Orthographic Knowledge and their Measures

Orthographic knowledge concerns the crystallized store of the orthographic representations (Deacon et al., 2019); it is widely accepted as including two components (e.g., Apel, 2011; Commissaire & Besse, 2019; Deacon et al., 2019): One that is word-specific and

Correspondence concerning this article should be addressed to Luís Querido. Universidade de Lisboa, Faculdade de Psicologia. 1649–004 Lisboa (Portugal).

E-mail: queridoluis@gmail.com

Acknowledgement: We thank the students, teachers, administrators and school personnel of the two intervenient schools. We also thank all the examiners who collected data in the field. Lastly, we thank the anonymous reviewers for their very helpful comments and suggestions that greatly contributed to improve the paper.

Conflicts of Interest: None

Funding Statements: This work partly supported by FCT – Foundation of Science and Technology (research Grant SFRH / BD / 72303 / 2010). Data collection was supported and carried out under the project "Developmental benchmarks of reading and writing, in European Portuguese, from first to sixth grade" (2008–2010), under the auspices of the National Reading Plan.

How to cite this article:
Querido, L., Fernandes, S., & Verhaeghe, A. (2021). Orthographic knowledge, and reading and spelling: A longitudinal study in an intermediate depth orthography. *The Spanish Journal of Psychology, 24.* e3. Doi:10.1017/SJP.2021.3

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

another that is more general (e.g., Apel, 2011). Word-specific orthographic knowledge also termed lexical orthographic knowledge involves the "ability to directly access specific representations in memory" (Binamé & Poncelet, 2016, p. 16), whereas general orthographic knowledge, or sublexical orthographic knowledge, refers to knowing orthographic regularities within an orthographic system including letter position frequencies, letter pattern redundancies (e.g., consonant doublets), sequential dependencies (permissible letter patterns, i.e., which letter can or cannot follow other) (Vellutino et al., 1994), and positional and contextual rules in the use of letters (e.g., in what position letters can be used) (Apel, 2011).

Two types of measures have been broadly used to assess and provide an indication of the child's level of orthographic knowledge, at both lexical and sublexical levels (e.g., Chung et al., 2018). In the classic Orthographic Choice Task (Olson et al., 1994), children are asked to choose between two possible phonological alternatives (e.g., rain-rane), the one correctly written. This task measures orthographic knowledge at the lexical level since to perform it and achieve a decision, the two elements of each pair have to be compared with stored word specific representations (e.g., Chung et al., 2018). Otherwise, the Wordlikeness Choice Task, in which participants have to choose among two or more non-words the one that most resembles a word (Stanovich & Siegel, 1994), focuses on the knowledge of sublexical letter patterns consistent with the rules of the language's orthographic code: For instance, knowledge of orthographic word position patterns, of allowable orthographic pattern frequencies, and of legal versus illegal consonant or vowel representations (Apel et al., 2019). In the task original format, "one member of each pair contains an orthographic sequence that never occurs in English in that particular position in a word (e.g., filv and dlun)" (Stanovich & Siegel, 1994; p. 33). The use of non-words in this type of tasks prevents the access to fully specified orthographic representations in memory, measuring then the awareness of the orthographic patterns of a given language.

Orthographic Knowledge and Literacy Development

It is well established that, in the very beginning of literacy acquisition, the abilities to analyze words into their sound constituents and to apply the grapheme-to-phoneme and phoneme-to-grapheme mappings are strongly involved in learning to read and to spell. Furthermore, seminal theories of literacy development consider that orthographic knowledge constitutes another key factor in reading and spelling acquisition (e.g., Ehri, 2014; Share, 1995).

According to Ehri (2005, 2014), lexical orthographic knowledge supports sight word reading - children read and spell familiar words directly by mapping word specific orthographic letter sequences with their mental representations stored in memory. Unknown or novel words could also be read and spelled using analogies to stored words in memory (e.g., reading *thump* by analogy to *jump*; Ehri, 2014, p. 6). In addition, sublexical orthographic knowledge can be useful to read and spell familiar and unknown words supplying expectations and constraints about how a word can be read or spelled according to the knowledge of recurring letter patterns (Ehri, 2005, 2014). For instance, the spelling pattern *-ight* that recurs in multiple words could help to read the words *right, night, light,* and the pseudoword[1] *pight.*

Orthographic Knowledge and Reading and Spelling: Empirical Evidence

Some recent studies examined the relationship between both the lexical and sublexical components of orthographic knowledge and reading and spelling in orthographies with varying degrees of consistency, concurrently (at the same time of test) and/or longitudinally.

The unique contribution of each component of orthographic knowledge on reading and spelling skills has received some attention (e.g., Conrad et al., 2013; Deacon et al., 2012; Conrad & Deacon, 2016) mostly in studies with a concurrent design.

Concurrent Studies

Findings from concurrent studies seem to indicate that orthographic knowledge is related to reading and spelling acquisition, regardless of the type of orthographic knowledge (lexical or sublexical), and independently of the consistency of the orthography.

The concurrent influence of lexical orthographic knowledge on reading skills was examined in a cross-linguistic study involving English and Greek - two orthographically different languages, respectively inconsistent and consistent (Georgiou et al., 2008). Results revealed that, at Grade 1, lexical orthographic knowledge was a significant predictor of reading skills both in English (decoding, reading efficiency and fluency) and in Greek (reading efficiency and fluency). Conrad et al. (2013) also observed a concurrent contribution of lexical orthographic knowledge to reading and spelling with English-speaking children aged 7 to 9. Similar findings were found in Persian, Dutch, and German (Arab-Moghaddam & Sénéchal, 2001;

[1]Sequence of letters, graphemes or phonemes that fulfills the phonological and orthographic constraints of the language but is not known as having any meaning in that language.

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

Bekebrede et al., 2009; Zarić et al., 2020), suggesting that also in consistent orthographies, word-specific orthographic knowledge contributes to reading and spelling.

With respect to sublexical orthographic knowledge, it was found to explain a significant amount of variance in first (Rothe et al., 2014) and third (Zarić, et al., 2020) graders' word reading and spelling in German, a consistent orthography. Likewise, a concurrent contribution of sublexical orthographic knowledge to reading and spelling was found in English-speaking children aged 7 to 9 (Conrad et al., 2013), and to fifth graders' spelling performance in Danish, an inconsistent orthography like English (Nielsen, 2017).

Longitudinal Studies

Although relevant for theories of reading development, the longitudinal influence of orthographic knowledge on reading and spelling skills throughout literacy development has been studied to a lesser extent, with unclear results. In fact, the findings showed an asymmetry in the contributions of lexical and sublexical orthographic knowledge to reading and spelling skills.

As far as lexical orthographic knowledge is concerned, results varied depending on the degree of orthographic consistency. Indeed, Georgiou et al. (2008) showed that in Greek, lexical orthographic knowledge at Grade 1 had a significant longitudinal contribution to reading skills such as reading efficiency and fluency at Grade 2, but not in English. This lack of longitudinal influence in English was corroborated in two later studies (Deacon et al., 2012; Conrad & Deacon, 2016). Deacon et al. (2012) did not find, in English speaking children from Grade 1 to 3, any contribution from lexical orthographic knowledge to word reading, after controlling for nonverbal ability, vocabulary, and phonological awareness. Conrad and Deacon (2016) also found no longitudinal predictive contribution from lexical orthographic knowledge (controlled for nonverbal ability and phonological awareness) to word reading skills (word reading accuracy, word reading efficiency, and phonological decoding) in English second and third graders.

Concerning sublexical orthographic knowledge, no systematic longitudinal relationship was found with literacy skills neither in English (reading skills: Deacon et al., 2012), nor in German (reading and spelling skills: Ise et al., 2014).

The Present Study

Studies examining the influence of the components of orthographic knowledge on reading and spelling skills, from early phases of literacy development to more advanced ones, and in orthographies with varying levels of consistency, are crucial in order to achieve a broader and thorough understanding of the role of orthographic knowledge in literacy acquisition.

As already referred, the available empirical data on the type of relationships are scarce, especially regarding longitudinal studies. In addition, there is a prevalence of studies carried out in English, focusing primarily on reading rather than spelling (e.g., Chung et al., 2018). Finally, it should also be noted that virtually all the results from this line of research have been obtained in children still in an initial phase of literacy acquisition.

The main objective of the present study was to contribute to a better understanding of the role of orthographic knowledge in literacy development by examining the longitudinal influence of both lexical and sublexical orthographic components on reading and spelling skills in European Portuguese. In the *continuum* of consistent - inconsistent orthographies, European Portuguese is considered an orthography of intermediate depth (for a deeper characterization see: Querido et al., 2020) in which there is a greater inconsistency in phoneme-grapheme conversion involved in spelling than in grapheme-phoneme conversion concerned in reading (e.g., Fernandes et al., 2008), similar to French (e.g., Sprenger-Charolles et al., 1998) or to Spanish (e.g., Defior et al., 2009).

To check how the influence of orthographic knowledge on reading and spelling skills may vary from an initial to a more advanced phase of literacy development, two longitudinal Cohorts of students were examined, one covering the second and third grades and the other encompassing the fourth and fifth grades.

Orthographic knowledge was assessed through the Orthographic Choice Task and the Orthographic Awareness Task – each at a different level of processing – lexical and sublexical, respectively. The stimuli of the Orthographic Choice Task were words for which the most frequent errors were observed during elementary grades in European Portuguese (Surrador, 1997), paired with their pseudohomophones. In the task evaluating sublexical orthographic knowledge, the focus was on two types of orthographically illegal letter patterns, one in word-initial consonant cluster in CCV and the other in word-final consonant.

Reading and spelling were assessed at the basic level of literacy skills through Word and Pseudoword Reading and Spelling Tasks. Functionally, words, and pseudowords represent known and unknown or novel words, respectively.

Relatively to word or pseudoword spelling, to our knowledge, until now, the longitudinal contribution of lexical orthographic knowledge, has not been examined, neither in inconsistent orthographies nor in consistent ones.

As seen before, most of the previous research about the relationships between orthographic knowledge and

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

literacy skills adopted concurrent designs. Being correlational studies, they did not allow to determine the direction of the relationship between variables. Longitudinal studies with autoregressive controls provide overcoming such limitation. This type of methodology has been used in developmental research to establish a temporal relationship between two variables (e.g., Deacon et al., 2012; Fernandes et al., 2018), To our knowledge, only the studies of Deacon et al. (2012) and Conrad and Deacon (2016) used this autoregressive methodology to study the direction of the relationship between orthographic knowledge and reading performance. In the present study, long-term effects were examined using cross-lag Sequential Regression Analyses (SRA) with autoregressive controls, allowing for the extraction of a unique effect of both components of orthographic knowledge evaluated at an early time, on reading and spelling skills assessed at a later time. Consistent with prior research, phonemic awareness was included in the analyses to control for the effects of phonological skills when determining whether orthographic knowledge uniquely contributes to reading (e.g., Stanovich et al., 1991) and spelling (e.g., Ouellette & Sénéchal, 2008) skills. Other control variables were also incorporated, namely non-verbal reasoning and vocabulary, to reduce the possibility that any effects may be due to variables other than the ones under study (see Kenny, 1975).

A set of four hypotheses was formulated. The first hypothesis (H_1) was that lexical orthographic knowledge contributed to word reading and word spelling since the very beginning of literacy acquisition in European Portuguese, an orthography more consistent than English. As stated by Ehri (2005, 2014), the mapping between word specific orthographic letter sequences and their mental representations stored in memory can assist children's reading and spelling of known words. This type of longitudinal influence of lexical orthographic knowledge was already found in Greek but not in English (Georgiou et al., 2008).

The second hypothesis (H_2) was that lexical orthographic knowledge contributed to the reading and spelling of pseudowords by using stored representations of words in memory. According to Ehri's (2005, 2014) theory, unknown or novel words could be read and spelled using analogies to stored words in memory (e.g., reading *thump* by analogy to *jump*; Ehri, 2014, p. 6). Previous empirical data (Georgiou et al., 2008) found no longitudinal contribution, from lexical orthographic knowledge to pseudoword reading neither in English nor in Greek, in a very initial phase of learning to read (from Grade 1 to Grade 2). However, it is conceivable that the reading and spelling of pseudowords using stored lexical representations would manifest a bit later in literacy instruction when decoding skills became more efficient to establish word specific representations.

The third and fourth hypotheses were that sublexical orthographic knowledge influenced the reading and spelling of words (H_3) and assisted the reading and spelling of pseudowords (H_4). It was theoretically proposed that sublexical orthographic knowledge contributes to reading and spelling familiar and unknown words by providing expectations and constraints about how they could be read or spelled according to recurring orthographic pattern knowledge (Ehri, 2005, 2014). To date, no empirical evidence pointing to this contribution was found in an early phase of learning to read, either in inconsistent (Deacon et al., 2012) or consistent orthographies (Ise et al., 2014). However, this has not yet been investigated in a more advanced phase of literacy development.

Method

Participants

One hundred and seventy children from two public schools in the Lisbon district participated in the study. In accordance with ethical APA guidelines, parents of all participating children provided informed consent consistent with the *Gabinete de Estatística e Planeamento da Educação do Ministério da Educação*[2]. The schools were made available by the Ministry of Education of the Portuguese Government in the scope of a larger project.

Two Cohorts were tested in three testing periods: (i) In the initial three months of the school year in one grade; (ii) in the final three months of that same school year; (iii) in the initial three months or in the last three months of the subsequent grade. Cohort 1 (83 children, of whom 37 girls) was tested in Grades 2 and 3; Cohort 2 (87 children, of whom 46 girls), in Grades 4 and 5. Due to practical constraints, the third testing period was not the same for the two Cohorts: In Cohort 1, it occurred in the initial three months of Grade 3, and in Cohort 2, it occurred in the last three months of Grade 5. Children's initial ages were 7 years and 11 months (SD = 3.08 months) for Cohort 1, and 10 years (SD = 3.76 months), for Cohort 2.

Students came from two classrooms, randomly chosen, per grade in each school. They were all native speakers of European Portuguese and had an average or above average cognitive functioning – 25th percentile or higher on the Raven's Colored Progressive Matrices (Simões, 1994). Children flagged by their parents or teachers as having learning, emotional or sensory disabilities were not included in the sample. These screening criteria determined the ineligibility of 15 and 13 children from Cohort 1 and 2, respectively. As stated

[2]Office of Statistics and Planning of Education of the Ministry of Education.

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

by the Ministry of Education, children from these schools belonged to middle and upper-middle class families. Data on the educational background from a questionnaire answered by the children's parents (accounting for 74.3% of the participants) indicated only 6.4% of fathers and 4.7% of mothers with less than a high school diploma, 11.7% of parents with high school graduation, 38.6% of fathers and 48.5% of mothers with university degrees, and additionally, 9.9% of fathers and 7.6% of mothers with post-graduate education (including 2.9% of fathers and 2.3% of mothers with a Ph.D.). Only one father (and no mother) was reported as unemployed.

Measures[3]

Verbal and Nonverbal Abilities

Vocabulary Peabody picture test (VPPT). VPPT was adapted from the Spanish version (Dunn et al., 1986). Four pictures with different meanings were presented per item and the participant was required to point to the picture that corresponds to a given spoken word. Concurrent validity with other vocabulary measures (e.g., Standford-Binet Vocabulary Subtest) had a mean value of .71 (Dunn et al., 1986, p. 90). Test-retest reliability over a 1-and-a-half-year interval for the cohort tested at 4th and 5th grades was .50.

Raven's colored progressive matrices. The Portuguese adaptation of the Raven's Colored Progressive Matrices (Simões, 1994) was used to measure general non-verbal reasoning. Cronbach alpha reported was .91.

Phonemic Awareness (PA)

In a Phoneme Deletion Test, children were asked to say aloud the phonological segment obtained after deleting the initial phoneme from a consonant cluster of a monosyllabic pseudoword. Ten CCV stimuli (e.g., blu and fla) were presented over headphones. Experimental items were preceded by three familiarization trials, which could be re-administered if the child failed to understand the task or asked the experimenter to repeat any part of the instruction. Stimuli presentation was controlled by E- Prime 1.1 (Schneider et al., 2002a, 2002b) running on a Pentium PC. The reliability of the test was .87 (Cronbach alpha).

[3]All of the tests considered were developed and administered to the participants as part of the project "Developmental benchmarks of reading and writing in European Portuguese from the 1st to 6th grades", which was conducted under the auspices of the Portuguese National Reading Plan. The stimuli set for each task are available from the corresponding author on request.

Reading aloud and Spelling Tasks

Since there are no standardized reading and spelling tests available in European Portuguese that include words and pseudowords for the range of ages under study, we developed reading and spelling tasks especially to accomplish the aims of the present study.

We used two word categories: Simple regular (i.e., the letter sequence was in accordance with the rules of Portuguese grapheme-phoneme and phoneme-grapheme correspondences, and each of the graphemes corresponded to one letter only), and complex regular (i.e., they differ from simple regular ones because one of the graphemes contained more than one letter - <ou>, <nh>, <lh> and <ch>) (cf. Fernandes et al., 2008). The frequency of each word was retrieved from Portulex, "a lexical database that contains words from children's schoolbooks for reading and language instruction from grades 1–4" (Teixeira & Castro, 2007). Simple and complex words had identical frequencies, $t(10) = 4.07$, $p > .10$, and number of letters, $t(10) = -1.66$, $p > .10$. For each category, simple and complex, there were two disyllabic words and four trisyllabic words. Pseudowords were constructed from simple and complex words by modifying the initial and one or more other letters in a way that made it impossible to find the words from which they were derived. Pseudowords respected the phonological and orthographic constraints of European Portuguese.

Reading aloud task. Each child was asked to read aloud, the best as they could, each item when it appeared on a computer monitor. Two lists were presented: one including 12 words (6 simple and 6 complexes), the other including 12 pseudowords (6 of each category). Within each list, the item presentation was random. In the reading task, the word list was presented first (cf. Fernandes et al., 2008). The reliability of this word reading task was above .89, Cronbach alpha, for all grades. The pseudoword list was presented one week after the word list to avoid the risk of priming. The reliability of the pseudoword reading task was above .80, Cronbach alpha, for all grades. For each task, all items were presented without any feedback. Stimuli presentation was controlled by E- Prime 1.1 (Schneider et al., 2002a, 2002b) running on a Pentium PC. Each item was displayed on the computer screen for a period no longer than 5 seconds. As soon as the child read one item, another appeared on the screen. The test score is the total number of correctly read stimuli (words or pseudowords).

Spelling task. Items used in this task were the same as those used in the reading task. Both word and pseudoword lists were presented separately in two different randomized orders. The test score is the total number of correctly spelled stimuli (words or pseudowords).

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

The word-spelling task was applied one week after the word-reading task to prevent recollection of the words previously read. The pseudoword-spelling task was also applied after the pseudoword-reading task, in this case with at least a one-day interval (cf. Fernandes et al., 2008). The reliability of the word and pseudoword spelling task was above .86, Cronbach alpha, for all grades. All the items were previously recorded and presented through stereo speakers, one at a time. To avoid the possibility of confusion between homophones, words were first presented in a sentence context, and then in isolation. Given that pseudowords cannot be presented in a sentence context, we presented them twice. Pseudowords presented the most frequent stress pattern in European Portuguese that is the one falling within the penultimate syllable. Children were asked to write each of the dictation items.

Orthographic Knowledge

Two tasks were developed as part of a broader project and for the purposes of the present study, one involving an orthographic choice, the other examining orthographic awareness (Querido et al., 2020).

Orthographic choice task. In the Orthographic Choice Task, children were shown 60 pairs of stimuli (e.g., *gente – jente; televisão – televizão; lobo - loubo*). The stimuli were selected based on the most frequent orthographic errors that occurred in elementary grades (Grade 1 to 4) in European Portuguese (Surrador, 1997). Only one member of each pair was orthographically correct (e.g., *gente/people*), the other corresponding to a pseudohomophone foil (e.g., *jente*). In each pair, stimuli were randomly displayed in a central column of an A5 sheet. It is assumed that the selection of the correct choice requires access to its specified orthographic representation in memory (e.g., Castles & Nation, 2008; Conrad et al., 2013; Chung et al., 2018). The task was to underline the member of each pair that was correctly spelled. The reliability of the test was .87, Cronbach alpha.

Orthographic awareness task. In the Orthographic Awareness Task (Querido et al., 2020), children were shown 14 pairs of pronounceable pseudowords (e.g., *prilo – rilop* and *drulo – srulo*). One member of each pair contained a string never occurring orthographically in European Portuguese in the initial (e.g., *srulo*) or final (e.g., *rilop*) position of words; the other member of the pair contained an orthographically legal string in the same position. For example, in European Portuguese, while -sr- is an illegal orthographic sequence in an initial word position, the corresponding phonetic form exists (e.g., [ˊsɾɐjɐ]), but is always spelled with an intermediate <e> between the two consonants (e.g., sereia/mermaid). In a similar way, only four consonants (<r>, <l>, <s> and <z>) are orthographically permissible in a final word position. However, for several other consonants (e.g., <t>, <p>, <b>, <g>) not orthographically legal in that position, the phonetic form exists (e.g., noite/night pronounced [ˊnojt]). Therefore, in the Orthographic Awareness Task (Querido et al., 2020), the incorrect item of each pair contains always a sequence orthographically illegal but existing phonologically in that position in European Portuguese. Although the items (e.g., prilo versus rilop) differ in both their orthography and their phonology, the correct choice can only be achieved through orthography rather than through phonology. Indeed, both pronunciations ([ilu] and [ɔp]) are plausible in European Portuguese (e.g., in the real words <quilo> / *kilo* and <xarope> / *syrup*: ['kilu] and [ʃɐ'rɔp]), but the orthographic string <op> is not legal in the final position of a word. There were two pairs of training stimuli before the experimental ones. The task was to underline the member of each pair that "could be a word" or "looks like a word". The reliability of the test was .74, Cronbach alpha.

The data considered for each forced-choice task (Orthographic Choice Task and Orthographic Awareness Task) were the proportion of chance-corrected successful detections. The chance level was .50 (for both Orthographic choice and Orthographic awareness) and the compensation for chance success was accomplished using the formula p = (p′ − c) / (1 − c), where p = the corrected detection proportion; p′ = the raw proportion; and c = the probability of being correct by chance (e.g., Clark et al., 1963).

General Procedure

In the first Cohort (C1), students tested at the beginning of Grade 2 were tested again at the end of Grade 2 and at the beginning of Grade 3; in the second Cohort (C2), students tested at the beginning of Grade 4 were tested again at the end of Grades 4 and 5.

The Vocabulary Peabody Picture test, Phonemic Awareness, and Reading Aloud tasks were individually administered in random order. They took place in a quiet setting provided by the school and were conducted in separate sessions. The students' responses to Phonemic Awareness and Reading Aloud tasks were recorded using a Memup mp3 recorder during the test session and played back later for analysis purposes.

The Raven's Colored Progressive Matrices test, the Orthographic Knowledge and Spelling tasks were administered in different sessions to groups of participants.

The Vocabulary Peabody Picture Test, the Raven's Colored Progressive Matrices, and the Orthographic Knowledge tasks were administered only at the beginning of the school year in the 2nd and 4th grades. The Reading and Spelling tasks were administered in all testing time periods of each cohort.

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

Table 1. *Means and Standard Deviations for Correct Responses in the Various Tests for Cohort 1 of Students by Testing Period*

	Grade 2						Grade 3		
	Beginning			End			Beginning		
	M	*SD*	95% CI	*M*	*SD*	95% CI	*M*	*SD*	95% CI
Matrices[a]	28.95	4.16	[28.04, 29.86]						
Peabody Vocabulary[b]	125.31	10.62	[122.95, 127.68]						
Phoneme Deletion (accuracy)	.66	.31	[.59, .73]						
Word Reading Task (accuracy)	.94	.07	[.93, .96]	.96	.06	[.95, .98]	.95	.08	[.93, .96]
Pseudoword Reading Task (accuracy)	.85	.17	[.82, .90]	.90	.11	[.88, .93]	.80	.16	[.76, .84]
Word Spelling Task (accuracy)	.75	.16	[.72, .79]	.90	.08	[.88, .92]	.90	.10	[.88, .92]
Pseudoword Spelling Task (accuracy)	.60	.18	[.56, .64]	.60	.17	[.56, .63]	.75	.18	[.71, .79]
Orthographic Choice Task[c] (accuracy)	.80	.08							
Corrected values	.59	.17	[.56, .63]						
Orthographic Awareness Task[c] (accuracy)	.76	.16							
Corrected values	.53	.31	[.46, .60]						

Note. **Beginning** = November-January; **End** = April-June; **accuracy** = mean proportion of correct responses.
[a] Mean of correct responses in 36. [b] Standardized results. [c] Chance level for complete test was .50.

Table 2. *Means and Standard Deviations for Correct Responses in the Various Tests for Cohort 2 of Students by Testing Period*

	Grade 4						Grade 5		
	Beginning			End			End		
	M	*SD*	95% CI	*M*	*SD*	95% CI	*M*	*SD*	95% CI
Matrices[a]	33.08	2.37	[32.57, 33.59]						
Peabody Vocabulary[b]	124.64	11.96	[122.08, 127.20]						
Phoneme Deletion (accuracy)	.87	.22	[.81, .92]						
Word Reading Task (accuracy)	.92	.10	[.90, .94]	.94	.07	[.93, .96]	.96	.06	[.95, .98]
Pseudoword Reading Task (accuracy)	.74	.16	[.70, .77]	.84	.12	[.81, .87]	.82	.14	[.79, .85]
Word Spelling Task (accuracy)	.88	.12	[.85, .90]	.92	.12	[.89, .95]	.94	.08	[.92, .96]
Pseudoword Spelling Task (accuracy)	.69	.17	[.66, .73]	.68	.17	[.65, .72]	.68	.15	[.65, .72]
Orthographic Choice Task[c] (accuracy)	.91	.06							
Corrected values	.82	.12	[.80, .85]						
Orthographic Awareness Task[c] (accuracy)	.78	.15							
Corrected values	.57	.30	[.50, .63]						

Note. **Beginning** = November-January; **End** = April-June; **accuracy** = mean proportion of correct responses.
[a] Mean of correct responses in 36. [b] Standardized results. [c] Chance level for complete test was .50.

All the tests were administered by a team of trained graduate students.

Results

Tables 1 and 2 show means, standard deviations, and range of scores for all measures, for Cohort 1 and 2, respectively. Performance scores in the different measures followed a normal distribution (Shapiro-Wilk, $p > .10$).A summary of concurrent and longitudinal correlations between measures is presented in Tables 3 (Cohort 1) and 4 (Cohort 2).

In Cohort 1 (Table 3), performance in the Orthographic Choice Task at the beginning of Grade 2 was significantly correlated with later reading and spelling measures (with the exception of Pseudoword Spelling at the end of Grade 2 and of Pseudoword Reading at the beginning of Grade 3). The performance in the Orthographic Awareness Task at the beginning of Grade 2 was only significantly correlated with a later spelling measure (Pseudoword Spelling at the beginning of Grade 3).

For Cohort 2 (Table 4), performance in the Orthographic Choice Task at the beginning of Grade 4 was

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

Table 3. *Correlation Matrix for all Measures in Cohort 1*

		Beginning of Grade 2									End of Grade 2				Beginning of Grade 3			
	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Matrices		.17	.17	.28*	.01	.15	.02	.36**	.03	.11	.12	.03	−.01	.03	.07	.15	−.03
2	Peabody Vocabulary			.04	.20	−.08	−.02	−.08	.16	−.06	.13	.02	.16	.01	.06	.05	.41**	.21
3	Phonemic Awareness accuracy				.21	.08	.26*	.18	.35**	.23*	.12	.26*	.36**	.23*	.08	.14	.38**	.13
4	Orthographic Choice Task					.14	.53**	.25*	.48**	.28*	.29**	.30**	.42**	.07	.38**	.20	.48**	.31**
5	Orthographic Awareness Task						.18	.18	.14	.17	.01	.19	.18	.04	.11	.08	.09	.37**
6	Word Reading Accuracy							.47**	.41**	.27*	.46**	.27*	.31**	.21	.27*	.27*	.47**	.05
7	Pseudoword Reading Accuracy								.30**	.06	.27*	.46**	.32**	.24*	.19	.38**	.34**	.09
8	Word Spelling Accuracy									.25*	.36**	.41**	.39**	.06	.26*	.30**	.52**	.21
9	Pseudoword Spelling Accuracy										.13	.17	.20	.09	.31**	.16	.28*	.19
10	Word Reading Accuracy											.39**	.16	.13	.33**	.34**	.23*	.09
11	Pseudoword Reading Accuracy												.34**	.21	.31**	.41**	.35**	.26*
12	Word Spelling Accuracy													.22*	.21	.35**	.44**	.46**
13	Pseudoword Spelling Accuracy														.17	.10	.04	.06
14	Word Reading Accuracy															.33**	.20	.23*
15	Pseudoword Reading Accuracy																.19	.21
16	Word Spelling Accuracy																	.16
17	Pseudoword Spelling Accuracy																	

* $p < .05$ ** $p < .01$

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

Table 4. *Correlation Matrix for all Measures in Cohort 2*

		Beginning of Grade 4									End of Grade 4				End of Grade 5			
	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Matrices		.26*	.14	.15	−.07	.07	.16	.19	.20	.10	−.03	.22*	−.04	.25*	.29*	.08	.23*
2	Peabody Vocabulary			.15	.26*	.01	.20	.14	.36**	.21	.21	.13	.31**	.11	.30**	.34**	.15	.36**
3	Phonemic Awareness accuracy				.15	−.04	.24*	.17	.19	−.03	.20	.23	.13	.21	.04	.09	−.02	.16
4	Orthographic Choice Task					.01	.39**	.40**	.67**	.27*	.29**	.26*	.56**	.09	.23	.16	.36**	.29*
5	Orthographic Awareness Task						.02	.06	.05	.02	−.21	.00	.03	.13	−.01	.28*	.09	.10
6	Word Reading Accuracy							.34**	.44**	.14	.21*	.16	.29**	.11	.14	.08	.39**	.36**
7	Pseudoword Reading Accuracy								.31**	.28*	.00	.33**	.22*	.39**	.17	.29*	.23	.27*
8	Word Spelling Accuracy									.39**	.36**	.11	.47**	.14	.20	.16	.48**	.51**
9	Pseudoword Spelling Accuracy										.26*	.19	.36**	.25*	−.01	.08	.16	.30*
10	Word Reading Accuracy											.36**	.35**	.06	.08	.06	.22	.19
11	Pseudoword Reading Accuracy												.36**	.19	.01	.13	.28*	.02
12	Word Spelling Accuracy													.18	.17	.16	.47**	.18
13	Pseudoword Spelling Accuracy														−.04	.19	.28*	.09
10	Word Reading Accuracy															.43**	.05	.06
15	Pseudoword Reading Accuracy																.05	.23
16	Word Spelling Accuracy																	.37**
17	Pseudoword Spelling Accuracy																	

* $p < .05$. ** $p < .01$.

significantly correlated with all later reading measures (with the exception of Word and Pseudoword Reading at the end of Grade 5), and with all later spelling measures (with the exception of Pseudoword Spelling at the end of Grade 4). Moreover, performance in the Orthographic Awareness Task at the beginning of Grade 4 was only significantly correlated with later Pseudoword Reading (end of Grade 5).

These correlations revealed that lexical orthographic knowledge was related to later reading and spelling either at an early or at a later phase of learning to read. Sublexical orthographic knowledge did not reveal such widespread relation with later reading and spelling measures.

Longitudinal Effects of Orthographic Knowledge on Reading and Spelling

The long-term predictive effects of orthographic knowledge on reading and spelling abilities were examined by means of cross-lag SRAs. Here, we first specified the set of predictors that make up the model. Next, we specified their order of entry, which reflects our theoretical framework and previous research findings. For all SRAs reported here, age, nonverbal reasoning, vocabulary, and phonemic ability were entered first to control for the contributions of age, general nonverbal and language abilities, and phonemic awareness.

We evaluated whether cross-lag contributions of the predictor variable (A at Time 1), entered at the fourth step, to an outcome variable (dependent Variable B, at Time 2) survived the additional control of B at Time 1, entered in the third step.

The same sequential regressions analyses examining the set of hypotheses were separately conducted for reading and spelling. Results for reading were firstly presented, followed by the ones for spelling.

Relationship between the Two Components of Orthographic Knowledge and Reading

This first set of sequential regressions analyses examined whether lexical or sublexical orthographic knowledge predicted word and pseudoword reading. The results are presented in Table 5 for Cohort 1 and 2.

In Cohort 1, performance in the Orthographic Choice Task at the beginning of Grade 2 only accounted for significant variance in word reading at the beginning of Grade 3 (6%). In a different way, the performance in the Orthographic Awareness Task did not account for any variance in word or pseudoword reading.

Concerning Cohort 2, performance in the Orthographic Awareness Task at the beginning of Grade 4 accounted (9%) for significant variance in pseudoword reading at the end of Grade 5. There were no other significant predictive effects.

Relationship between the Two Components of Orthographic Knowledge and Spelling

In this set of sequential regressions analyses, we examined whether word and pseudoword spelling were predicted by lexical or sublexical orthographic knowledge.

Results are presented in Table 6 for Cohort 1 and 2.

In Cohort 1, performance in the Orthographic Choice Task at the beginning of Grade 2 made a significant contribution to word spelling at the end of Grade 2 (6%) and to pseudoword spelling at the beginning of Grade 3 (8%). Furthermore, performance in the Orthographic Awareness Task at the beginning of Grade 2 accounted for significant variance on pseudoword spelling at the beginning of Grade 3 (12%). We did not observe any other significant predictive effects.

In Cohort 2, only one significant contribution was obtained. Performance in the Orthographic Choice Task at the beginning of Grade 4 significantly predicted word spelling at the end of Grade 4 (21%).

A statistical post hoc power analysis was performed considering Cohen's (1988) criteria (large/medium/small). Analyses indicated that, in the prediction of word and pseudoword reading and spelling, the power to detect effects from the Orthographic Choice and Orthographic Awareness Tasks, at the .05 level, was large, being above .50, in 84.4% of the regression analyses. There were, however, some exceptions. Four analyses (12.5%) were of medium power (.32, .46, .41, and .49, respectively for the effect of the Orthographic Awareness Task in the prediction of word reading at Grade 3 and of word spelling at Grade 5, and for the effect of the Orthographic Choice Task in the prediction of pseudoword spelling at Grades 2 and 4). Only one analysis (3.1%) revealed a small power (.21 for the effect of the Orthographic Awareness Task in the prediction of pseudoword spelling at Grade 2).

Discussion

The present study aimed at examining whether there were longitudinal predictive effects of the lexical and sublexical components of orthographic knowledge on word and pseudoword reading and spelling skills in European Portuguese, a language with intermediate depth orthography. It also intended to explore how these relations might vary along with reading and spelling development, from an early phase (Grade 2) to a more advanced one (Grade 5).

In accordance with our first hypothesis (H_1), orthographic knowledge at the lexical level had a predictive

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

Table 5. *Summary of Longitudinal Sequential Regression Analysis Predicting Cohort 1 (Grade 2 and 3) and 2 (Grade 4 and 5) Reading Measures Controlling for Non-Verbal Reasoning (NR), Vocabulary (V), Phonemic Awareness (PA), Word Reading (WR) or Pseudoword Reading (PWR), and Lexical Orthographic Knowledge (LOK) or Sublexical Orthographic Knowledge (SubLOK)*

		Grade 2 WR		Grade 3 WR			Grade 2 PWR		Grade 3 PWR			Grade 2 WR		Grade 3 WR			Grade 2 PWR		Grade 3 PWR	
Step	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2
1	NR	.09		−.03		NR	.01		.07		NR	.12		.06		NR	.07		.11	
	V	.11	.04	.01	.01	V	.05	.01	.03	.02	V	.11	.04	.07	.01	V	.06	.01	.06	.02
2	PA	−.06	.01	−.02	.00	PA	.15	.06*	.04	.02	PA	−.03	.01	.00	.00	PA	.17	.06*	.07	.02
3	WR	.56	.30***	.14	.06*	PWR	.39	.15***	.39	.16**	WR	.53	.26***	.22	.05	PWR	.38	.16***	.39	.15**
4	LOK	.03	.00	.29	.06*	LOK	.13	.01	.09	.01	SubLOK	−.40	.00	.07	.00	SubLOK	.09	.01	.05	.00
		Grade 4 WR		Grade 5 WR			Grade 4 PWR		Grade 5 PWR			Grade 4 WR		Grade 5 WR			Grade 4 PWR		Grade 5 PWR	
Step	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2
1	NR	.05		.15		NR	−.12		.16		NR	.05		.17		NR	−.13		.21	
	V	.09	.05	.26	.13**	V	.11	.03	.27	.16**	V	.12	.05	.24	.11*	V	.12	.03	.25	.16**
2	PA	.12	.03	−.06	.00	PA	.19	.06	−.01	.00	PA	.12	.03	−.07	.00	PA	.17	.05	.00	.00
3	WR	.14	.04	−.02	.00	PWR	.26	.08*	.22	.05	WR	.20	.04	.10	.01	PWR	.31	.09**	.21	.04
4	LOK	.21	.04	.22	.04	LOK	.11	.01	.07	.00	SubLOK	−.19	.04	.01	.00	SubLOK	−.01	.00	.30	.09**

Note. All the beta weights are from the final step of the regression model.

* $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

Table 6. *Summary of Longitudinal Sequential Regression Analysis Predicting Cohort 1 (Grade 2 and 3) and 2 (Grade 4 and 5) Spelling Measures Controlling for Non-Verbal Reasoning (NR), Vocabulary (V), Phonemic Awareness (PA), Word Spelling (WS) or Pseudoword Spelling (PWS), and Lexical Orthographic Knowledge (LOK) or Sublexical Orthographic Knowledge (SubLOK)*

		Grade 2 WS		Grade 3 WS			Grade 2 PWS		Grade 3 PWS			Grade 2 WS		Grade 3 WS			Grade 2 PWS		Grade 3 PWS	
Step	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2
1	NR	–.14		–.10		NR	–.02		–.14		NR	–.10		–.09		NR	–.01		–.07	
	V	.09	.03	.36	.19**	V	.03	.00	.14	.04	V	.12	.02	.37	.18**	V	–.01	.00	.21	.03
2	PA	.28	.14**	.24	.14***	PA	.24	.07	.08	.02	PA	.29	.12**	.23	.12**	PA	.20	.04	.09	.02
3	WS	.19	.07*	.36	.14***	PWS	.10	.01	.09	.02	WS	.26	.06*	.41	.14***	PWS	.02	.00	.08	.02
4	LOK	.28	.06*	.15	.02	LOK	–.06	.00	.30	.08*	SubLOK	.11	.01	.02	.00	SubLOK	.02	.00	.35	.12**
		Grade 4 WS		Grade 5 WS			Grade 4 PWS		Grade 5 PWS			Grade 4 WS		Grade 5 WS			Grade 4 PWS		Grade 5 PWS	
Step	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2	Predictor	β	Δ R^2	β	Δ R^2
1	NR	.17		.09		NR	–.20		.19		NR	.16		.08		NR	–.21		.19	
	V	.10	.10*	.01	.02	V	.12	.03	.30	.20**	V	.11	.09*	–.00	.01	V	.10	.04	.31	.21**
2	PA	.00	.00	–.17	.01	PA	.24	.05	.06	.00	PA	.03	.00	–.12	.01	PA	.23	.04	.09	.01
3	WS	–.09	.07*	.23	.13**	PWS	.11	.01	.08	.01	WS	.26	.06*	.29	.07*	PWS	.11	.01	.09	.01
4	LOK	.60	.21***	.23	.03	LOK	–.09	.01	.12	.01	SubLOK	–.02	.00	.12	.01	SubLOK	.07	.00	.06	.00

Note. All the beta weights are from the final step of the regression model.

* $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

effect on the later ability to read and spell words in an early phase of literacy instruction (Grades 2 and 3) and on the later word spelling ability in a more advanced phase (Grade 4). This finding supports the theoretical view that word-specific orthographic knowledge plays an important role in supporting sight word reading and correct word spelling (e.g., Ehri, 2014).

Concerning pseudowords, a contribution of lexical orthographic knowledge was observed only to spelling and in an early phase of literacy instruction (from Grade 2 to 3), supporting partially our second hypothesis (H_2). Indeed, this contribution did not extend to reading pseudowords, contrary to the theoretical proposal according to which the use of word specific representations stored in memory allows children not only to spell pseudowords but also to read them (Ehri, 2005).

In studies conducted with English-speaking children, no long-term influence from the lexical component of orthographic knowledge to word (Conrad & Deacon, 2016; Deacon et al., 2012; Georgiou et al., 2008) and pseudoword reading skills (Georgiou et al., 2008) was observed. Interestingly, in Greek, a consistent orthography, results obtained from beginner readers revealed a longitudinal predictive effect from lexical orthographic knowledge on word reading, but not on pseudoword reading (Georgiou et al., 2008), as it was also observed in European Portuguese. This seems to indicate that, in an initial phase of literacy acquisition, word-specific orthographic knowledge does not support reading skills acquisition in English, but that it provides such support to word reading in orthographies more consistent such as Greek and European Portuguese.

Still in line with Ehri's theoretical view, we further hypothesized that the sublexical component of the orthographic knowledge longitudinally benefits the reading and spelling of words (H_3) and pseudowords (H_4). This could be because this type of orthographic knowledge provides the expectations and constraints about how a word or a pseudoword (novel word) could be read or spelled accordingly with the knowledge of recurring letter patterns (Ehri, 2005).

The present results did not provide support to the third hypothesis (H_3), given that there was no longitudinal predictive effect from sublexical orthographic knowledge to subsequent word reading and spelling performance in neither cohort. When considering the initial phase of literacy development, this evidence is in line with results of previous studies which also did not find any longitudinal influence of sublexical orthographic knowledge on word reading in English (Deacon et al., 2012), and on word reading and spelling in German (Ise et al., 2014). The results with Portuguese children in a more advanced phase of literacy development also showed no such longitudinal influence, possibly suggesting that sublexical orthographic knowledge does not in any way influence the reading or the spelling of words. However, as far as we know, there was no other study examining this issue beyond the initial phase of learning to read, in English or in more consistent orthographies.

In contrast, the fourth hypothesis (H_4) concerning the longitudinal influence of the sublexical orthographic knowledge on pseudoword reading and spelling was partially supported. Indeed, sublexical knowledge assessed at the beginning of Grade 2 and Grade 4 predicted pseudoword spelling at the beginning of Grade 3, and pseudoword reading at the end of Grade 5, respectively. Despite the smaller power of the analysis of the influence of sublexical orthographic knowledge on pseudoword spelling, these findings can be considered as consistent with the view that orthographic knowledge at the sublexical level plays some significant role in reading and spelling development. This could be sustained by the widely accepted idea that recognizing letter patterns enhances the decoding process in reading, and that the knowledge of specific and legal letter patterns might be especially helpful in producing/spelling unknown or novel words (e.g., Conrad & Deacon, 2016).

The overall set of results obtained in the present study revealed that the lexical component of orthographic knowledge, compared to the sublexical one, anyway had a greater number of contributions, particularly for spelling. Comparatively to reading, spelling was predicted by orthographic knowledge more often, mainly in the early phase of literacy acquisition. Also significant is the fact that only the spelling of pseudowords (potentially new words) benefitted from the influence of the two components of orthographic knowledge. When lexical representations are still beginning to be built in the initial phase of literacy development, correct word spelling may depend not only on well-specified stored representations of words but also on orthographic pattern knowledge. These findings indicate a likely differential role of orthographic knowledge components on reading and spelling skills, at least in European Portuguese. The greater inconsistency in phoneme-grapheme conversion involved in spelling than in grapheme-phoneme conversion implicated in reading, in this orthography (e.g., Fernandes et al., 2008) can explain why the contribution of orthographic knowledge is particularly strong for spelling development. Furthermore, it is widely accepted that compared to reading, correct spelling is more exigent, demanding fully specified word orthographic representations (e.g., Conrad et al., 2019). This is in agreement with findings obtained with Portuguese first graders, revealing an early use of the orthographic lexicon for spelling but not for reading (Fernandes et al., 2008). As already referred, studies

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

examining the longitudinal influence of lexical and sublexical orthographic knowledge on both reading and spelling are scarce, even in English. However, some empirical support for the idea of a differential role of orthographic knowledge on reading and spelling skills comes from studies using a concurrent design with consistent orthographies such as Persian (Arab-Moghaddam & Sénéchal, 2001), Dutch (Bekebrede et al. 2009), and German (Zarić et al., 2020), all showing that word-specific orthographic knowledge contributes more to spelling than to reading.

Compared to the systematic effects found in the concurrent studies carried out in orthographies varying in consistency, findings from longitudinal studies suggest a differential impact of orthographic consistency on the role of orthographic knowledge components on reading and spelling acquisition (see Georgiou et al., 2008, for different predictive models of longitudinal predictors of reading and spelling depending on orthographic consistency). In our view, it may be of theoretical interest discussing a few entangled factors with implications for this issue. Among others, two somewhat associated factors to be considered are the phase of reading and spelling acquisition and the degree of orthographic consistency. Concerning the fact that participants may not have reached the same level of literacy instruction and, consequently, the same level of decoding ability, it is broadly acknowledged that the duration of this latter acquisition varies across orthographies with different consistency levels (e.g., Seymour et al., 2003). Indeed, the proficiency of decoding is attained later in inconsistent orthographies than it is in more consistent ones (e.g., Caravolas, 2018). Moreover, it is widely recognized that this ability, also referred to as phonological recoding, is crucial for the establishment of word-specific orthographic knowledge (e.g., Share, 1995). In an inconsistent orthography such as English, this development occurs latter, with the consequence of a delay in the efficient use of lexical orthographic knowledge, compared to what is observed in more consistent orthographies. As previously mentioned, in an initial phase of literacy acquisition, word-specific orthographic knowledge does not assist reading skills acquisition in English, but it affords some support in orthographies more consistent such as Greek and also European Portuguese. Therefore, we can suggest that orthographic consistency, through its characteristics and specific influence on literacy development, may impact the relationship between lexical orthographic knowledge and reading skills with respect to the point in time in which it occurs. As suggested by Deacon et al. (2012), we cannot exclude the possibility that, in English, lexical orthographic knowledge influences reading later in literacy development. It is worth to note that in European Portuguese, an orthography more consistent than English, we observed this influence in an initial phase of reading learning but not in a more advanced one. Studies conducted in a range of orthographies varying in consistency and over more advanced phases of literacy acquisition are needed to better understand the effect of orthographic consistency on the role of lexical orthographic knowledge in reading development. Such studies can importantly contribute to distinguish between the universal and language-specific role of the components of orthographic knowledge in literacy acquisition.

Several limitations of this study should be noted. Some aspects such as the sample dimension and the number of studied relations prevented us to use other methods (e.g., path analyses) than SRAs. Despite the longitudinal character of the study, SRAs are still correlational analyses which preclude us from making strong inferences of causality. Training and intervention studies are required to investigate more adequately causal relations between the two components of orthographic knowledge and reading and spelling development. Moreover, intervention studies focused on orthographic knowledge, with children at risk or having specific learning disabilities, would help to highlight its efficacy and effectiveness along with the reading and spelling acquisition. Also, our results are based on two specific measures of both components of orthographic knowledge. It is possible that the use of other measures would lead to a different pattern of results. Furthermore, our longitudinal study was carried out with a long-time lag between the orthographic knowledge assessment and the outcome measures of reading and spelling. It would be enlightening to examine these longitudinal relations, varying time intervals between assessments of the studied variables.

Taking into account the very long-time intervals between two testing moments in each cohort of this study in European Portuguese, lexical orthographic knowledge seems to have a long lasting and widespread influence on the ability to read words and spell words and novel words. Besides, sublexical orthographic knowledge seems to support, although in a limited way, the reading and spelling of novel words. These findings reinforce the idea that orthographic knowledge is not only an outcome but also an important predictor of reading and spelling skills apart from phonological awareness and letter knowledge (Apel, 2011). They also support the notion that different sources of knowledge are available for Portuguese children when learning to read and spell. Therefore, in literacy acquisition, direct and systematic instruction should emphasize, beyond phonics, the learning and teaching of orthographic knowledge, allowing the establishment of word-specific orthographic representations and promoting orthographic patterns knowledge.

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

References

Apel, K. (2009). The acquisition of mental orthographic representations for reading and spelling development. *Communication Disorders Quarterly*, *31*(1), 42–52. http://doi.org/10.1177/1525740108325553

Apel, K. (2011). What is orthographic knowledge? *Language, Speech, and Hearing Services in Schools*, *42*(4), 592–603. http://doi.org/10.1044/0161-1461(2011/10-0085)

Apel, K., Henbest, V. S., & Masterson, J. (2019). Orthographic knowledge: Clarifications, challenges, and future directions. *Reading and Writing*, *32*(4), 873–889. http://doi.org/10.1007/s11145-018-9895-9

Arab-Moghaddam, N., & Sénéchal, M. (2001). Orthographic and phonological processing skills in reading and spelling in Persian/English bilinguals. *International Journal of Behavioral Development*, *25*(2), 140–147. http://doi.org/10.1080/01650250042000320

Bekebrede, J., van der Leij, A., & Share, D. L. (2009). Dutch dyslexic adolescents: Phonological-core variable orthographic differences. *Reading and Writing*, *22*(2), 133–165. http://doi.org/10.1007/s11145-007-9105-7

Binamé, F., & Poncelet, M. (2016). The development of the abilities to acquire novel detailed orthographic representations and maintain them in long-term memory. *Journal of Experimental Child Psychology*, *143*, 14–33. http://doi.org/10.1016/j.jecp.2015.10.010

Caravolas, M. (2018). Growth of word and pseudoword reading efficiency in alphabetic orthographies: Impact of consistency. *Journal of Learning Disabilities*, *51*(5), 422–433. http://doi.org/10.1177/0022219417718197

Castles, A., & Nation, K. (2008). Learning to be a good orthographic reader. *Journal of Research in Reading*, *31*(1), 1–7. https://doi.org/10.1111/j.1467-9817.2007.00367.x

Chung, S. C., Chen, X., & Deacon, S. H. (2018). The relation between orthographic processing and spelling in grade 1 French immersion children. *Journal of Research in Reading*, *41*(2), 290–311. http://doi.org/10.1111/1467-9817.12104

Clark, W. C., Rutschmann, J., Link, R., & Brown, J. C. (1963). Comparison of flicker-fusion thresholds obtained by the methods of forced-choice and limits on psychiatric patients. *Perceptual and Motor Skills*, *16*(1), 19–30. http://doi.org/10.2466/pms.1963.16.1.19

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Erlbaum

Commissaire, E., & Besse, A.-S. (2019). Investigating lexical and sub-lexical orthographic processing skills in French 3rd and 5th graders. *Journal of Research in Reading*, *42*(2), 268–287. http://doi.org/10.1111/1467-9817.12268

Conrad, N. J., & Deacon, S. H. (2016). Children's orthographic knowledge and their word reading skill: Testing bidirectional relations. *Scientific Studies of Reading*, *20*(4), 339–347. http://doi.org/10.1080/10888438.2016.1183128

Conrad, N. J., Harris, N., & Williams, J. (2013). Individual differences in children's literacy development: The contribution of orthographic knowledge. *Reading and Writing*, *26*(8), 1223–1239. http://doi.org/10.1007/s11145-012-9415-2

Conrad, N. J., Kennedy, K., Saoud, W., Scallion, L., & Hanusiak, L. (2019). Establishing word representations through reading and spelling: Comparing degree of orthographic learning. *Journal of Research in Reading*, *42*(1), 162–177. http://doi.org/10.1111/1467-9817.12256

Deacon, S. H., Benere, J., & Castles, A. (2012). Chicken or egg? Untangling the relationship between orthographic processing skill and reading accuracy. *Cognition*, *122*(1), 110–117. http://doi.org/10.1016/j.cognition.2011.09.003

Deacon, S. H., Pasquarella, A., Marinus, E., Tims, T., & Castles, A. (2019). Orthographic processing and children's word reading. *Applied Psycholinguistics*, *40*(2), 509–534. http://doi.org/10.1017/S0142716418000681

Defior, S., Jiménez-Fernández, G., & Serrano, F. (2009). Complexity and lexicality effects on the acquisition of Spanish spelling. *Learning and Instruction*, *19*(1), 55–65. http://doi.org/10.1016/j.learninstruc.2008.01.005

Dunn, L. M., Padilla, E. R., Lugo, D. E., & Dunn, L. M. (1986). *Manual del Examinador para el Test de Vocabulário en Imágenes Peabody* [Examiner's manual for the Peabody Picture Vocabulary Test]. American Guidance Service.

Ehri, L. C. (2005). Learning to read words: Theory, findings, and issues. *Scientific Studies of Reading*, *9*(2), 167–188. http://doi.org/10.1207/s1532799xssr0902_4

Ehri, L. C. (2014). Orthographic mapping in the acquisition of sight word reading, spelling memory, and vocabulary learning. *Scientific Studies of Reading*, *18*(1), 5–21. http://doi.org/10.1080/10888438.2013.819356

Fernandes, S., Querido, L., Verhaeghe, A., & Araújo, L. (2018). What is the relationship between reading prosody and reading comprehension in European Portuguese? Evidence from grades 2 to 5. *Journal of Research in Reading*, *41*, S102–S129. http://doi.org/10.1111/1467-9817.12248

Fernandes, S., Ventura, P., Querido, L., & Morais, J. (2008). Reading and spelling acquisition in European Portuguese: A preliminary study. *Reading and Writing*, *21*(8), 805–821. http://doi.org/10.1007/s11145-007-9093-7

Georgiou, G. K., Parrila, R., & Papadopoulos, T. C. (2008). Predictors of word decoding and reading fluency across languages varying in orthographic consistency. *Journal of Educational Psychology*, *100*(3), 566–580. http://doi.org/10.1037/0022-0663.100.3.566

Ise, E., Arnoldi, C. J., & Schulte-Körne, G. (2014). Development of orthographic knowledge in German-speaking children: A 2-year longitudinal study. *Journal of Research in Reading*, *37*(3), 233–249. http://doi.org/10.1111/j.1467-9817.2012.01535.x

Kenny, D. A. (1975). Cross-lagged panel correlation: A test for spuriousness. *Psychological Bulletin*, *82*(6), 887–903. http://doi.org/10.1037/0033-2909.82.6.887

Lima, C. F., & Castro, S. L. (2010). Reading strategies in orthographies of intermediate depth are flexible: Modulation of length effects in Portuguese. *European Journal of Cognitive Psychology*, *22*(2), 190–215. http://doi.org/10.1080/09541440902750145

Nielsen, A.-M. V. (2017). Knowledge of conditional spelling patterns supports word spelling among Danish fifth graders. *Journal of Research in Reading*, *40*(3), 313–332. http://doi.org/10.1111/1467-9817.12067

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press

Olson, R. K., Forsberg, H., Wise, B., & Rack, J. (1994). Measurement of word recognition, orthographic, and phonological skills. In G. R. Lyon (Ed.), *Frames of reference for the assessment of learning disabilities: New views on measurement issues* (pp. 243–277). Brookes.

Ouellette, G., & Sénéchal, M. (2008). Pathways to literacy: A study of invented spelling and its role in learning to read. *Child Development*, *79*, 899–913. http://doi.org/10.1111/j.1467-8624.2008.01166.x

Querido, L., Fernandes, S., Verhaeghe, A., & Marques, C. (2020). Lexical and sublexical orthographic knowledge: Relationships in an orthography of intermediate depth. *Reading and Writing*, *33*, 2459–2479. http://doi.org/10.1007/s11145-020-10052-2

Rothe, J., Schulte-Körne, G., & Ise, E. (2014). Does sensitivity to orthographic regularities influence reading and spelling acquisition? A 1-year prospective study. *Reading and Writing*, *27*(7), 1141–1161. http://doi.org/10.1007/s11145-013-9479-7

Schneider, W., Eschman, A., & Zuccolotto, A. (2002a). *E-Prime: User's guide*. Psychology Software Incorporated.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002b). *E-prime computer software and manual*. Psychology Software Tools Inc.

Seymour, P. H., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology*, *94*(2), 143–174. http://doi.org/10.1348/000712603321661859

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition*, *55*(2), 151–218. http://doi.org/10.1016/0010-0277(94)00645-2

Simões, M. R. (1994). *Investigações no âmbito da aferição nacional do teste das Matrizes Progressivas Coloridas de Raven (M.P.C.R.)* [Investigations in the context of the national assessment of Raven's Colored Progressive Matrices] [Unpublished doctoral dissertation]. Universidade de Coimbra, Coimbra, Portugal.

Sprenger-Charolles, L., Siegel, L. S., & Bonnet, P. (1998). Reading and spelling acquisition in French: The role of phonological mediation and orthographic factors. *Journal of Experimental Child Psychology*, *68*(2), 134–165. http://doi.org/10.1006/jecp.1997.2422

Stanovich, K. E., & Siegel, L. S. (1994). Phenotypic performance profile of children with reading disabilities: A regression-based test of the phonological-core variable-difference model. *Journal of Educational Psychology*, *86*(1), 24–53. http://doi.org/10.1037/0022-0663.86.1.24

Stanovich, K. E., West, R. F., & Cunningham, A. E. (1991). Beyond phonological processes: Print exposure and orthographic processing. In S. Brady & D. Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y. Liberman* (pp. 219–235). Lawrence Erlbaum Associates.

Sucena, A., Castro, S. L., & Seymour, P. (2009). Developmental dyslexia in an orthography of intermediate depth: The case of European Portuguese. *Reading and Writing*, *22*(7), 791–810. http://doi.org/10.1007/s11145-008-9156-4

Surrador, A. (1997). *Ortografia do Português: Contributos para uma análise dos desvios à norma ortográfica em crianças do Ensino básico* [Portuguese orthography: Contributions to an analysis of deviations from the orthographic norm in elementary school children] [Unpublished master dissertation]. Universidade de Lisboa, Lisboa, Portugal.

Teixeira, C., & Castro, S. L. (2007). *Portulex: Base de dados lexical de manuais do 1° ao 4° anos de escolaridade* [Portulex: Lexical database of manuals from 1st to 4th school grades]. Laboratório de Fala da Faculdade de Psicologia da Universidade do Porto.

Vellutino, F. R., Scanlon, D. M., & Tanzman, M. S. (1994). Components of reading ability: Issues and problems in operationalizing word identification, phonological coding, and orthographic coding. In G. R. Lyon (Ed.), *Frames of reference for the assessment of learning disabilities: New views on measurement issues* (pp. 279–332). Paul H Brookes Publishing Co.

Zarić, J., Hasselhorn, M., & Nagler, T. (2020). Orthographic knowledge predicts reading and spelling skills over and above general intelligence and phonological awareness. *European Journal of Psychology of Education*, *2020*. http://doi.org/10.1007/s10212-020-00464-7

https://doi.org/10.1017/SJP.2021.3 Published online by Cambridge University Press