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Early Context-Conditioned Orthographic Knowledge in European Portuguese: The Spelling of the Schwa

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This longitudinal study examined how the phonemic-orthographic context affects the spelling of the schwa (/ɨ/) by Portuguese beginning spellers at two time points in the first school grade. The schwa is phonetically unstable and phonologically ill-defined, has an unpredictable realization, is frequently deleted at the syllable's end, and is often spelt as <e>, a very high frequency grapheme with numerous phonological renditions. In addition to cognitive and other alphabetic tasks, 41 first graders were asked to spell 40 consistent words of medium-low frequency: 5 CV.CV (consonant, vowel. consonant, vowel) with well-articulated vowels; 10 C/ɨ/C.VC, the first vowel being a schwa, thereby creating potential phonological consonantal clusters, half legal (/fɨliʃ/, /fliʃ/), half illegal (/pɨdal/, /pdal/); 10 CV.C/ɨ/, the last vowel being a schwa, potentially creating phonological monosyllables half with a legal coda (/mɔlɨ/, /mɔl/) and half with an illegal coda (/n'avɨ/), (/nav/); in addition, the children spelt 15 CVC ending with /l/, /ɾ/ and /ʃ/, the only legal Portuguese codas. Participants were also asked to spell equivalent pseudowords at a second point in time. Our results show that children were sensitive to allowable letter patterns from the Time 1 assessment point. Although alphabetic spelling was not entirely mastered, children used <e> more in first syllables than at the end of the word, and more in illegal than in legal phonological consonantal clusters, although the pattern of significant differences did change over time. The results were similar for pseudowords. Also, children used <e> more at the CV.C/ɨ/ words whose last C was /l/, than in monosyllabic CVC words ending with /l/. This was not observed with pseudowords, where the grapheme <e> was used with a similar frequency in the two types of items. Overall, these results show that children's acquisition of this kind of context-conditioned orthographic knowledge occurs simultaneously with alphabetic letter-sound learning and depend largely on intuitive statistical learning reflecting the regularities of the written code to which they are exposed.

Keywords: spelling, context conditioned spelling, schwa spelling, spelling development, orthographic regularities, European Portuguese, early spelling

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INTRODUCTION

At the beginning of formal schooling children rely heavily on phonology when spelling words, trying to match each sound they can detect in a word to a non-arbitrary letter (Caravolas, 2004; Pollo et al., 2005; Fernandes et al., 2008; Sargiani and Albuquerque, 2016; Chaves-Sousa et al., 2017).

Phonology is an essential component of early spelling and may be the most relevant information source when children begin the journey of making sense of how alphabetic systems work. Thus, learning the phonological underpinning of spellings and the relations between sounds and letters constitutes an initial key acquisition in spelling development. Accordingly, different accounts of spelling development agree on the idea that this phonological pathway is a core mechanism both for grasping the alphabetic principle (Treiman, 2017a, 2018) and developing the ability to spell correctly (Vale, 2000; Caravolas, 2004; Ehri, 2005; Barbosa et al., 2016; Albuquerque and Alves Martins, 2019; Treiman et al., 2019a).

Yet early spelling is not based purely on phonology (Caravolas et al., 2005; Treiman, 2017a; Treiman et al., 2018). Recent work (Treiman et al., 2019b) has shown that 3–6-year old Portuguese-speaking Brazilian pre-phonological spellers do not choose letters at random when writing letter sequences that do not represent any sound of the words they were asked to spell. Older children tend to use letters and digrams more frequently than younger children, in proportion to their frequency of occurrence in the texts to which they are exposed. Similarly, a comparative study showed that, corresponding to the orthographic features of Portuguese, 4–5-year old Brazilian children used more vowels and more consonant-vowel (hitherto referred to as CV) alternation than did US children (Pollo et al., 2009). These findings reflect young children's ability at a very early age to detect and extract letter patterns from inputs, and show that they may learn graphotactic aspects of writing, that is which sequences of letters go and do not go together, even before they learn how letters represent sounds (Treiman, 2017b). Taken together, the above-mentioned evidence raises the question of how children deal with these two sources of information (phonology and graphotactics) in early spelling, before either has been firmly acquired and therefore may compete with each other.

Sometimes orthographic patterns include letters that have minimal or no phonological support. For instance, in Portuguese the <e> in <mole> (soft) is not relevant for reading but represents the schwa in the word. The schwa may or may not be pronounced (respectively, /mɔlɨ/ or /mɔl/) depending on the speech rate. Essentially in colloquial speech rate the difference between the two oral productions is mostly undetectable without the use of the acoustic analytical techniques used in a speech laboratory. In this study we aimed to examine how soon Portuguese beginning spellers marked phonologically absent (or minimal) segments, such as schwas, that ought to be written if the canonical orthographic form of the word is to be preserved.

Phonological Information in Early Spelling

Most studies undertaken in different alphabetic orthographies find learning to spell follows similar developmental paths. Children typically progress from spellings that predominantly capture partial phonological patterns of words, to phonologically plausible complete spellings that are orthographically incorrect, before reaching a reliable capacity to produce the majority of standard correct spellings (Abreu et al., 2004; Ritchey et al., 2010; Bahr et al., 2012; Dich and Cohn, 2013; Sucena, 2017; Treiman, 2017b). There is also good evidence that these qualitatively different types of spelling can coexist and that beginning spellers can use different kind of orthographic knowledge, such as accurate written forms of specific words and graphotactic information (Martinet et al., 2004; Deacon et al., 2008; Conrad et al., 2013). Nevertheless, the phonological perspective on development emphasizes the idea that there exists a phonological foundation of spelling that requires the youngest spellers to conscientiously analyze word structure and select letters to represent it.

Studies of invented spelling show that children with little knowledge of letters and little alphabetic instruction create their own spellings using phonological information as an important base for choosing letters. The numerous examples in the literature regarding the use of letter names is an eloquent illustration of this. For instance, US kindergarten children may spell <cr> for *car* in which <r> stands for /ar/, the name of the letter <r>; or they may produce the spelling <t> for the non-word /tib/ which has the letter name /ti/, but be unable to spell any phonological structure of /mib/ or /feb/ which do not have letter names (Read, 1986; Treiman, 1994; Treiman and Tincoff, 1997; Read and Treiman, 2013). Comparable findings are to be found in research into other languages, such as French, Spanish, Japanese, Greek, Mayan (Fijalkow, 2007, journal special issue), and Hebrew (Levin et al., 2002).

Likewise, a similar significant proportion of phonologically motivated spellings has been observed in early spelling by Portuguese children. Five-year old kindergartners with very little tuition in written language but knowing some letters, would spell <HR> for the word *agarre* (/ɐgaR/-grasp) using the name of the first consonant (/ɐga/) and the sound of the second one (/R/), a phonologically high salient trill; the same children would spell <SD> for *sede* (/sedɨ/-thirst) where the first consonant name may be known as /se/ (there is another name too, /ɛs/) and the last consonant sound is /dɨ/, the latter possibly processed as a near syllable-like structure due to the schwa (Vale, 2000). Sargiani and Albuquerque (2016) verified that in a group of Brazilian kindergartners who knew an average of 20.6 out of 26 letters, 76.3% could represent some part or the entire sound sequence of words. Most of them (57.9%) used mainly letter names but also letter sounds (<dto> for /dedu/, finger; <kblo> for /kabelu/, hair) to assist their spellings.

In the same vein, a few studies of Portuguese first graders 3 months after starting formal alphabetic instruction (Vale and Cary, 1998; Vale, 2000) showed that children chose an appropriate letter significantly more often (81.8% of the time) to spell the first consonant of a word if it matched a full letter name (<p> for /penɐ/, feather) or was followed by a schwa (<p> for /pɨdal/-pedal) than if the letter did not have those features (64.7% of the time; /põtɨ/-bridge). Other studies of Portuguese speaking pre-literate Brazilian children have come to similar conclusions (Cardoso-Martins and Batista, 2005; Pollo et al., 2005).

In their initial attempts to spell, children sometimes mark letters that do not pertain to the written word (that often have an infrequent orthographic pattern) but that represent individual sounds in the pronunciation of the word. First grade Portuguese children may spell <tacsi> (instead of <táxi>) for /taksi/, using a graphemic pattern (<cs>) that does not exist in the Portuguese orthography (Vale, 2000). Portuguese-speaking Brazilian children spelt the sequence /ks/ in the non-word /fɔks/ as <cs>, <qs> and <ks>, all of which contravene standard orthography (Pinheiro, 1995). Treiman (1993) showed that these kind of sound-based graphemic substitutions linked to pronunciations also occur among English speaking children (e.g., <chruk> for *truck*, since *truck* and *chuck first* sounds are similar). These findings highlight the significant weight given to phonology among younger spellers.

Furthermore, Treiman et al. (2019a) have shown that beginning spellers do better on representing all the sounds in a word than on registering all its letters. For instance, if a child spells <bak> for *back*, the entire phonological sequence is represented but not the entire sequence of letters. Portuguese first graders at the beginning of the school year wrote 22.4% of consistent words in a phonologically-plausible complete form (<tor> for *torre*-/toRɨ/-tower), only 8.7% of which were orthographically correct (<torre>) (Vale, 2000). These findings concur with earlier research in California by Ehri and Wilce (1982) showing that second graders found silent letters significantly harder to remember than pronounced letters when shown a letter on a card and asked if it was in a word they had previously read.

When formal reading and spelling training begins, explicit teaching of phoneme and grapheme correspondences arguably strengthens children's capacity to use sounds in words to choose letters in spellings. Most Portuguese teachers state they use phonic methods (Spear-Swerling et al., 2016) which in children's first attempts to deal with the alphabet focuses their attention on letters and sounds. This agrees with data showing that early first grade Portuguese children can correctly identify 66% of consonant graphemes by their sound (Pedro et al., 2017) and about 88% of all letter sounds by the end of first grade (Duncan et al., 2013). Letter knowledge and phonological skills are well-known correlates and predictors of early spelling (Caravolas et al., 2001; Caravolas, 2004). Taken together, these two components explained 75.3% of the variance in Portuguese-speaking Brazilian first graders' spelling of a list of words (CVCV and CVCVCV) that included between one and three letter names each (Barbosa et al., 2016). In sum, the above-mentioned studies indicate that, in line with their counterparts learning to spell in other alphabetic orthographies, when Portuguese-speaking children begin acquiring their alphabet, they make substantial use of the sounds of words when spelling (Fernandes et al., 2008; Sucena, 2017).

One aspect of the phonologically-attuned way children ground their early spellings is that the phonological properties of the sounds contribute to the children's ability to represent them. Treiman et al. (1995) found that first graders had difficulty in spelling the nasal consonant segments in final consonant clusters, especially when preceding voiceless obstruents (e.g., spelling <vos> for /vans/). According to the authors, this difficulty reflected the fact that in this context the nasal consonant is a minimal segment that children may confuse with the nasalized vowel. Those children also tended to omit the liquids /r/ and /l/ in final consonant clusters (e.g., <pit> for /pIlt/), probably because these segments are phonologically close to the vowels and thus were processed as being part of it. Similar findings have been reported in other studies (van Bon and Uit De Haag, 1997, for Dutch; Read and Treiman, 2013). Syllable stress affects early spellings as well. Treiman et al. (1993) showed that first graders and kindergartners dropped unstressed vowels more often than stressed ones and omitted reduced vowels (schwas) with particular frequency. These evidences are not English specific, as the following examples in Portuguese will show, and they are particularly relevant to the current study that seek to examine how Portuguese schwas are processed by early spellers.

In Portuguese, there are only a few studies that have addressed the issue of the spelling of phonemes that are harder to isolate. A study by Miranda and Veloso (2017) of about 1,000 spontaneous texts written by Brazilian first and second graders showed that 77% of the observed errors in CVC orthographic syllables related to nasal vowels. The largest part of these errors concerned substitutions of /ẽ/ by /e/ (e.g., spelling <mega> instead of <manga>, /mẽge/-sleeve). This kind of orthographic error seems to indicate that, for those children, the nasal quality of the vowels was not clearly established and that these two vowels were phonologically processed as being similar to each other. Another study (Alves, 2012) showed that Portuguese first graders spelt orthographically-consistent fricative onsets more accurately than orthographically-consistent plosive ones. Fricatives are phonologically more accessible than plosives because the latter cannot be pronounced in isolation. Thus, fricatives may have been easier for children to identify and to learn to match with an appropriate letter (Byrne and Fielding-Barnsley, 1990; Kolinsky et al., 2018). There is also evidence that Portuguese schwas are challenging for beginning spellers. Rosa and Nunes (2010) presented first graders with oral sentences that included both a stem-word and its derived form containing a schwa (e.g., *martelo*, /meɾtɛlu/-hammer; *martelar*, /meɾtɨlaɾ/-to hammer), and asked them to spell the derived word. Children produced errors on 57% of the schwas, even though the derived words preserved the spelling of the full-articulated respective stem vowel.

The above-mentioned studies point directly or indirectly to the fact that, when beginning to learn how words are written, children largely rely on sound-related information that can be readily perceived, and experience difficulties in cases where sounds are harder to hear, to identify, to distinguish or to process in isolation.

Graphotactic Information in Early Spelling

Like it was briefly stated when presenting this study framework at the beginning of the Introduction, graphotactic regularities provide children with a very early means of shaping the information they need for spelling, as can be confirmed in the example of the respective proportions of consonant-and vowel-alternation in the letter patterns produced by pre-phonological spellers (Treiman et al., 2019b). Another aspect of graphotactic knowledge, sensitivity to legal combination of letters, is also apparent from very early attempts to write. Non-phonological features of the spellings of young US children already using phonology to support their productions include, for example, avoidance of spelling the doublets <hh> and <yy>, which do not occur in English (Treiman, 1993). Evidence also exists that US 6 year-olds more frequently spell double consonants in the final position than in the initial position of CVC items, in line with English orthography (Wright and Ehri, 2007). In the same vein, Gingras and Sénéchal (2019) showed that more frequent double consonants had a facilitative effect on French first graders' spelling accuracy: for each 1% growth in frequency, there was an increase of 0.65% in spelling accuracy. First graders are also aware of contextual features of orthography. Hayes et al. (2006) observed that children spelt the sound /k/ more often using <k> before <i> and <c> before <a> which reflects a regularity of English orthography. Pacton et al. (2005) reported similar findings with French first graders, who spelt <-ette> after <v> more often than after <t>, consistent with French orthography. Recently Gingras and Sénéchal (2019) found that silent letters reduced the spelling accuracy of French first graders by 6.49%, with those occurring more frequently (such as <tt>) being less prone to errors than less frequent ones (such as <dd>).

In European Portuguese there is strong competition between the grapheme <u>, whose name and sound is /u/, and the grapheme <o>, whose name is /ɔ/ but which is much more frequent in representing /u/ (Gomes, 2001). A study run with first graders (Vale et al., 2018) showed that, from the middle to the end of the school year, children significantly increased the use of the letter <o> to spell the sound /u/ (42.7–59.6% across different positions) reflecting the high frequency of the letter <o> to spell /u/ in Portuguese. However, children increased the error rates too because they bypassed the rule that when the /u/ sound is part of a stressed syllable it is always spelt with /u/, an overly sophisticated piece of knowledge for Portuguese beginning spellers.

Given the critical role of phonological information in tandem with graphotactic sensitivity effects in early spelling, it was of interest to investigate how Portuguese children begin the process of spelling schwas. In Portuguese, the schwa is phonetically unstable and phonologically ill-defined, has an unpredictable realization, and is frequently deleted at the syllable's end (Veloso, 2012). However, the schwa is a segment that occurs very frequently: in Porlex, a computerized lexical database of European Portuguese (Gomes, 2001), 40% of the words have at least one schwa. In addition, very frequent words, such as prepositions (e.g., *de*, /dɨ/, of; *que*, /kɨ/, that), pronouns (e.g., *ele*, /elɨ/, he), a multitude of different verb forms, and many nouns also contain it. The orthographic counterpart is that virtually all schwas are spelt with <e>, the second most frequent grapheme in the Portuguese orthographic system, and the third most frequent in word final position (Quaresma and Pinho, 2007). For instance, as the only three legal codas in Portuguese are /r/, /l/, and /ʃ/ (the exception being circa two dozen words that end with /n/ as in <glúten>, <cólon>), other phonological codas must be written adding an <e> after the consonant, as in *chave* (<chave>, /ʃavɨ/ or /ʃav/, key). Furthermore, out of six alternatives, the rendition of <e> as a schwa is the most frequent one (Gomes, 2001; Gomes and Castro, 2003). Schwas also occur in between consonants and this is another relevant characteristic of the Portuguese language to the present study. According to the theoretical principles of Portuguese phonology descriptions, onset clusters have no more than two consonants (CC) and only allow /l/ or /r/ in the second position (C+/l/ or C+ /r/). But, in fact, contrary to this phonological principle, when a schwa is theoretically supposed to occur in between two consonants, due to its non-pronounceable nature (Veloso, 2012, 2016) many words beginning with a Cɨ.CV structure are often produced as starting with a phonologically complex onset, an illegal one if C_2 is not /l/ or /r/ (e.g., *remetente*, /Rɨmɨtẽtɨ/ or /Rmtẽt/, sender; *pescar*, /p1Skaɾ/ or /pʃkaɾ/, to fish). Orthographically, this kind of "illegality" is not observed because the schwa in these words is always represented with an <e> which changes the phonological consonantal cluster into a written canonical CV syllable.

In view that the input to spelling given to children in this short-longitudinal study involves a sequence of phonemes where schwas are very unlikely, as it has been explained previously, to be conscientiously perceived, we aimed at examining if and when Portuguese first graders showed sensitivity to graphotactic contextual constraints by using <e> to represent the schwa. Would children more frequently use <e> in words where the theoretical schwa risked creating a phonologically illegal coda (e.g., /dosɨ/ or /dos/, sweet) than in words where it might create a legal one (/mɔlɨ/ or /mɔl/, soft)? Would children use <e> in the first syllable, where the theoretical schwa risked a phonologically illegal onset (/pɨdal/ or /pdal/, pedal) more frequently than when they perceive a legal onset (/fɨliʃ/or/fliʃ/, happy)? Would children's productions differ over time? As all the words used in the study to answer these specific questions had theoretical schwas, thus keeping the target phonological structure constant, the differences detected in the spelling of the <e> would improve our understanding of the relative unique importance of orthographic input on spelling development. In addition, as CV.C/ɨ/ and CVC items could be processed as phonologically similar we sought to examine whether children would add an <e> after a "true" CVC word (pseudoword). Again, the question concerns how, over time, inputs of letter patterns might shape the spelling of phonological codas (e.g., /l/) that can sometimes be part of orthographic C+ <e> sequences (e.g., <mole>, soft).

The relevance of this study is 2-fold: contributing to a better understanding of spelling development in European Portuguese and also contributing to learning how graphotactic context sensitivity interacts with phonological information in early phases of spelling development in an intermediate consistent orthography. In such an orthography we would expect to have alternative orthographic patterns for a number of phoneme sequences within a moderate ratio when compared to other orthographies. That is exactly what occurs in Portuguese when contrasted with French and Spanish. The phoneme-grapheme ratio is 1:1.9 in Portuguese, 1:1.4 in Spanish and 1:3.7 in French (Serrano et al., 2010).

MATERIALS AND METHODS

Participants

A group of 41 first graders, of which 22 were girls, participated in the study. Children attended two parallel classes in the same school. At the first assessment point (December–January), 3 months after the school year began, their ages varied between 6;0 and 6;11 years, with a mean of 6;6 (standard deviation of 0;4). General cognitive ability scores ranged between percentiles 10 and 99, with a percentile mean of 44 (standard deviation of 26;13). The students were all native speakers of European Portuguese and information gathered informally from parents indicated that families had mostly low socioeconomic status, with the majority of parents having non-differentiated professions such as cleaners, craft workers, rural workers, or machine operators. Children with sensory or motor disabilities that prevented their autonomy and/or with a diagnosis of developmental disorder were not included. Teachers used an unsystematic albeit predominantly synthetic phonic method to teach reading and writing.

Tests and Tasks

In addition to the experimental spelling tasks, participants underwent a general cognitive ability test as well as having their letter knowledge and reading assessed in order to characterize their general cognitive and alphabetic profiles.

General Cognitive Ability

The Raven Colored Progressive Matrices—Parallel Form (Raven et al., 2009) was used. The test measures non-verbal general cognitive ability and is composed of three series of 12 items each. The maximum score is 36 points and scores were transformed into a percentile using Portuguese norms.

Letter Sound Knowledge

Letter Sound Spelling—In this task children were asked to spell from dictation 33 grapheme sounds [all the Portuguese phonemes except the four glides (Gomes, 2001)], eight of them requiring a complex grapheme (five nasal vowels and three consonants). One point was given for each correct answer. All the possible graphemes for representing a phoneme were accepted. The test was carried out both at the beginning and end of the study (hitherto referred to as T1 and T2, respectively).

Reading Level

Ten-Words reading task—This was a list of 10 highly frequent monosyllabic and disyllabic content words chosen from ESCOLEX (Soares et al., 2014), a computerized grade-level lexical corpus developed from Portuguese Elementary and Middle School textbooks. It was used to assess children's early reading ability at T1. Children were given one point for each correct production.

Word Reading Test —1 [Teste de Leitura de Palavras (TLP-1), Viana et al., 2014]—This is a standardized 30 single word reading test with 1st grade norms for accuracy. Item difficulty analyses were used to select words from an initial pool of 142 words. The test's psycholinguistic features are as follows: 17 short and 13 long words (above two syllables); 17 high-frequency and 13 low-frequency words; 21 regular and 9 irregular words (Chaves-Sousa et al., 2017). The test was taken at the end of the school year, at T2. The scores of TLP-1 are standardized ones.

TABLE 1 | Spelling conditions and examples of words and pseudowords used in spelling tasks.

Spelling conditions		N (W+Pw)	Words	Pseudowords
CV.CV orthographically consistent with two fully articulated vowels		5 + 5	<viga>-/vigɐ/	<niga>-/nigɐ/
C/ɨ/.CVC, first vowel being a schwa may create a phonological cluster onset (CCVC)	Legal onset	5 + 5	<feliz> /fɨliʃ/;/fliʃ/	<beliz> /bɨliʃ/;/bliʃ/;
	Illegal onset	5 + 5	<pedal> /pɨdal/;/pdal/;	<depal> /dɨpal/; /dpal/
CV.C/ɨ/, last vowel being a schwa may create a phonological monosyllable (CVC)	Legal coda	5 + 5	<mole> /mɔlɨ/; /mɔl/	<pole> /pɔlɨ/; /pɔl/
	Illegal coda	5 + 5	<nave> /navɨ/; /nav/	<mave> /mavɨ/; /mav/
CVC "true" monosyllables	/l/coda	5 + 5	<til>-/til/	<dil>-/dil/
	/r/coda	5 + 5	<cor>-/kor/	<nor>-/nor/
	/ʃ/coda	5 + 5	<luz>-/luʃ/	<fuz>-/fuʃ/

Word and Pseudoword Spelling Tasks

Word spelling task—Children spelt a list of 40 words at T1 and T2. The words were selected from ESCOLEX (Soares et al., 2014). SFI (Standard Frequency Index) was used as an index of the frequency of first grade written words. SFI is a simply presented index derived directly from *U*, and thus takes into account the estimated frequency per million and the dispersion across different books. ESCOLEX also provides the percentile values for the statistical index of frequency.

Examples of stimuli per condition are presented in **Table 1**. There were four types (conditions) of words: (a) 5 CV.CV orthographically consistent disyllables containing two fully articulated vowels. These words were included to obtain a spelling ability baseline; (b) 10 C/ɨ/.CVC words. As the first vowel position (V_1) in these words was filled with a theoretical schwa, these could be processed as CCVC syllables. In half of the words, the schwa could prompt a phonological sequence where the first and second consonants would form a legal phonological (e.g., /fɨliʃ/, /fliʃ/) and orthographic (e.g., <fl>) cluster onset. In the other half, the schwa could prompt a frequently heard but theoretically illegal phonological cluster onset (/pɨdal/, /pdal/) that is never observed orthographically (e.g., <pd> is an illegal orthographic sequence); (c) 10 CV.C/ɨ/ words. As the last vowel position (V_2) in these words was filled with a theoretical schwa, these could be processed as CVC syllables. In half of the words, the schwa could motivate a phonological monosyllable (e.g., /mɔlɨ/, /mɔl/) that can be represented by an orthographically legal coda (e.g., <l>). In the other half the schwa could motivate a frequently heard but theoretically illegal phonological coda (e.g., /n'avɨ/, /nav/) that is never observed orthographically (e.g., there is no <v> codas).These schwas did not result from vowel reduction processes (observable in derived words) and therefore did not represent a subjacent fully specified vowel [for instance, knowing that *martelar* [/mɐɾtɨlaɾ/, /mɐɾtlaɾ/]—to hammer, should be spelled with an <e> to represent the schwa as the word derived from *martelo* [/me*R*tɛlu/]—hammer]; rather, they are phonological vowels *per se*, the European Portuguese empty "non-pronounceable" vowel (Veloso, 2012, 2016); (d) 15 CVC monosyllables, five for each of the three legal codas, /l/, /r/ and /ʃ/. "True" monosyllables were included in order to examine the extent to which children would place an <e> grapheme after the coda, and then to compare their use with that in the CV.C/ɨ/ (CVC) words.

The mean frequency across disyllable words containing two fully articulated vowels was in the $\geq$25 $\leq$50 percentile range. In each condition of the words with theoretical schwas (four: C/ɨ/.CVC legal and illegal onset; CV.C/ɨ/ legal and illegal coda; see **Table 1**) the mean frequency of words fell into the percentile range of $\geq$25 $\leq$50. A Kruskal-Wallis one-way ANOVA test showed that the distribution of frequencies was statistically equal for the different conditions [$H(3) = 0.976$, $p = 0.807$]. For the monosyllables, the mean frequency of words in each condition (three codas: /l/, /r/ and /ʃ/; see **Table 1**) was also situated in the percentile range of $\geq$25 $\leq$50 and the distributions of the frequencies were statistically equivalent [$H(2) = 0.857$, $p = 0.652$].

The spelling of the CV.CV words with two fully articulated vowels was scored two ways. One was the traditional method using the correctness criterion, with one point awarded for each word spelt correctly. As correctness may not be the best measure for reflecting beginning spellers' knowledge, because it neglects differences between a fully and a partially correct or a phonologically plausible spelling (Ritchey et al., 2010), we also used Letter Distance scoring, a non-binary measure based on the concept of string edit distance. Letter distance (LD) refers to the number of letter deletions, additions, and substitutions when comparing the child's spelling with a word's conventional spelling. Each deletion or addition is penalized one point and a substitution 1.4 points (Treiman et al., 2019a). For example, considering the word <tela> (screen), <el> was given 2 points (2 deletions), <vela> 1.4 points (substitution) and <tel> 1 point (deletion). Thus, the lower the score, the higher is the quality of the spelling. We computed the mean LD score across words written by each child.

Regarding the experimental stimuli, we used three scoring procedures. We used two non-binary measures to examine the children's ability to spell the items: the LD, as described above, and the Phoneme distance (Treiman et al., 2019a). Phoneme distance (PhD) is the number of transformations needed to convert the child's spelling into the closest phonologically plausible spelling of the word. As in the case of LD, there were penalties for substitutions (1, 4 points), deletions (1 point) and additions (1 point). For example, for the word <veloz> (fast), the spelling <velox> no points were deducted because <x> can be phonologically equal to <z> in that position, and <volo> was deducted 2.4 points (a substitution and a deletion).

In order to examine the spelling of the schwa with <e>, the aim of this study, we used Target scoring, awarding (a) one point for the <e> grapheme in each word if it occurred after a consonant in the correct position, even if the word was not entirely represented (e.g., <feli> instead of <feliz>, happy; <ave> instead of <nave>, spaceship); (b) one point for the <e> grapheme in each word even if the consonant was not accurately represented but the word structure was correct (e.g., <bedor> instead of <redor>, around). However, if the spelling seemed to be produced randomly it was given zero points (e.g., <pepo> for <ferir>, to hurt). It was also given zero points if the <e> was not written (e.g., <fliz> instead of <feliz> or <nav> for <nave>) or was not preceded by a consonant (e.g., <erire> for <ferir>). This last condition was taken out of caution. Given the schwa nature, to spell a schwa for its own sake, without the previous adjacent consonant, seems logically odd, suggesting the child would be using <e> randomly because of its high frequency and not because it represented a necessary orthographic feature.

Pseudoword spelling task—At T2, children were also asked to spell 40 pseudowords, in order to control for the potential impact of acquired lexical knowledge. Those were created by changing the first consonant or switching the consonants of a real word, while maintaining its phonological and orthographic features. The pseudowords scorings were the same as those used with the words from which they were built. **Table 1** presents the stimuli conditions and examples.

General Procedure

Children were tested twice in the first grade. They were tested in December/January, about 3 months after the start of the school year (T1) and again during the last 2 months of the school year (T2). All testing sessions took place in a quiet location in their own school.

At T1, there were two testing sessions of circa 20 and 45 min, respectively. In the first session, the Raven CPM-P and the Ten-words reading task were carried out individually; in the second session the Letter Sound Spelling and the Word Spelling tasks were administered. At the end of the school year (T2), a further two sessions were undertaken. In the first, lasting about 30 min, children individually underwent the Word Reading Test (TLP-1) and the Pseudoword Spelling task; in the second, the Letter Sound Spelling task and the Word spelling task were completed, together lasting circa 30–35 min.

The Word and Pseudoword Spelling tasks and the Letter Sound Spelling tasks were administered in small groups of between five and seven children. The stimuli were recorded and presented to children in a random order for each group using a laptop and speakers. All the words and pseudowords were presented in a colloquial prosodic manner, by a female voice. We emphasize that all the orthographically disyllabic experimental stimuli had theoretical schwas (C/ɨ/.CVC and CV.C/ɨ/) and that there is no context that makes its production or deletion predictable, although they are frequently deleted and considered "non-pronounceable" (Veloso, 2010, Veloso, 2012), specially when produced in a colloquial manner as we have presented them to children. As it was stated above, to distinguish between the production or non-production of a schwa in a word is very hard, or impossible, even for a trained person, let alone for young children with a very weak alphabetic knowledge.

When asked to spell the pseudowords, children were told they were invented words that could be spelt with the same letters as used with real words. A training item was used before the spelling task. For each spelling task children were given a lined sheet of paper with a number in each line and were asked to spell an orally presented item on each line as accurately as they could. Only when children had finished spelling one item would another be presented. The children's work was closely monitored in order to prevent them skipping lines.

RESULTS

Alphabetic Knowledge Level

Descriptive alphabetic profiles at T1 and T2 are presented in **Table 2**. As we can see, the children studied had only an incipient alphabetic knowledge at T1. They decoded and spelt less than half of the short consistent words. At T2 they performed at a typical level in the TLP-1 reading test and they significantly progressed from T1 to T2 in terms of representing sounds by letters, achieving very good, though not perfect, levels of consistent CV.CV word and pseudoword spelling. The children spelt words and pseudowords at the same ability level, as can be seen by one-way repeated-measures ANOVA [$F_{(1,40)} = 2.71$, $p = 0.108$], suggesting they were using a predominantly phonological alphabetic mode of rendering speech in written form.

Letter and Phoneme Distance Scores

Before analyzing the spelling of the schwa, we first examined the degree of proximity between the spelling of the items produced by the children and their conventional spelling (words only) and with its plausible fully phonological spelling (both words and pseudowords). The spelling correctness of the experimental words posed a bigger challenge to the children than the simple CV.CV words with fully articulated vowels. This occurred because there were words with a complex syllabic structure and because all had theoretical schwas. **Table 3** shows the LD and PhD scores obtained at T1 and T2 for the words and pseudowords containing a theoretical schwa.

As we aimed to verify the learning progression and compare the two distance scores a series of repeated-measures ANOVA were implemented. A two-way 2 (time: T1 × T2) × 2 (scoring procedure: LD × PhD) repeated-measures ANOVA was performed on the written productions. As expected, children spelt better in T2 than in T1 [$F_{(1,40)} = 67.96$, $p < 0.001$, $\eta^2_p = 0.63$] and obtained lower scores on Phoneme distance than on Letter distance [LD × PhD, $F_{(1,40)} = 410.33$, $p < 0.001$, $\eta^2_p = 0.91$], signaling that at these early phases of learning, strict alphabetic knowledge surpassed orthographic contextual and lexical ability. As expected, the difference between the scoring measures was larger at T1 than at T2 [time × scoring procedure: $F_{(1,40)} = 16.39$, $p < 0.001$, $\eta^2_p = 0.29$], reflecting increases in orthographic knowledge over time.

In comparing the words' syllabic structure, two two-way 2 (time: T1 × T2) × 2 (word structure: CV.CVC × CV.CV) repeated-measures ANOVAs showed that the two scoring measures (LD and PhD measures) revealed the same main effects. Spelling improved significantly over time [LD: $F_{(1,40)} = 67.64$, $p < 0.001$, $\eta^2_p = 0.63$; PhD: $F_{(1,40)} = 58.32$, $p < 0.001$, $\eta^2_p = 0.59$] and, at T2, PhD was close to zero for the majority of the words, indicating that children sought to represent every sound of the words better than at T1. CV.CVC structure was more prone to errors than CV.CV [LD: $F_{(1,40)} = 28.91$, $p < 0.001$, $\eta^2_p = 0.42$; PhD: $F_{(1,40)} = 37.31$, $p < 0.001$, $\eta^2_p = 0.48$]. This effect was qualified by time when using LD scoring [time × LD scoring: $F_{(1,40)} = 16.46$, $p < 0.001$, $\eta^2_p = 0.29$] reflecting the fact that at T2 there was no significant difference between word structures [paired-$t_{(40)} = 1.58$, $p = 0.123$]. With PhD scoring, the interaction was marginally significant [time × PhD scoring: $F_{(1,40)} = 3.99$, $p = 0.052$, $\eta^2_p = 0.09$] indicating that CV.CVC words were a little more difficult to spell at both T1 and T2 than CV.CV ones.

Pseudoword spelling, assessed at T2 only, was scored using the PhD criterion. The pattern of results for syllable structure was similar to the one obtained with words: the CV.CVC structure was found to be more difficult to spell than CV.CV one [paired-$t_{(40)} = 3.37$, $p = 0.002$, $d = 0.36$]. A one way repeated-measures ANOVA (lexicality: words × pseudowords) showed that pseudowords had lower scores than words [lexicality: $F_{(1,40)} = 5.70$, $p = 0.02$, $\eta^2 = 0.13$] suggesting that familiarity possibly helped to retain phonological strings in the children's memory, thereby increasing the accuracy with which the words' sounds were written when compared with pseudowords.

Spelling the Schwa With <e> in C/ɨ/.CVC and CV.C/ɨ/ Items

Statistical analyses of spelling the schwa with an <e> examined three main effects: Time, Schwa position, and Orthographic legality. The orthographic legality effect refers to the comparison of words (and pseudowords) that potentially could be processed as containing illegal as opposed to legal orthographic onsets or codas created by the theoretical yet non-pronounceable schwa (**Table 1**). As we aimed to compare scores at different conditions over time a series of repeated-measures ANOVAs were performed.

We calculated the mean <e> production across words written by each child under each condition (**Table 4**) which were analyzed using a three-way 2 (time: T1 × T2) × 2 (orthographic legality: legal × illegal) × 2 (schwa position: C/ɨ/.CVC × CV.C/ɨ/) repeated-measures ANOVA. The three main effects were significant [time: $F_{(1,40)} = 21.24$, $p < 0.001$, $\eta^2_p = 0.35$; orthographic legality: $F_{(1,40)} = 25.44$, $p < 0.001$, $\eta^2_p = 0.39$; schwa position: $F_{(1,40)} = 13.37$, $p = 0.001$, $\eta^2_p = 0.25$]. The analysis produced also a significant triple interaction [$F_{(1,40)} = 20.76$, $p < 0.001$, $\eta^2_p = 0.34$]. As our main aim was to

TABLE 2 | Scores on ancillary alphabetic tasks at T1 and at T2.

	T1		T2			
	M	**SD**	**M**	**SD**	***F* (1, 40)**	**η^2**
Reading						
Ten-words reading CR	3.92	3.36				
TLP-1 (standardized score)			101.1	8.68		
Letter sound spelling**	12.19	6.04	27.83	4.03	387.53*	0.91
Word spelling***						
CV.CV-2 fully articulated vowels CR	2.32	1.66	3.76	1.28	41.37*	0.51
CV.CV-2 fully articulated vowels LD	1.37	1.15	0.42	0.53	45.05*	0.53
Pseudoword spelling***						
CV.CV-2 fully articulated vowels CR			3.44	1.47		

*$p < 0.001$; **33 maximum; ***5 maximum; M, mean; SD, Standard deviation; CR, Correct response; LD, Letter distance.*

TABLE 3 | Spelling means and standard deviations using letter distance and phoneme distance scorings.

		T1		T2			
		Words		Words		Pseudowords	
Spelling conditions		**M**	**SD**	**M**	**SD**	**M**	**SD**
C/ɨ/.CVC	Letter distance	2.49	1.30	1.11	0.81		
	Phon. distance	1.52	1.07	0.62	0.69	0.76	0.84
CV.C/ɨ/	Letter distance	1.66	1.09	0.96	0.45		
	Phon. distance	1.04	0.88	0.39	0.40	0.51	0.58
CVC	Coda /l/ LD	1.41	0.69	0.72	0.53		
	Coda /l/ PhD	0.84	0.76	0.24	0.33	0.24	0.33
	Coda /r/ LD	1.90	1.11	0.79	0.74		
	Coda /r/ PhD	1.17	1.19	0.37	0.54	0.36	0.53
	Coda /ʃ/ LD	1.94	0.66	1.13	0.55		
	Coda /ʃ/ PhD	1.43	0.81	0.25	0.38	0.25	0.38

LD, Letter Distance; PhD, Phoneme Distance.

examine if, and in what orthographic conditions, children spelt the schwa at the two Time Points and since an effect attributable to Time was detected, the data was subsequently analyzed using a two-way 2 (orthographic legality: legal × illegal) × 2 (schwa position: C/ɨ/.CVC × CV.C/ɨ/) repeated-measure ANOVA for each Time Point.

For T1, we counted all the vowels spelt in the <e> position across words in each of the four types of words with schwa, using the criteria mentioned for Target scoring. On average, children marked 3.4 vowels out of 5, of which 2.6 were <e>, showing that vowels were produced more often than not at the schwa position.

A two-way 2 (orthographic legality: legal × illegal) × 2 (schwa position: C/ɨ/.CVC × CV.C/ɨ/) repeated-measures ANOVA was applied to the <e> spelling. Children marked <e> more often in the context of the potentially illegal orthographic structure than in the legal context [legality: $F_{(1,40)} = 7.53$, $p = 0.009$, $\eta_p^2 = 0.16$] and an equivalent amount in each of the schwa positions [schwa position: $F_{(1,40)} = 1.42$, $p = 0.240$]. The fact that the interaction was non-significant [legality × schwa position: $F_{(1,40)} = 3.03$, $p = 0.089$] shows that more <e> were marked in the potentially illegal context in both schwa positions.

The same analyses were performed at T2. Except for the potentially legal context of CV.C/ɨ/, almost all the schwas were spelt and therefore all the effects were significant. Children spelt <e> more often in the context of the potentially illegal orthographic structure than in the legal context [legality: $F_{(1,40)} = 29.87$, $p < 0.001$, $\eta_p^2 = 0.43$]. They also spelt more <e> in the first syllable position (potential phonological CC onset: C/ɨ/.CVC) than in the final word position (potential phonological coda, CV.C/ɨ/) [schwa position: $F_{(1,40)} = 43.44$, $p < 0.001$, $\eta_p^2 = 0.52$]. The interaction [legality × schwa position: $F_{(1,40)} = 14.82$, $p < 0.001$, $\eta_p^2 = 0.27$] shows that the difference between legal and illegal contexts was larger in the final word position, which means that children considered the words that could prompt a phonological legal coda to be true codas [legality in final position: paired-$t_{(40)} = 5.07$, $p < 0.001$, $d = 1.07$] more often than they considered potentially legal onsets to be true complex onsets [legality in first syllable: paired-$t_{(40)} = 2.17$, $p = 0.036$, $d = 0.34$].

TABLE 4 | Means and standard deviations of the spelling of the schwa with <e> in C/ɨ/.CVC (CCVC) and CV.C/ɨ/ (CVC) stimuli and the spelling of <e> after CVC coda.

		T1		T2			
		Words		Words		Pseudowords	
Spelling conditions		**M**	**SD**	**M**	**SD**	**M**	**SD**
C/ɨ/.CVC (CCVC)	Legal onset	2.15	1.85	4.22	0.91	4.32	0.96
	Illegal onset	3.00	1.97	4.54	0.954	4.29	0.84
CV.C/ɨ/ (CVC)	Legal coda	2.66	1.79	2.27	1.91	1.83	1.88
	Illegal coda	2.88	1.50	3.98	1.19	3.70	1.20
CVC	/l/ coda	2.34	1.94	1.78	1.89	1.85	2.06
	/r/ coda	1.97	1.85	1.44	1.84	1.41	1.88
	/ʃ/ coda	0.70	1.15	0.39	0.77	0.70	1.38

Note: the maximum punctuation for each set of items was 5.

With pseudowords, as had been the case with words, a two-way 2 (orthographic legality: legal × illegal) × 2 (schwa position: C/ɨ/.CVC × CV.C/ɨ/) repeated-measures ANOVA was performed on the spelling of <e>. The pattern of results was comparable to that obtained with words. Children wrote <e> more often in the potentially illegal contexts than in the potentially legal ones [legality: $F_{(1, 40)} = 28.30$, $p < 0.001$, $\eta_p^2 = 0.41$] and more in first syllable position than in word final position [schwa position: $F_{(1, 40)} = 53.63$, $p < 0.001$, $\eta_p^2 = 0.57$]. The interaction [legality × schwa position: $F_{(1, 40)} = 28.05$, $p < 0.001$, $\eta_p^2 = 0.41$] reflects the fact that the difference between legal and illegal contexts was significant in word final position as it was shown by a paired-*t* test [$t_{(40)} = 5.63$, $p < 0.001$, $d = 1.18$] but not in first syllable position where the schwa was represented with <e> independently of context's legality [paired-$t_{(40)} = 0.21$, $p = 0.838$].

When comparing the spelling of schwa with <e> between words and pseudowords a lexicality effect was observed [legality: *paired*-$t_{(40)} = 2.23$, $p = 0.031$, $d = 0.28$] showing that children spelt more <e> in words than in pseudowords.

Relations Between Alphabetic Knowledge and the Spelling of the Schwa

To examine the relationship between basic alphabetic knowledge and the spelling of the schwa, a series of zero order correlations as well as a regression analysis were conducted. Accuracy on reading, letter sound knowledge and spelling of orthographically consistent CV.CV words/pseudowords with two full vowels were correlated with the total amount of <e> produced by children to represent the schwa at each assessment Time point. In addition, general cognitive ability was also entered in order to test for its role in schwa spelling. None of the measures taken at T1 correlated significantly with T2 spelling of the schwa with <e> and thus only concurrent correlations of each Time point are presented in **Table 5**.

At T1 all the alphabetic task performances were significantly associated with the production of <e>. To further ascertain which of these early alphabetic measures could explain alone, or combined, the amount of <e> spellings to represent the theoretical schwas a multiple linear regression was carried out. Using the forward method, the regression model only kept the variable "letter sound spelling" which predicted 25.5% of the variance [$F_{(1, 38)} = 13.02$, $p = 0.001$, R^2 change = 25.5], removing the other two (consistent CV.CV words spelling: $B = 0.28$, $p = 0.07$; Ten-Words reading: $B = 0.037$, $p = 0.844$). At T2 only the consistent CV.CV word spelling obtained weak-medium significant associations with the total of <e> spellings in words, explaining 10.3% of its variance. The same pattern was obtained with pseudowords, as only CV.CV spelling accuracy explained 10.1% of the individual differences of the total <e>s produced. Cognitive general ability did not significantly correlate with the spelling of <e>s although there were significant correlations between this measure and the alphabetic task' performances.

Spelling an <e> After CVC Codas

We also examined whether children spelt the <e> grapheme after "true" CVC codas. As these analyses were run on a target structure of the words first we checked for children ability to spell the words using LD and PhD measures. A two-way 2 (time: T1 × T2) × 2 (scoring procedure: LD × PhD) repeated-measure ANOVA showed that, as had occurred with the other words, children significantly progressed from T1 to T2 [time: $F_{(1, 40)} = 85.98$, $p < 0.001$, $\eta_p^2 = 0.68$] and their scores suffered fewer penalties using the PhD than the LD measure [scoring procedure: $F_{(1, 40)} = 253.41$, $p < 0.001$, $\eta_p^2 = 0.86$] at both the time points [time × scoring procedure: $F_{(1, 40)} = 0.01$, $p = 0.920$]. We can see from **Table 3** that at T1 their spelling ability was incipient but at T2 their PhD score was close to zero, meaning they could represent most of the sounds of the words they were asked to spell.

At T2 pseudowords were also spelt. A one-way 3 coda type (Coda type:/l/ × /r/ × /ʃ/) repeated-measures ANOVA run on the PhD measure showed children were equally able to spell the different type of pseudowords [$F_{(2, 80)} = 2.15$, $p = 0.123$], as can be seen in **Table 3**.

In examining the production of <e> in CVC items, a two-way 2 (Time: T1 × T2) × 3 (coda type: /l/ × /r/ × /ʃ/) repeated-measures ANOVA applied to the mean number of <e>. The

TABLE 5 | Correlations between ancillary alphabetic measures and the total amount of <e> spelling representing the schwa at T1 and at T2.

Time 1—Words	**1**	**2**	**3**	**4**	**5**
1. Raven-CPM		0.201	0.382*	−0.118	0.297
2. Ten-words reading			0.641**	−0.390*	0.346*
3. Letter sound spelling T1				−0.419**	0.505**
4. CV.CV-2 full vowels CR T1					0.461**
5. Total of <e> spelling T1					
Time 2—Words	**1**	**2**	**3**	**4**	**5**
1. Raven-CPM		0.372*	0.354*	−0.117	0.211
2. TLP-1 (word reading)			0.651**	−0.575**	0.180
3. Letter Sound Spelling T2				−0.429**	0.031
4. CV.CV-2 full vowels CR T2					0.321*
5. Total of <e> spelling 2					
Time 2—Pseudowords	**1**	**2**	**3**	**4**	**5**
1. Raven-CPM		0.327*	0.354*	0.324*	0.115
2. TLP-1 (word reading)			0.651**	0.542**	0.060
3. Letter sound spelling T2				0.556**	0.017
4. CV.CV-2 full vowels CR T2					0.319*
5. Total of <e> spelling T2					

**p < 0.05; **p < 0.01; CR, Correct response.*

analysis showed that the frequency of addition of <e> after the last consonant did not change significantly with time [time: $F_{(1,40)} = 2.83$, $p = 0.095$] but it was not the same for the three codas [coda type: $F_{(2,80)} = 36.20$, $p < 0.001$, $\eta^2_p = 0.48$] both at T1 and T2 [time × coda type: $F_{(2,80)} = 0.27$, $p = 0.739$]. Pairwise comparisons with Bonferroni adjustments revealed that the number of <e> was smaller for /ʃ/ than for /l/ and for /r/ ($p < 0.001$ for each case) which did not differ from each other ($p = 0.115$) at either assessment time point.

We also computed the mean number of the <e> graphemes that children wrote after CVC codas and the mean number of consonants in final position (codas) without the <e> grapheme across words by type of coda (/l/, /r/ and /ʃ/). These results were compared with paired-*t* test analyses for each coda type. At T1, there were more <e> after /l/and /r/ than final consonants but the differences were not significant [/l/: $t_{(40)} = 1.37$, $p = 0.178$; /r/: $t_{(40)} = 1.64$, $p = 0.109$]. For the /ʃ/ coda, children spelt significantly more consonants than <e> after the consonant [$t_{(40)} = 2.61$, $p = 0.013$, $d = 0.65$].

At T2, children spelt the coda more frequently with the consonant only than added an <e> after the consonant. The differences were significant for /r/ [$t_{(40)} = 2.63$, $p = 0.012$, $d = 0.79$] and /ʃ/ [$t_{(40)} = 9.95$, $p < 0.001$, $d = 2.78$] but not for /l/ [$t_{(40)} = 1.74$, $p = 0.09$].

At T2, children were asked to spell pseudowords. A one-way 3 coda type analysis showed that the frequency with which <e> was written after codas differed according to coda type [$F_{(2,80)} = 12.03$, $p < 0.001$, $\eta^2 = 0.23$]. Pairwise comparisons using Bonferroni adjustments showed that, as with words, <e> was produced with less frequency after /ʃ/ when compared to /l/ and to /r/ ($p < 0.001$ and $p = 0.017$, respectively). The spelling of <e> did not statistically differ when comparing /l/ with /r/ ($p = 0.07$).

As had been observed with words at T2, children marked more consonants in the final position, the codas, than they marked <e> after the consonant for each of the three codas. Paired-t analyses showed that these differences were significant for /r/ [$t_{(40)} = 2.61$, $p = 0.013$, $d = 0.78$] and /ʃ/ [$t_{(40)} = 2.56$, $p = 0.014$, $d = 0.64$], but not for /l/ [$t_{(40)} = 1.39$, $p = 0.172$].

At T2, CVC words and pseudowords were spelt with the same level of ability, as revealed by a 2-way 2 (lexicality: words × pseudowords) × 3 (Coda type: /l/, /r/ and /ʃ/) repeated-measures ANOVA using the PhD measure [lexicality: $F_{(1,40)} = 1.00$, $p = 0.323$]. Additionally, the coda type did not influence the quality of spelling [coda type: $F_{(2,80)} = 2.17$, $p = 0.121$] either in words or pseudowords [lexicality × coda type: $F_{(2,80)} = 1.00$, $p = 0.372$].

The frequency of <e> being written after the last consonant in words and pseudowords did not differ [lexicality: paired-$t_{(40)} = -0.98$, $p = 0.332$].

Spelling of <e> in CV.C/ɨ/ and CVC Items

All the CV.C/ɨ/ stimuli had /l/ as a last consonant (e.g., *mole* /mɔlɨ/-, soft). This is because in the Portuguese orthography there is only one very infrequent CV.CV noun that ends in a schwa after /r/ (<gare>) and two that end in a schwa after /ʃ/ (only one which could be considered as having medium frequency (<duche>-/duʃɨ/), but is a potential homophone of <dos>-/duʃ/-, "of the").

CV.C/ɨ/ stimuli having /l/ as last consonant were compared with the "true" CVC ones having /l/ as coda (e.g., *sul*, /sul/, south) regarding the amount of <e> children spelt in final position for each type of words. The frequency distributions of occurrence of the two kinds of words did not differ significantly ($U = 12.00$, $z = -0.104$, $p = 0.917$). The mean provision of <e> across type of words was compared using two-way 2 (time: T1 × T2) × 2 (word type: CV.C/ɨ/ × CVC) repeated-measures ANOVA. Children spelt a similar amount of <e> over time [time: $F_{(1, 40)} = 1.67$, $p = 0.204$] but more <e> in CV.C/ɨ/ than in CVC words [word type: $F_{(1, 40)} = 10.17$, $p = 0.003$, $\eta^2 = 0.20$] at both T1 and T2 [time × word type: $F_{(1, 40)} = 0.83$, $p = 0.369$].

A paired-*t* test run with pseudowords comparing CV.C/ɨ/ with CVC items revealed that, unlike the test performed on words, no significant difference was observed between the two types of structure in the frequency with which <e> was added after the last consonant [$t_{(40)} = 0.14$, $p = 0.888$].

DISCUSSION

The aim of this study was to examine how children in early phases of learning how to spell would cope with a specific task, that of orthographically representing the schwa.

The European Portuguese schwa (/ɨ/) is a very frequent segment that, at the phonetic level, has the lowest intensity and duration values, has an unpredictable realization and is often subject to deletion. At the phonological level, it is ill-specified (an empty vowel). This set of properties makes it "non-pronounceable" (Veloso, 2012, 2016). In current language production these features result in rearrangements of the words' syllabic structure that change simple onsets into complex ones (e.g., Cɨ in CɨCV words became a CCV structure), sometimes creating illegal Portuguese onsets (e.g., *pequeno*, /pkenu/, small) or changes CV syllables into codas, sometimes illegal ones (e.g., *nove*, /nɔv/, nine). In both circumstances, the pronunciation of the words with or without the schwa is not altered, or only minimally so, to the ears of a regular listener. In order to tell that a Portuguese schwa is being produced there is need for an in-depth highly conscious speech analysis and people often disagree about the result. Thus, this seems a precarious phonological basis for young learners to spell this vowel since research has massively shown that children beginning to learn to spell rely heavily on the speech "sounds" they can isolate in order to choose the appropriate letters to write (Treiman, 2017a). Moreover, many studies have also demonstrated that less accessible phonemes are more prone to spelling errors, often being deleted from written productions.

However, Portuguese children are frequently exposed to words with schwas both orally and, from the very beginning of schooling, also in written materials, as there are very frequent words that contain at least one schwa. Furthermore, the schwa is always written with an <e>.

In this short-longitudinal study, first graders were asked, 3 months after spelling instruction had begun and again at the end of the same school year, to spell words and pseudowords with different orthographic structures, some with schwas. Examining if and in what syllabic structures beginning spellers used <e> to represent the schwa provided further and deeper understanding the extent of the contribution graphotactic input makes to early spellings.

Descriptive results from the first assessment time point (T1) showed that children had only incipient alphabetic knowledge. On average, when asked to spell, they knew less than half of the sound-letter correspondences, they could only read four out of ten short frequent words, and the Distance scorings of their word spellings revealed they were able to represent roughly half of each word's letters. As expected at early phases of spelling development, children were better at representing the sounds of the words (with any possible letter) than their letters (the canonical orthographic form), and words with complex syllabic structure (CV.CVC) gave rise to more errors than words with simpler ones (CV.CV) in both Distance scorings. This indicates that children were trying, although with difficulties, to capture each sound of a word and producing the respective graphemic string via assembling phoneme-grapheme conversion processing. Other studies (Sprenger-Charolles and Siegel, 1997; Serrano et al., 2004; Fernandes and Martinelli, 2018) have found a similar pattern of performance in early spelling showing that, even imperfect, phoneme analyses and its grapheme correspondence explained a great amount of written productions. CV.CVC words, besides having a more demanding syllabic structure to analyze, are also longer than CV.CV words. The interaction between syllabic structure and phonological length at such an early phase of learning also impacts on spelling accuracy as was shown in a study recently run with Portuguese elementary school children (Mesquita et al., 2020) and also in previous ones (Serrano et al., 2010; Notarnicola et al., 2012).

In spite of their weak alphabetic knowledge, when spelling the words with schwa each child marked, on average, 13.68 out of 20 vowels representing the schwa, of which 10.69 were <e>. Thus, even at an early phase of their formal alphabetic learning, children tended to represent schwa vowels, mostly with the appropriate letter <e>. Since the schwa lacks phonological value, and the children's alphabetic knowledge was still incipient, this result is fairly surprising. In line with recent work (Kessler et al., 2013; Kessler et al., 2018, Kessler et al., 2019b; Treiman and Kessler, 2013), a statistical learning perspective on early sensitivity to letter patterns would seem to provide a plausible account of this finding. According to these authors children develop very early, from the initial exposures to written materials, an intuitive sense of fitting letter sequences, even when their phonological analytic abilities are minimum.

Interestingly, we observed that children used <e> more in the potentially illegal orthographic contexts than in the legal ones, both in the first syllable position (C/ɨ/.CVC) and in the final word position (CV.C/ɨ/). Since all the words in this comparison had schwas and children had been formally taught about written words for such a short time, this finding is also remarkable and concurs with the statistical learning perspective of spelling development mentioned above. From a phonological perspective, it is difficult to conceive that such a non-existent, or such a minimal amount of, acoustic information could provide children with the basis for attempting to represent an empty vowel at a point in their spelling development where phonemes are so hard to process. Alternatively, the idea that children could be using their lexical knowledge to spell the <e> in those words is hardly acceptable as an explanation. First of all, the words with potentially orthographically illegal patterns and those with potentially legal ones were equally frequent and thus lexical knowledge would theoretically be similar for the two kind of words; and secondly, since children spelt, on average, only half of the letters each word comprised, they were as yet unaware of how they were spelt. Rather, it seems more likely that those beginning spellers were already able to perceive certain prominent graphotactic regularities of their language's orthography, in line with the recent findings of Treiman and colleagues that show that knowledge of letter patterns may be the first source of children learning about orthographic regularities (Pollo et al., 2009; Kessler et al., 2013; Treiman et al., 2019b). This means that children have become aware that some letters "go together" and others do not, i.e., as early as 3 months into formal training in spelling, children were already becoming sensitive to which consonants are accepted as a cluster or a coda and which ones need a "silent" <e> in order to conform to graphotactic input.

Regarding the schwa position in the C/ɨ/.CVC structure, if the <e> is not spelt, a CC onset will result. Portuguese CC onsets are infrequent, constituting only about 5% of the syllabic structures [PORLEX (Gomes, 2001)] and, more crucially, with very few exceptions, the C_2s allowed are <l> or <r>. In addition, in 88% of the C/ɨ/.CVC words in PORLEX, the second consonant is neither /l/ nor /r/. This means that if the <e> is omitted in such words, the two first consonants would create an illegal onset. So, most of the time that there is a schwa in first syllable, children see a written form where there is an <e> between two consonants they never see as a written cluster. This suggests that while they have virtually no exposure to CC onsets other than C+/l/ and C+/r/, they frequently encounter C<e>C in word beginnings.

Concerning the schwa in the CV.C/ɨ/ words, a similar explanation is plausible. More than 50% of the Portuguese syllables are CV strings (Freitas, 2017), 81% of syllable types are open syllables and 71% of schwas occur in C/ɨ/ syllables (Gomes, 2001). Crucially, only /l/, /r/, and /ʃ/ are allowed as codas. Thus, by the time they were tested, children may have already noticed the dominance of CV structures (Treiman et al., 2019b) and the role of <e> as a resource to use when last consonants do not conform to their expectations.

The dominant role of the canonical CV structure is reinforced to a certain extent by the results obtained with "true" CVC words. When the codas were /l/ or /r/, children added <e> more than spelt final consonants only, although the differences were not statistically significant. The differences in both cases were nevertheless of medium size ($d = 0.39$ and $d = 0.44$, respectively) suggesting a possible trend to adopt the CV template, adding an <e> when what they had heard did not clearly prompt the use of any other vowel. However, when the coda was /ʃ/, the situation was reversed, with children marking more consonants only than adding <e> to the last consonant. The reason may be related, once more, to frequency. The coda /ʃ/ is the most frequent one in CVC monosyllables (Gomes, 2001) and some of the monosyllables ending in /ʃ/ are the most frequent in first grade textbooks. For instance, the words *mas* (but), *das*/*dos* (of the), *nas*/*nos* (in the), to name just a few, are all in the 90th percentile of frequency (ESCOLEX, Soares et al., 2014). Also, if we consider that virtually all plurals end in /ʃ/, orthographically represented by <s>, it is reasonable to claim that children have frequently been exposed to many instances where written words end with a consonant with the sound /ʃ/. This could also explain why, in all the analyses performed, the frequency of <e> in CVC items was lower after the /ʃ/ coda than after any other coda.

At the end of first grade (T2) children had more solid alphabetic knowledge. They read words at the typical level, according to a standardized reading test, and their spellings were closer to the established orthographic form. PhD scorings were close to zero, reflecting that children had become more skillful at spelling phonemic sequences. Scoring for PhD revealed that CV.CV words were easier to process than CV.CVC ones. In contrast, LD scoring showed that the two syllable structures prompted a similar level of difficulty. This difference between score measures was probably due to the fact that children produced more <e> in CV.CVC than in CV.CV structures. This caused the number of penalizations to converge in both syllables types in terms of LD scoring (i.e., more correct letters in CV.CV but more <e> in CVC.CV).

At T2 children also spelt pseudowords. As with words, CV.CV pseudowords were easier to spell than CV.CVC, replicating the pattern of results obtained at T1 and also the known effects of syllable structure/length mentioned above. Phoneme distance scorings showed that words were better spelt than pseudowords, indicating that lexical knowledge helped children, at least, to retain the phonemic sequences in their memories and then translate them into graphemic sequences.

Having verified that at T2 children could spell almost all the phonemes of the words and pseudowords, let's focus on our target issue, the spelling of the schwa. Compared with the first assessment, the quantity of <e> in written productions improved significantly at T2. However, even though all these words (CV.C/ɨ/ and C/ɨ/.CVC) contained theoretical schwas, children did not mark the <e> equally in all the orthographic contexts. Once again, they produced <e> more often in potentially orthographic illegal contexts than in legal ones. This suggests that, beyond phonology, graphotactic input was a critical source of information guiding children to spell the schwa, reflecting their knowledge about letter sequences. Supporting this perspective is the fact that children marked <e> more in words than in pseudowords, indicating that some of the <e> schwas they included in the words they wrote were based more on orthographic knowledge than on phonological information.

A different trend from T1 emerged however. Unlike T1, where the difference between illegal and legal orthographic contexts regarding the production of <e> was equal in both first syllable and word final position, at T2, the difference in the amount of <e> produced between potential illegal and legal orthographic contexts was greater in words' final position than in their first syllable. A similar pattern of results was observed with pseudowords, which rules out a putative influence of lexical knowledge in explaining differences between the two types of words. This pattern of results at T2 suggests that children perceived the words that could prompt a phonologically legal coda more often as true codas than they interpreted potentially legal onsets as true complex onsets. This would be a fair representation of the orthographic system features as it will be argued below.

The difference between <e> productions in words' first syllable and in final position mentioned above may reflect different aspects of the orthographic regularities to which children were being exposed. First, children marked an <e> more often in first syllables, where non-representing the schwa could potentially create complex onsets. In marking the <e> they maintained the initial CV structure. This concurs with the bias displayed by Portuguese children to often transform written CC onsets into CV structures (Vale and Cary, 1999; Santos et al., 2014; Mesquita et al., 2020). Transforming CC onsets in CV syllables is a more frequent error than deleting one of the consonants (usually the second). In a study by Vale and Cary (1999), first graders at the end of the school year inserted an <e> between the two consonants of a legal CC onset in 48.6% of their productions creating CV syllables (e.g., <cerus> instead of <cruz>, cross, or <celase> instead of <classe>, class). Santos et al. (2014) documented that this kind of spelling error lasts at least until fourth grade, adding that, when first graders are asked to spell "problematic consonantal groups," such as /pnew/ (<pneu>, tire/tire) or /aft*e*/ (<afta>, cold sore/mouth ulcer), they tend to insert an <e> between the two consonants more often than when the consonantal groups conform to phonological theoretical principles (C+/l/; C+/r/). Inserting <e> in between consonant clusters has been explained on the basis of a phonological restoration strategy children would use to preserve the canonical phonological CV input. By using this strategy, children would add a phonological schwa between the consonants and then would spell the schwa usually with <e> (Santos et al., 2014). However, these authors acknowledge that the addition of <e> in spelling is more frequent than the addition of the schwa in oral productions for the same children, which lessens the explanatory power of the phonological explanation. Thus, when spelling the words with schwa in C/ɨ/.CVC structures, the reason why the first graders in the present study tended to maintain the CV format by inserting the <e> was probably (as indicated above) that they were reproducing the CV syllable structure that they have noticed is so dominant in the Portuguese orthographic system, and not so much that they had detected an empty vowel. Crucially, children adopted this practice more often with the words that had the potential to prompt an illegal onset, suggesting that they perceived, as they had already demonstrated at T1, which letter sequences are more likely to be accepted. In addition, complex onsets are infrequent (5% of the syllabic structures) and children's spellings tended to mirror that orthographic trait. This line of explanation seems more plausible than the proposition that, at such an early stage of learning, children were able to detect a vowel with no phonological value so as to use it in spelling. Other studies have already documented young spellers' sensitivity to the occurrence of letter sequences and their specific positions in words (Cassar and Treiman, 1997; Pacton et al., 2001; Caravolas et al., 2005).

In the case of CV.C/ɨ/ items, children marked an <e> after almost all consonants that could be processed as illegal codas. Otherwise, the <e> was written only in half of those that could prompt legal ones. This was probably due to the fact that, in those legal contexts, all words ended theoretically with /lɨ/, being that the orthographic patterns <l> and <le> have similar frequencies in representing short words whose last consonant is a lateral one, as it will be discussed next.

Some Portuguese linguistic studies have shown that when there is place for a theoretical /ɨ/, the consonant that precedes the schwa has a longer duration than when the phonological forms have two consecutive consonants, even when the schwa is not produced. For instance, the difference between /kɨrer/ (to want) and /krer/ (to believe) would be the duration of /k/, observed in spectrographic analyses (Andrade, 1993). According to Veloso (2003) and Santos et al. (2014) these acoustic cues would also explain the differences between words ending in /ʃ/ and ending in /ʃ/+ <e>, as well as ending in /r/ and /r/ + <e> in Portuguese pre-literate children's segmentations of words in syllables and in written productions of literate children, even when those children did not produce the schwas orally. The same kind of explanation, however, does not seem to fit the /l/ vs. /l/ + <e> case since, according to Veloso (2003), Portuguese children do not process these two kinds of words with lateral consonants in any systematically different way. The mixed way in which children sometimes differentiate, sometimes do not between words ending in /l/ and those ending in /l/ + <e> led Veloso (2003) to suggest that, nowadays, the distinction between these two phonological contexts may no longer be relevant. At this light, the differences in the adding of <e> among coda contexts has a phonological explanation. According to Veloso (2003), the schwa has probably ceased being part of the children's phonological implicit knowledge in the context of the lateral consonant but it still remains in the other two contexts.

Again, these phonologically-based explanations for preliterate children and beginning spellers explicit processing of speech ought to be taken with caution. One reason is that, as mentioned above, for children without the support of orthographic knowledge, it seems reasonable to admit that the phonetic/phonological differences between produced or not produced schwas, and also between the acoustical length of a consonant followed or not followed by a schwa are difficult, if not impossible to detect explicitly. If it is difficult for an educated adult, Veloso himself (Veloso, 2003), to be sure about the production or non-production of a schwa, how can we expect that a beginning speller count such a non-pronounceable, elusive, probably deleted, segment as a "sound" to be written? It is well-established that the explicit representation of phonemes is the harder cornerstone of the alphabetic principle acquisition (Morais et al., 1979; Morais, 2018) and that schwas are hard to spell (Treiman et al., 1993; Rosa and Nunes, 2010). Moreover, it is not clear why the provided explanation by Veloso (2003) would work for /ʃ/ and /r/ but not for /l/.

The results obtained by Veloso, and indeed the findings of the present study, may have other, perhaps more plausible, explanations if we were to examine orthographic regularities.

Since CV.C/ɨ/ items sound as monosyllables in current language use, it is important to consider children written experiences with monosyllables. At the end of school year, first graders were already taught about final <V+l>, <V+r>, <V+s>, and <V+z> patterns. Thus, they had trained the spelling of several CVC words and they have surely noticed that the final consonants are virtually only <s>, <z>, <r>, or <l>. Although monosyllabic words are not frequent, some CVC words are very frequent [e.g., <ler> [to read], <ter> [to have]; <mar> [sea]; <sol> [sun]; <mil> [thousand]; see above for those ending in /ʃ/]. Except for a scant number of verbal forms that end in <re> [e.g., <pare> [stop]; <tire> [take it]] or with <che> [e.g., <feche> [close it]: <lanche> [a verb and a noun: snack]], the short words that end in /r/ or /ʃ/ are mostly written with a final consonant. Comparatively, there are more short nouns ending in /l/ that are spelt with <le>: <pele> (skin); <mole> (soft); <vale> (valley) and also several verb forms. Even a brief look at the ESCOLEX grade 1 written lexical database will confirm these differences. Thus, we have tallied 20 phonological monosyllables that, in singular form, end in /ʃ/ written with a final consonant (<z> or <s>), and two written as <che> (<feche> and <lanche>). We counted 21 phonological monosyllables that, in singular form, end in /r/ written with a final consonant (<r>), and three with <re> (<gire>, [spin]; <chore>, [cry]; <pare>, [stop]). Finally, we totaled 15 phonological monosyllables ending in /l/ in singular form written with a final consonant (<l>) and 13 written with <le> [e.g., <cole>, [glue]; <nele>, [in it]]. It is clear that children are exposed to different frequencies of CVC and CVC+ <e> orthographic patterns for the three legal phonological codas. Children's spellings in the current study for CV.C/ɨ/ and CVC items mirrored the pattern of CVC orthographic word endings found in their books: more spellings of /ɨ/ and /r/ without <e>, a mixture of spellings of /l/, some with, some without <e>; massive adding of <e> with other final consonants. Of course, first graders at the end of the school year are also acquainted with the final consonant of phonological disyllables and their written representation, being that the <le> pattern is more frequent than that of <re> or <che> (Gomes, 2001). An analysis of the frequencies of letters in the absolute final position shows that <s> is the fourth most frequent, <r> is the sixth and <l> is the ninth (Quaresma and Pinho, 2007).

Consistent with the above statements, by the end of the school year (T2), in contrast to the study's starting point (T1), when spelling "true" CVC items, children more often correctly left the final consonant alone, rather than adding an <e> after it, except when the final consonant was /l/. Importantly, as the frequency of written <e> after the last consonant in the present study was similar for both words and pseudowords, as were the orthographic effects referring to the different codas comparison, we may argue that lexical knowledge was not a determining factor for the differences observed among codas.

Thus, while we cannot discard the influence of phonology in spelling different codas of CVC items, we clearly need to take into account the frequency with which its specific letter patterns occur in order to better understand spelling development and the difficulties children may face. Each of these three Portuguese phonological codas may be spelt with different orthographic patterns (with or without <e>) and these results suggest that the frequency of their occurrence seemed to help the children to spell these types of words. The improved spellings at the end of the school year, with a lower incidence of <e> after "true" codas, except for /l/, indicates the growing role and importance of graphotactic sensitivity over time.

One last comparison was made in order to test whether phonology was the key support for spelling. A comparison of CV.C/ɨ/, where the last C was /l/ [/mɔlɨ/, [soft]], with CVC items, where the coda was /l/ [/sɔl/, [sun]], showed that children used more <e> in spelling CV.C/ɨ/ than in CVC words. Crucially, this did not occur with pseudowords, where a similar number of <e> was deployed in both types of items. This suggests that, when frequency was controlled (pseudowords), phonology appeared not to be the leading principle in spelling this specific kind of coda (the "lateral plus schwa" ending). On the contrary, these results suggest that, unless the word was known, children did not really know whether to mark or not the <e> after the /l/, because they had been exposed to a mixture of <l> alone and <l+e> to represent that particular phonological input.

In sum, Portuguese children showed significant sensitivity to orthographic input frequency beyond phonology information from the beginning of spelling development as it was observed by the pattern of <e> spellings to represent schwas in different orthographic conditions and in comparisons between CVC monosyllables ending in /l/ and CV.C/ɨ/ where the last C was /l/.

The children's individual differences in spelling the <e> graphemes to represent the schwas at T1 were significantly predicted by foundational alphabetic knowledge expressed by the ability to choose any appropriate letter to represent a phoneme (a letter sound). At T2 the spelling of the <e> was moderately associated with the ability to spell consistent short CV.CV items which involved mainly the use of the alphabetic principle, that is the knowledge about regular phoneme-grapheme correspondences. These results are interesting for different reasons. First, they indicate that the two types of knowledge, alphabetic, and letter pattern knowledge, may in fact be associated and second, they suggest that that association may change with development. The relationship between alphabetic principle knowledge and knowledge about allowable letter patterns is not yet well-understood. Some studies' results support the idea that there are moderate associations between the two skills (Conrad et al., 2013: Kessler et al., 2013) and, on the other hand, there are data that suggest that a dissociation could exist between the ability to attend to the appearance of writing and the skills to learn phonological based spelling (Treiman et al., 2019b). While it seems reasonable to think that when children spell or decode a word correctly this reinforces their knowledge about letter patterns and conversely when they apply their knowledge about letter patterns this improves their spelling, we believe the exchange between the two skills remains to be determined. Furthermore, the reciprocity between the two may differ with the letter pattern complexity. A letter pattern linked to word position may be easier to extract from input than a letter pattern linked to vowel stress and this difference may impact the relationship between alphabetic knowledge and letter pattern knowledge. The results of this study showed that early knowledge about how to represent sounds by letters explained 25% of variance of schwa spelling with <e>. It also showed that the strength of the association between the two type of skills decreased over time. This suggests that this type of context-conditioned letter pattern knowledge may depend largely on information beyond phonology-orthography correspondences that grows with exposure to written language.

Unlike basic alphabetic knowledge, general non-verbal cognitive ability was not associated with the <e> spelling suggesting that the implicit learning mechanism supporting graphotactic knowledge may be independent of intelligence (Siegelman and Frost, 2015). The low magnitude correlations observed between letter sound spelling and general cognitive ability were in line with several studies (Caravolas et al., 2001; Cardoso-Martins et al., 2001) showing, as the present study, that those associations did not translate to general cognitive ability being a significant factor of variance in spelling, which means that orthographic knowledge seems to involve more language and specific knowledge than a sound relation to intelligence.

Overall, this study showed that knowledge about letter patterns is gained very early in spelling development. As children did not spell the expected <e> in all the orthographic conditions, the findings of this study contributed to showing that when children begin to learn to spell, phonology is not the only support for their spelling efforts, even in an orthography of intermediate consistency, such as the European Portuguese one. In some conditions, for instance the spelling of the schwa, graphotactic learning plays a unique role from the very first attempts to spell. This result concurs with recent findings showing that the frequency of letter patterns has a facilitative effect on spelling accuracy beyond orthographic consistency (Gingras and Sénéchal, 2019).

Although the findings of this study are stimulating, it must be admitted that the study involved a relatively small sample of children mainly from relatively poor backgrounds. As foundational literacy achievement is related to family socio-economic status (Duncan and Seymour, 2000; Fluss et al., 2009; Buckingham et al., 2013) it seems worthwhile replicating this type of study with a larger and more diverse sample of children. Future research would also benefit from employing other types of manipulation of words and pseudowords such as for example, using the same consonants before the schwa and without schwa in order to control for consonant phonological length. Such studies would have theoretical and practical importance since they could better inform us regarding the main drivers of spelling development, as well as helping to identify more precisely the conditions most conducive to the facilitation and hindering of spelling acquisition. For instance, the content of intervention programs, like the Portuguese GraphoGame Fluent (Carvalhais et al., 2020) which has proven to be helpful in improving spelling levels of poor readers, would benefit from specific information such as the one shown in this study regarding the conditions more prone to elicit the schwa spelling errors. Also, the results we obtained clearly suggest that practice/exposure to written language is a powerful tool to learn about the orthographic system and thus teachers should be aware of the great value of systematic daily work with written language.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

AV designed the study, co-created the stimuli, conducted the literature review, analyzed the data using SPSS, and drafted and revised the manuscript. RP co-created the stimuli, collected the data, and co-analyzed the data using SPSS. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2020.513577/full#supplementary-material

REFERENCES

Abreu, M. G., Nunes, T., and Rosa, J. (2004). Desenvolvimento da escrita [spelling development]. *Investig. Práticas* 5, 35–49.

Albuquerque, A., and Alves Martins, M. (2019). Enhancing children's literacy learning: from invented spelling to effective reading and writing. *L1 Educ. Stud. Lang. Literature* 19, 1–24. doi: 10.17239/L1ESLL-2019.19.01.02

Alves, C. D. (2012). *Efeito das Propriedades Segmentais em Tarefas de Consciência Segmental, de Leitura e de Escrita [Effect of Segmental Properties on Segmental Awareness, Reading and Writing Tasks]* (Dissertation Thesis). Faculdade de Letras, Universidade de Lisboa, Lisboa, Portugal.

Andrade, A. (1993). *Estudo Acústico de Sequências de Oclusivas em Português Europeu [Acoustic study of stop consonants sequences in European Portuguese].* Actas do IX Encontro Nacional da Associação Portuguesa de Linguística. Lisbon: APL/Colibri.

Bahr, R. H., Silliman, E. R., Berninger, V. W., and Dow, M. (2012). Linguistic pattern analysis of misspellings of typically developing writers in Grades 1-9. *J. Speech Lang. Hear. Res.* 55, 1587–1599. doi: 10.1044/1092-4388(2012/10-0335)

Barbosa, M., Medeiros, L., and Vale, A. P. (2016). Relação entre os níveis de escrita, consciência fonológica e conhecimento de letras [Relationship between levels of spelling, phonological awareness and knowledge of letters]. *Estudos Psicol.* 33, 667–676. doi: 10.1590/1982-02752016000400010

Buckingham, J., Wheldall, K., and Beam-Wheldall, R. (2013). Why poor children are more likely to become poor readers: the school years. *Aust. J. Educ.* 53, 190–213. doi: 10.1177/0004944113495500

Byrne, B., and Fielding-Barnsley, R. (1990). Acquiring the alphabetic principle: a case for teaching recognition of phoneme identity. *J. Educ. Psychol.* 82, 805–812. doi: 10.1037/0022-0663.82.4.805

Caravolas, M. (2004). Spelling development in alphabetic writing systems: a cross linguistic perspective. *Eur. Psychol.* 9, 3–14. doi: 10.1027/1016-9040.9.1.3

Caravolas, M., Hulme, C., and Snowling, M. J. (2001). The foundations of spelling ability: evidence from a 3-year longitudinal study. *J. Memory Lang.* 45, 751–774. doi: 10.1006/jmla.2000.2785

Caravolas, M., Kessler, B., Hulme, C., and Snowling, M. (2005). Effects of orthographic consistency, frequency, and letter knowledge on children's vowel spelling development. *J. Exp. Child Psychol.* 92, 307–321. doi: 10.1016/j.jecp.2005.08.001

Cardoso-Martins, C., and Batista, A. C. E. (2005). O conhecimento do nome das letras e o desenvolvimento da escrita: evidencia de crianças falantes do português [Letter name Knowledge and spelling development: evidence from Portuguese-speaking children]. *Psicol. Reflexão Crítica* 18, 330–336. doi: 10.1590/S0102-79722005000300006

Cardoso-Martins, C., Resende, S. M., and Rodrigues, L. A. (2001). Letter name knowledge and the ability to learn to read by processing letter-phoneme relations in words: evidence from Brazilian Portuguese-speaking children. *Read. Writing* 10, 10–20. doi: 10.1023/A:1015213514722

Carvalhais, L., Limpo, T., Richardson, U., and Castro, S. L. (2020). Effects of the Portuguese Graphogame on reading, spelling, and phonological awareness in second graders struggling to read. *J. Writing Res.* 12, 9–34. doi: 10.17239/jowr-2020.12.01.02

Cassar, M., and Treiman, R. (1997). The beginnings of orthographic knowledge: children's knowledge of double letters in words. *J. Educ. Psychol.* 89, 631–644. doi: 10.1037/0022-0663.89.4.631

Chaves-Sousa, S., Ribeiro, I., Viana, F. L., Vale, A. P., Santos, S., and Cadime, I. (2017). Validity evidence of the test of word reading for Portuguese elementary students. *Eur. J. Psychol. Assessment* 33, 460–466. doi: 10.1027/1015-5759/a000307

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

Deacon, S. H., Conrad, N., and Pacton, S. (2008). A statistical learning perspective on children's learning about graphotactic and morphological regularities in spelling. *Can. Psychol.* 49, 118–124. doi: 10.1037/0708-5591.49.2.118

Dich, N., and Cohn, A. C. (2013). A review of spelling acquisition: spelling development as a source of evidence for the psychological reality of the phoneme. *Lingua* 133, 213–229. doi: 10.1016/j.lingua.2013.04.010

Duncan, L. G., Castro, S. L., Defior, S., Seymour, P. H. K., Baillie, S., Leybaert, J., et al. (2013). Phonological development in relation to native language and literacy: variations on a theme in six alphabetic orthographies. *Cognition* 127, 398–419. doi: 10.1016/j.cognition.2013.02.009

Duncan, L. G., and Seymour, P. H. K. (2000). Socio-economic differences in foundation-level literacy. *Br. J. Psychol.* 91, 145–166. doi: 10.1348/000712600161736

Ehri, L. C. (2005). Learning to read words: theory, findings, and issues. *Sci. Stud. Read.* 9, 167–188. doi: 10.1207/s1532799xssr0902_4

Ehri, L. C., and Wilce, L. S. (1982). The salience of silent letters in children's memory for word spellings. *Memory Cogn.* 10, 155–166. doi: 10.3758/BF03209217

Fernandes, D., and Martinelli, S. (2018). Dificuldades de escrita em alunos do ensino fundamental [Spelling difficulties in elementary school children]. *Rev. Psicol. Teoria Prática* 20, 189–199. doi: 10.5935/1980-6906/psicologia.v20n1p200-210

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

Fijalkow, J. (2007). Invented spelling in various contexts: introduction to a special issue of L1 educational studies in language and literature. *L1 Educ. Stud. Lang. Literature* 7, 1–4. doi: 10.17239/L1ESLL-2007.07.03.03

Fluss, J., Ziegler, J. C., and Warszawski, J. (2009). Poor reading in French elementary school: the interplay of cognitive, behavioral and socioeconomic factors. *J. Dev. Behav. Pediatr.* 30, 206–216. doi: 10.1097/DBP.0b013e3181a7ed6c

Freitas, M. J. (2017). "Aquisição da fonologia em língua materna: a sílaba [Native language acquisition: the syllable]," in *Aquisição de Língua Materna e não Materna: Questões Gerais e Dados do Português*, eds M. J. Freitas and A. L. Santos (Berlin: Language Science Press), 71–94.

Gingras, M., and Sénéchal, M. (2019). Evidence of statistical learning of orthographic representations in grades 1–5: the case of silent letters and double consonants in French. *Sci. Stud. Read.* 23, 37–48. doi: 10.1080/10888438.2018.1482303

Gomes, I. (2001). *Ler e escrever em português europeu [Reading and Spelling in European Portuguese]* (Dissertation thesis). Universidade do Porto, Porto, Portugal.

Gomes, I., and Castro, S. L. (2003). Porlex, a lexical database in European Portuguese. *Psychologica* 32, 91–108.

Hayes, H., Treiman, R., and Kessler, B. (2006). Children use vowels to help them spell consonants. *J. Exp. Child Psychol.* 94, 27–42. doi: 10.1016/j.jecp.2005.11.001

Kessler, B., Pollo, T. C., Treiman, R., and Cardoso-Martins, C. (2013). Frequency analyses of prephonological spellings as predictors of later success in conventional spelling. *J. Learn. Disabil.* 46, 252–259. doi: 10.1177/0022219412449440

Kolinsky, R., Leite, I., Carvalho, C., Franco, A., and Morais, J. (2018). Completely illiterate adults can learn to decode in 3 months. *Read. Writing* 31, 649–677. doi: 10.1007/s11145-017-9804-7

Levin, I., Patel, S., Margalit, T., and Barad, N. (2002). Letter names: effect on letter saying, spelling, and word recognition in Hebrew. *Appl. Psycholinguist.* 23, 269–300. doi: 10.1017/S0142716402002060

Martinet, C., Valdois, S., and Fayol, M. (2004). Lexical orthographic knowledge develops from the beginning of reading acquisition. *Cognition* 91, B11–B22. doi: 10.1016/j.cognition.2003.09.002

Mesquita, A., Carvalhais, L., Limpo, T. , and Castro, S. L. (2020). Portuguese spelling in primary grades: complexity, length and lexicality effects. *Read. Writing* 33, 1325–1349. doi: 10.1007/s11145-019-10012-5

Miranda, A. R., and Veloso, J. (2017). "Consciência linguística: aspetos fonológicos [Linguistic awareness: phonological aspects]," in *Aquisição de Língua Materna e não Materna: Questões Gerais e Dados do Português*, eds M. J. Freitas and A. L. Santos (Berlin: Language Science Press), 439–458.

Morais, J. (2018). "The methods issue revisited: from a developmental and a socio-cultural-political perspective," in *Reading and Dyslexia: From Basic Functions to Higher Order Cognition*, eds T. Lachmann & T. Weis (Cham: Springer), 3–25.

Morais, J., Cary, L., Alegria, J., and Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? *Cognition* 7, 323–331. doi: 10.1016/0010-0277(79)90020-9

Notarnicola, A., Angelelli, P., Judica, A., and Zoccolotti, P. (2012). Development of spelling skills in a shallow orthography: the case of Italian language. *Read. Writing Interdiscipl. J.* 25, 1171–1194. doi: 10.1007/s11145-011-9312-0

Pacton, S., Fayol, M., and Perruchet, P. (2005). Children's implicit learning of graphotactic and morphological regularities. *Child Dev.* 76, 324–339. doi: 10.1111/j.1467-8624.2005.00848_a.x

Pacton, S., Perruchet, P., Fayol, M., and Cleeremans, A. (2001). Implicit learning out of the lab: the case of orthographic regularities. *J. Exp. Psychol. General* 130, 401–426. doi: 10.1037/0096-3445.130.3.401

Pedro, C., Lousada, M., Pereira, R., Hall,. A., and Jesus, L. (2017): The letter knowledge assessment tool. *Logopedics Phoniatrics Vocol.* 43, 129–141. doi: 10.1080/14015439.2017.1384055

Pinheiro, A. M. V. (1995). Reading and spelling development in Brazilian Portuguese. *Read. Writing* 7, 111–138. doi: 10.1007/BF01026950

Pollo, T. C., Kessler, B., and Treiman, R. (2005). Vowels, syllables, and letter names: differences between young children's spelling in English and Portuguese. *J. Exp. Child Psychol.* 92, 161–181. doi: 10.1016/j.jecp.2005.01.006

Pollo, T. C., Kessler, B., and Treiman, R. (2009). Statistical patterns in children's early writing. *J. Exp. Child Psychol.* 104, 410–426. doi: 10.1016/j.jecp.2009.07.003

Quaresma, P., and Pinho, A. (2007). "Análise de Frequência da Língua Portuguesa [Frequency analysis for the Portuguese language]," in *Proceedings of the Ibero-American Conference InterTIC 2007* (Porto: IASK), 267–272.

Raven, J., Raven, J. C., and Court, J. H. (2009). *CPM-P Raven - Coloured Progressive Matrices Test, Parallel Form*. Lisboa: Cegoc-Tea.

Read, C. (1986). *Children's Creative Spelling*. London: Routledge and Kegan Paul.

Read, C., and Treiman, R. (2013). "Children's invented spelling: what we have learned in forty years," in *Rich Languages From Poor Inputs*, eds M. Piattelli-Palmarini and R. C. Berwick (New York, NY: Oxford University Press), 197–211.

Ritchey, K. D., Coker, D. L., and McCraw, S. B. (2010). A comparison of metrics for scoring beginning spelling. *Assessment Effect. Intervention* 35, 78–88. doi: 10.1177/1534508409336087

Rosa, J., and Nunes, T. (2010). Can children's spelling of schwa vowels in stems be improved? *Educar Rev.* 38, 113–127. doi: 10.1590/S0104-40602010000300008

Santos, R., Freitas, M. J., and Veloso, J. (2014). Consonantal clusters in school: phonological development and orthographic knowledge. Diacrítica. *Ciências Linguagem* 28, 407–436.

Sargiani, R., and Albuquerque, A. (2016). Análise das Estratégias de Escrita de Crianças Pré-Escolares em Português do Brasil [Kindergartners's spelling strategies analyses in Brazilian Portuguese]. *Psicol. Escolar Educ.* 20, 591–600. doi: 10.1590/2175-3539201502031057

Serrano, F., Genard, N., Sucena, A., Defior, S., Alegria, J., Mousty, P., et al. (2010). Variations in reading and spelling acquisition in Portuguese, French and Spanish: a cross-linguistic comparison. *J. Portuguese Linguist.* 9–10, 183–205. doi: 10.5334/jpl.106

Serrano, F., Jiménez Fernandez, G., and Defior, S. (2004). "Development of spelling skills in Spanish orthography: a longitudinal study," in *Proceedings Writing 2004* CD, eds L. Allal and J. Dolz. (Geneva: Adcom Production).

Siegelman, N., and Frost, R. (2015). Statistical learning as an individual ability: theorotical perspectives and empirical evidence. *J. Memory Lang.* 81, 105–120. doi: 10.1016/j.jml.2015.02.001

Soares, A. P., Medeiros, J. C., Simões, A., Machado, J., Costa, A., Iriarte, Á., et al. (2014). ESCOLEX: a grade-level lexical database from European Portuguese elementary to middle school textbooks. *Behav. Res. Methods* 46, 240–253. doi: 10.3758/s13428-013-0350-1

Spear-Swerling, L., Lopes, J., Oliveira, C. R., and Zibulski, J. (2016). How Portuguese and American teachers plan for literacy instruction. *Ann. Dyslexia* 66, 71–90. doi: 10.1007/s11881-015-0107-x

Sprenger-Charolles, L., and Siegel, L. (1997). A longitudinal study of the effects of syllabic structure on the development of reading and spelling skills in French. *Appl. Psycholinguist.* 18, 485–505. doi: 10.1017/S014271640001095X

Sucena, A. (2017). Sensibilidade precoce às combinações ortográficas entre crianças falantes do português europeu [Early sensitivity to orthographic patterns in European Portuguese children]. *Investig. Práticas* 7, 26–40.

Treiman, R. (1993). *Beginning to Spell: A Study of First Grade Children*. New York, NY: Oxford University Press.

Treiman, R. (1994). Use of consonant letter names in beginning spelling. *Dev. Psychol.* 30, 567–580. doi: 10.1037/0012-1649.30.4.567

Treiman, R. (2017a). Learning to spell: phonology and beyond. *Cogn. Neuropsychol.* 34, 83–93. doi: 10.1080/02643294.2017.1337630

Treiman, R. (2017b). Learning to spell words: findings, theories, and issues. *Scie. Stud. Read.* 21, 265–276. doi: 10.1080/10888438.2017.1296449

Treiman, R. (2018). Teaching and learning spelling. *Child Dev. Perspect.* 12, 235–239. doi: 10.1111/cdep.12292

Treiman, R., Berch, D., and Weatherston, S. (1993). Children's use of phoneme-grapheme correspondences in spelling: Roles of position and stress. *J. Educ. Psychol.* 85, 1–12. doi: 10.1037/0022-0663.85.3.466

Treiman, R., Cardoso-Martins, C., Pollo, T. C., and Kessler, B. (2019b). Statistical learning and spelling: evidence from Brazilian prephonological spellers. *Cognition* 182, 1–7. doi: 10.1016/j.cognition.2018.08.016

Treiman, R., and Kessler, B. (2013). Learning to use an alphabetic writing system. *Lang. Learn. Dev.* 9, 317–330. doi: 10.1080/15475441.2013.812016

Treiman, R., Kessler, B., Boland, K., Clocksin, H., and Chen, Z. (2018). Statistical learning and spelling: older prephonological spellers produce more wordlike spellings than younger prephonological spellers. *Child Dev.* 89, e431–e443. doi: 10.1111/cdev.12893

Treiman, R., Kessler, B., and Caravolas, M. (2019a). What methods of scoring young children's spelling best predict later spelling performance? *J. Res. Read.* 42, 80–96. doi: 10.1111/1467-9817.12241

Treiman, R., and Tincoff, R. (1997). The fragility of the alphabetic principle: Children's knowledge of letter names can cause them to spell syllabically rather than alphabetically. *J. Exp. Child Psychol.* 64, 425–451. doi: 10.1006/jecp.1996.2353

Treiman, R., Zukowski, A., and Richmond-Welty, E. D. (1995). What happened to the "n" of sink? Children's spellings of final consonant clusters. *Cognition* 55, 1–38. doi: 10.1016/0010-0277(94)00638-2

Vale, A. P. (2000). *Correlatos metafonológicos e estratégias iniciais de leitura-escrita de palavras no português: uma contribuição experimental [Metaphonological correlates and early strategies of word reading and spelling in Portuguese: an experimental contribution]* (Dissertation thesis). University of Trás-os-Montes e Alto Douro (UTAD), Vila Real, Portugal.

Vale, A. P., and Cary, L. (1998). Escrita inventada e deteção fonémica em leitores principiantes: preditores do desempenho ulterior em Leitura e Escrita [Invented spelling and phonemic detection in beginning readers: predictors of later reading and spelling]. *Rev. Portuguesa Pedagogia* 1, 29–56.

Vale, A. P., and Cary, L. (1999). "A comparison between Portuguese pre-readers versus beginning readers phoneme analysis ability: effects of Portuguese orthographic structure?" in *Psycholinguistics on the Threshold of the Year 2000*, eds M. da Graça Pinto, J. Veloso, and B. Maia (Porto), 377–381.

Vale, A. P., Martins, B., and Silva, A. R. (2018). Exposure frequency effect on early orthographic representation: a longitudinal study of the spelling of Phoneme /u/ in European Portuguese. *I Workshop on Cognitive Science of Culture - Literacy: An Acculturation of the Brain* (Lisbon: Faculdade de Psicologia da Universidade de Lisboa).

van Bon, W. H. J., and Uit De Haag, I. J. C. A. F. (1997). Difficulties with consonants in the spelling and segmentation of CCVCC pseudowords: differences among Dutch first graders. *Read. Writing Interdiscipl. J.* 9, 363–386. doi: 10.1023/A:1007942911807

Veloso, J. (2003). "A distinção entre palavras terminadas em consoante e palavras terminadas na sequência ortográfica "consoante+≪-e≫" num grupo de crianças falantes do português europeu em idade pré-escolar [The distinction between words ending in consonant and words ending in the spelling sequence "consonant +≪ - e ≫'' in a group of Portuguese-speaking kindergarten children]," in *Língua Portuguesa: Estruturas, Usos e Contrastes* (Porto: CLUP), 259–258.

Veloso, J. (2012). Vogais centrais do português europeu contemporâneo: uma proposta de análise à luz da fonologia dos elementos [Central vowels of contemporary European Portuguese: an analysis proposal in the light of the phonology of the elements]. *Letras Hoje* 47, 234–243.

Veloso, J. (2016). "O sistema vocálico e a redução e neutralização das vogais átonas em português europeu contemporâneo [The vowel system and the reduction and neutralization of unstressed vowels in contemporary European Portuguese]," in *Manual de Linguística Portuguesa*, eds A. M. Martins and E. Carrilho (Berlin: De Gruyter), 636–662.

Viana, F. L., Ribeiro, I., Vale, A. P., Chaves-Sousa, S., Santos, S., and Cadime, I. (2014). "TLP - teste de leitura de palavras [TLP – word reading test]," in *Manual Técnico* (Lisboa: CEGOC-TEA). Registo N.° 5106/2013.

Wright, D. M., and Ehri, L. C. (2007). Beginners remember orthography when they learn to read words: the case of doubled letters. *Appl. Psycholinguist.* 28, 115–133. doi: 10.1017/S0142716406070068

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