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Effects of Orthographic Consistency, Frequency, and Letter Knowledge on Children's Vowel Spelling Development

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Abstract

This study investigated children's sensitivity to spelling consistency, and lexical and sublexical (rime) frequency, and their use of explicitly learned canonical vowel graphemes in the early stages of learning to spell. Vowel spellings produced by 78 British children at the end of reception year (mean age 5 years, 7 months) and 6 months later in mid-Year 1 were assessed. Regression analyses revealed that, at both test times, knowledge of sound–letter correspondences influenced spelling performance; however, unconditional consistency of vowel spellings affected children's spelling most strongly, over and above additional effects of word and rime frequency and the complexity of the target vowel grapheme. The effect of conditional consistency of vowel spellings given coda contexts was not significant. Thus, young children are sensitive to various statistical properties of the orthography from the earliest phases of spelling development, and in particular, to the unconditional consistency of the vowel spelling pattern.

Key words: spelling development, vowel, consistency, letter knowledge, implicit, explicit, grain size

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A considerable amount is known about the phonological basis of spelling development (Gentry, 1982; Henderson, 1980). Read (1975) demonstrated that children first attempt to represent the most salient phonemes of words with letters that they know. Then, as their letter knowledge and phoneme awareness skills grow, their spellings increasingly approximate the full phonological structures of words (see also Ehri, 1997; Treiman, 1993). However, in English, the ability to code the individual phonemes of words is not sufficient, because the orthography is highly inconsistent unless contextual and morphological factors are considered (see Kessler & Treiman, 2001, 2003). Critical questions in relation to spelling development are *what* types of orthographic knowledge children acquire over and above sound-letter encoding, and *when* and *how* they acquire this knowledge.

With respect to the *when* and *how* questions, stage or phase models of spelling development (e.g., Ehri, 1995, 1999; Frith, 1985) emphasize that "orthographic knowledge" is acquired only after the initial phoneme–letter encoding phase, and that it is primarily derived from developing reading skill and experience with print; that is, much of this learning may occur implicitly, over and above any explicit instruction about spelling rules. However, such models remain vague about the types of orthographic knowledge that children acquire and when in development they do so.

Recent studies suggest that one type of knowledge that is acquired early is that of graphotactic conventions for permissible letter sequences (Cassar & Treiman, 1997; Pacton, Perruchet, Fayol, & Cleeremans, 2001; Treiman, 1993), and, contrary to a strict phase-theory account, sensitivity to graphotactic conventions is measurable among many English-speaking kindergarten children whose spellings do not yet encode the full phonological structure of words. There is also evidence that children are sensitive to lexical variables such as word frequency in the very early stages of spelling. Martinet, Valdois, and Fayol (2004), for example, reported that, after only three months of literacy instruction, first-grade French children spelled explicitly taught irregular graphemes—those whose spelling cannot be derived from a simple phoneme-to-letter mapping strategy—more accurately when they appeared in words that occurred frequently in their reading scheme than in words that occurred infrequently.

Together, the above findings suggest that knowledge about certain orthographic and lexical regularities is acquired from the earliest stages of literacy development and that to some extent this learning must be implicit and incidental. In writing systems with many inconsistent letter–sound relationships, such as English and French, another important part of the research agenda is to specify more fully how and when children learn to abstract knowledge about the variability of phoneme–grapheme relationships and of the contexts in which particular graphemes may occur; in other words, how and when children learn to cope with the lack of spelling consistency. In the present study, we addressed these questions with a particular focus on children's learning about the consistency of vowel spellings.

An approach to quantifying the consistency of the English orthography was developed by Kessler and Treiman (2001). They computed the *unconditional* and the *conditional probabilities* of spelling–sound and sound–spelling mappings of the onset, vowel, and coda segments of monosyllabic words in adults' and children's word corpora. We focus here on the findings relevant to spelling, that is, those for sound–spelling correspondences. Kessler and Treiman

(2001) defined unconditional probability of sound-to-spelling correspondences as the proportion of all words with a given phoneme that has a particular spelling, given all the possible spellings of that phoneme. Conditional probability additionally takes into account the identity of another phoneme in the syllable. For example, the conditional probability of the correspondence /ɛ/ → *ea* given coda /d/ was defined as the proportion of all words with vowel /ɛ/ and coda /d/ that have the vowel spelling *ea*. A similar procedure was followed for vowel spellings given onsets. These calculations showed, for both child and adult word corpora, that the conditional probability values are significantly higher than the unconditional probability values. Vowels were found to be the least consistent parts of syllables, but vowel predictability is increased if account is taken of the coda. In the child corpus, the predictability of the spelling of an American English vowel was on average .509 when context was ignored; but it increased to .797 when the ensuing coda phoneme was considered. However, the conditioning influence of onsets on vowel spellings was not significant (see also Kessler & Treiman, 2003).

The effect of consistency on English vowel spelling has only been investigated in studies with adults (e.g., Barry & Seymour, 1988; Perry & Ziegler, 2004; Treiman, Kessler, & Bick, 2002). Treiman et al. (2002) found that adult spellers exploit the statistical interdependencies between vowels and their surrounding consonantal contexts in the spelling of vowels, especially those between vowels and codas. More recently, Perry and Ziegler (2004) assessed the concurrent effects of rime-level consistency (viz. conditional probabilities), unconditional probabilities of vowels, and the frequency of particular rime spellings on vowel spelling. They found that the latter two factors exerted a much stronger influence, although the effects of rime consistency also tended to be significant. These studies show that adults take both types of statistical information into consideration when spelling.

As would be expected from the corpus statistics, studies with children have demonstrated that learning to spell vowels is particularly difficult (e.g. Stage & Wagner, 1992; Treiman, 1993). Kessler and Treiman's (2001) findings thus raise the question of when in development children become sensitive to the unconditional probabilities of vowel spellings and to the statistical interdependencies between vowels and codas. One hypothesis is that, because young English-speaking children become aware of onsets and rimes before they are aware of phonemes (e.g., Treiman & Zukowski, 1996), they may initially attempt to spell words on the basis of onset and rime units. Accordingly, if they treat onsets and rimes as unanalyzed wholes, young spellers may first become sensitive to rime frequencies but remain oblivious to characteristics of their constituent phonemes. Specifically, they may not show sensitivity to either unconditional or conditional consistencies of vowels until later stages of learning. Alternatively, in light of the ample evidence that children's earliest spelling strategies consist predominantly of sequential phoneme-to-letter mappings (Caravolas et al., 2001; Rittle-Johnson & Siegler, 1999; Treiman, 1993), they may first become sensitive to the unconditional probabilities of vowel spellings and only later, when their letter representations and phonological recoding skills are well established, begin to attend to the orthographic interdependencies between vowels and codas.

This last view, which is based on behavioral evidence, finds support in distributional and connectionist accounts derived from the field of implicit learning (e.g., Cleeremans, 1993; Perruchet & Gallego, 1997). Distributional theorists propose that the implicit learning of complex structures, such as an orthographic system, is constrained by perceptual–attentional resources that initially encompass the smallest units, or primitives (in this case, letters), which are the building blocks of higher-level units (syllables, words). Cleeremans's (1993, 1997, also Pacton et al., 2001) connectionist model assumes that the learner learns by becoming increasingly sensitive to the probability of transitions between sequences of letters. After first exposures to text on a letter-by-letter basis, the learner quickly becomes sensitive to the overall frequency of the various letters, and although a representation of each letter with its full set of possible successors is stored in memory, she or he cannot initially represent or use contextual information and so only predicts letters on the basis of frequency. Gradually, the learner becomes increasingly sensitive to the sequential constraints present in the system and comes to be able to predict letters on the basis of a given letter as well as its context and eventually also its absolute position within the word.

Of course, in most phonics-based approaches to literacy teaching such as the one used in the schools in the present study, children are not simply left to discover the writing system on their own; they also receive at least some explicit instruction in letter-sound and/or letter-name correspondences and in phonological encoding. English-speaking children who are explicitly taught phonics skills learn to read (e.g., Landerl, 2000) and spell (e.g., Bruck, Treiman, Caravolas, Genesee, & Cassar, 1998) better than children who do not receive this type of instruction. In line with these behavioral findings, Hutzler, Ziegler, Perry, Wimmer, and Zorzi (2004) recently demonstrated that connectionist models were best able to simulate children's patterns of learning of alphabetic decoding skills when the implicit learning process began with explicit training in grapheme–phoneme correspondence rules.

To investigate when and how knowledge about vowel consistency is acquired, we assessed the vowel spellings of English children at two time points in their first and second year of schooling and investigated whether their spelling was sensitive to unconditional and conditional consistency. In order to gain a more complete understanding of the factors that operate in early spelling development, we also measured the relative importance of lexical frequency, which might reflect effects of sight word learning. In addition, we examined the role of written rime frequency in order to determine whether, like adults (Perry & Ziegler, 2004), children are initially sensitive to these larger units apart from sensitivity to the properties of their constituent elements (vowels and codas). The concurrent estimation of the effects of rime frequency and conditional vowel (given coda) consistency further enabled us to control for the possibility that vowel–coda sequences that occur in many different words (e.g., *o* followed by *t* as in *lot, pot, hot, not*, etc.) may produce larger benefits of conditional consistency than sequences that occur in only one word (e.g., *ach* followed by *t* as in *yacht*), despite the fact that the latter (e.g., *ach* given *t*) might have a strong conditional consistency of 1.0. Finally, as the children in our study were mainly using a phonological encoding strategy at both test times, the success of which depends on phoneme awareness and knowledge of letters which were explicitly taught during the first school year (see Caravolas et al., 2001), we also assessed the influence on spelling performance of letter-sound knowledge and of the length of the correct vowel spelling.

The children in our study were not explicitly taught about the probabilities with which particular vowel spellings occur, but they were explicitly taught canonical correspondences between vowel phonemes and letters. We therefore assumed that if the degree of consistency of any given vowel helped children to spell it correctly over and above their explicitly learned knowledge of the canonical spelling for that vowel, this presumably reflected an effect of implicitly acquired knowledge. In addition, we predicted that if children acquire spelling skills by first attending to small grain units, and only later become able to attend to and exploit statistical information about larger-grain-sized units such as rimes, then effects of unconditional consistency and canonical letter knowledge should emerge as earlier and stronger predictors of vowel spelling ability than effects of rime frequency and conditional consistency.

Method

Participants

One hundred and fifty-two children were recruited from 18 reception-year classes in nine schools in the city of York, England (for further details see Caravolas et al., 2001). The data presented here were obtained at the end of reception year (Time 1) and approximately six months later, in the middle of year 1 (Time 2). All children were given a spelling test as part of a larger battery at the end of reception year, and those who demonstrated measurable vowel-spelling ability (approximately half of the sample) were retained for the present study. Here we report data from the 78 children (33 girls, 45 boys) who produced correct vowel spellings for more than 10% of the words in the spelling test (described below) at the end of reception year. At Time 1, the mean age of the group was 5 years, 7 months (range 4;3 to 6;6 years). All children were monolingual native speakers of English and were taught by a phonics-based method of literacy instruction based on the literacy hour guidelines of the National Literacy Strategy (Department for Education and Employment, 1998). In reception year, this program focuses primarily on learning letter–sound associations and on basic decoding skills. Letter names are not formally taught. Table 1 provides information about the children's overall literacy skills, namely letter knowledge, word reading, and word spelling, at the two time points under consideration in the present study.

Stimuli

The spelling of 95 words was assessed. All words were monosyllabic and monomorphemic and represented common, highly imageable, objects and actions (see Table 2 for examples). They varied in onset and coda complexity, sampled a wide variety of phonemes and phoneme sequences, and varied in terms of frequency of occurrence. Each of the 95 stimuli was rated for several properties that might influence spelling accuracy, depending on the type of spelling strategy the children used. Table 2 provides an illustration of scores on each variable for a sample of the test words, and the full word list and respective ratings are available on http://www.york.ac.uk/res/crl/index1.html. A sample of children's spelling productions at each test time is provided in the Appendix.

Canonical letter sound presence. The children had been taught a specific canonical letter sound for each vowel: the traditional short vowel sounds. Children who pursue a letter-sound strategy might attempt to spell each vowel with the letter that was taught as having that sound, if any. We rated each word on the degree to which such a strategy would be accurate. For example, the children were taught that /ɛ/ is the sound associated with the letter *e*. Thus, the letter *e* in the word *bed* was rated as 2 because the vowel is spelled entirely consistently with the expected letter *e*; and, the sequence *ai* in *said* would be rated as 0 because the vowel spelling does not include the expected letter *e*. Intermediate circumstances rated a 1, such as when there is an additional letter in the vowel spelling besides the one that canonically spells the vowel (*head*), or when the vowel sound is a phonemically lengthened form of the canonical vowel sound (*there* /ðɛː/). In the spelling test, 63 of the 95 words contained a canonical vowel spelling.

Vowel grapheme simplicity. It is well established that children learn to spell single-letter graphemes more easily than multi-letter graphemes (e.g., Treiman, 1993). We reasoned that children's ability to spell vowels accurately may be influenced by the brevity of the target vowel spellings. Accordingly, we rated vowel spelling simplicity as a function of the number of letters that each vowel spelling contained, such that the least complex graphemes were rated the highest and the most complex were rated the lowest. For example, the *e* in *bed* was rated 3, the *oo* in *book* was rated 2, and the *ear* in *heart* was rated 1. Scores were inverted in this fashion so that higher numbers would be positively associated with better predicted spelling performance.

Word frequency. To assess the potential effects of sight word learning on vowel spelling accuracy, we calculated the log frequency of each word in the spelling list, based on the adjusted frequencies per million in the corpus of words used in kindergarten and Grade 1 U.S. reading materials (Zeno, Ivenz, Millard, & Duvvuri, 1995). Before adding one and taking the logarithm, the word frequencies ranged from 0 to 2096 occurrences per million, with a mean frequency of 177.20. We assumed that these American frequencies would be generally similar to those in British English.

Rime frequency. We calculated the log frequencies of the rimes occurring in our word list in order to ascertain whether children's vowel spellings are influenced by frequencies of sublexical units in printed words. The frequencies were obtained from the Zeno et al. (1995) corpus of kindergarten and first grade words. For each written rime type in our word list, such as the *en* of *hen* and *pen,* we summed the logarithm of the frequency of each word in our list that contains that rime. Thus the log rime frequency of *hen* and *pen* is 35.18. Values in our word list ranged from 0.69 (for *vase*) to 71.56 (for *mat*).

Computation of probability of phoneme–letter mapping. We computed the proportional frequency (probability) with which the word's vowel phoneme is spelled with the letter actually found in the word, as computed across a corpus of words that were judged as likely to have been encountered by children in print by the end of Year 1. Details of the computations follow.

Base vocabulary selection. Because spelling can vary considerably across different strata of the English vocabulary, computing consistency across all words would run some risk of incorporating information that is not salient to very young spellers with limited literacy experience. We therefore computed consistency over just those words that children would be likely to have seen in print by the end of first year. We also limited the purview to one-syllable words, which agrees with the structure of the words used as stimuli in the experiment. This decision was motivated in part because young children have more familiarity with writing shorter words than longer ones, and in part because one-syllable words often have different spelling properties from longer words. To avoid redundancy, regularly inflected forms like *books* were excluded in favor of the base form, *book*. Abbreviations, contractions, and regularly capitalized words were all excluded as well.

In order to judge whether a child will have had a reasonable chance of encountering a word in print, the following criteria were used. All words were included that were listed by England's National Literacy Strategy as words to be mastered by the end of second year. To extend that small selection, the familiar adult vocabulary used by Kessler and Treiman (2001) was subjected to a series of tests. If a word was tested by Metsala (1997), it was included only if its age of acquisition was reported as 6.5 (corresponding to the second grade in the US) or earlier. Otherwise if a word was tested by Nusbaum, Pisoni, and Davis (1984), it was included only if its familiarity to college students, on a scale of 1–7, was at least 6.4; regression analysis showed that this rating corresponds to Metsala's 6.5 age of acquisition. A word not evaluated by either Metsala or Nusbaum was included only if Zeno, Ivenz, Millard, and Duvvuri (1995) reported a *U* value (frequency in school textbooks, adjusted by distribution across texts) of at least 1 for any grade up through US second grade. Words that passed these tests were judged by two reception-year and two first-year teachers in York, as well as by one of the authors (Caravolas). Words were retained only if at least one of the judges considered the word to be one that a child would be likely to encounter in school by the end of first year. The final inventory contained 1,612 words.

Consistency measurement. Each word was listed in the most common spelling and pronunciation used in Northern England, to reflect the accent spoken by children in York. The pronunciations were each parsed into onset, vowel, and coda. All the letters of the spelling were then aligned with the three parts of the pronunciation. Final silent *e* was treated as contributing to the spelling of the vowel (e.g., *name*), the coda (*dance*), or both (*dice*). One of the most important differences from typical alignments of North American spellings and pronunciations (Kessler & Treiman, 2001) is that in cases where American pronunciation assigns *r* to the coda, Northern English always assigns the *r* to the vowel. For example, in *part, ar* spells the vowel /aː/, and in *hear, ear* spells the vowel /ɪː/.

The computation of the unconditional and conditional probabilities of the sound-to-spelling correspondences was based on pure type counts, not weighted by word frequency. Each word that the children were asked to spell in the experiment, therefore, had three spelling probability measures, depending on the pronunciation and spelling of its vowel and the pronunciation of the onset and coda consonants. The probabilities approach 0 as spellings become more rare or unusual representations for a given vowel, and are 1.0 when no other word with the same vowel sound (and, for conditional measures, coda) has a spelling different from the word under consideration.

These calculations yielded a mean unconditional value for vowels of .723 and a mean conditional value for vowel-given-coda of .846. We also calculated the conditional probabilities of vowels given the onset, but these probabilities were very highly correlated with the unconditional vowel probabilities ($r = .79$, $p < .001$) and produced suppressor effects when both variables were included in the model. On the basis of this result, and Kessler and Treiman's (2001) finding that onsets did not improve vowel spelling probabilities above chance levels in the children's corpus, we report only the results for unconditional and vowel-given-coda analyses.

Spelling Test Procedure

Each word was presented as a line drawing. The pictures and adjacent lines for writing were presented in four booklets (see Caravolas et al., 2001, for further details). The child named each picture for the experimenter and then attempted to write the word. Spellings were elicited from picture prompts so as to obtain spellings based on the children's own pronunciations of the words. Along with the spelling booklet, each child had an accompanying strip of alphabet letters, which was provided to encourage at least partial spellings of words that children were hesitant to attempt. The strip presented lowercase letters, in a large font, on two lines: the top line contained all of the consonants in alphabetical order, and the second line contained all of the vowels in alphabetical order. Groups of two to four children were tested over four sessions. Each child worked on a separate booklet in order to discourage copying. If a child could not name the picture prior to writing it, the experimenter provided a semantic cue, and if this failed then the first phoneme was given. If this also failed, the experimenter pronounced the word and asked the child to repeat it twice prior to attempting to spell it. However, because the children had been asked to spell all of the words at an earlier testing point (which is not discussed in the present study because the children could spell virtually no vowels correctly at that time), they rarely failed to name the pictures. Children were encouraged to refer to the letter strip, and all spelling productions were praised. Each spelling session lasted 15 to 20 minutes.

Scoring of vowel spellings. For the purpose of the present study, we were mainly interested in the types of variables that help children produce correct vowel spellings. Therefore, we considered only the accuracy of the vowel spellings such that a correct spelling was awarded 1 point while all imperfect attempts were awarded 0.

Results

As can be seen in Table 1, the children were in the early stages of learning to read and write at Time 1. They knew the sounds associated with most of letters, but fewer than half of the letter names, and they could read on average 16 words on the BAS Basic Reading test (Elliott, 1996). By mid-grade 1 (Time 2), most children knew the letter sounds and approximately two thirds of the letter names, and they could read on average 30 words on the BAS test. Their ability to spell the 95 test words was low at both test times, with mean accuracy scores around 30% at Time 1 and just over 55% at Time 2. The vowel accuracy scores revealed that at Time 1 the children were able to spell the vowels correctly in 52% of the words on average, and that by Time 2 their vowel spelling skills had improved considerably (*M* = 73.82%), but were still far from ceiling levels. Thus at both test times we were able to investigate the extent to which vowel spelling accuracy could be predicted from the following variables: unconditional probability of vowel spellings, conditional probability of vowel-given-coda spellings, log word frequency, log rime frequency, presence of canonical vowel letter sound, and the simplicity of the vowel grapheme.

Bivariate Correlations

Preliminary bivariate correlations between each predictor and by-item vowel spelling accuracy (collapsing across participants) at Time 1 and Time 2 revealed that all predictors were positively associated with spelling performance (see Table 3). The strongest associations at both test times were obtained between vowel spelling and unconditional probability of the vowel, the presence of the canonical letter sound in the vowel spelling, and the simplicity of the vowel grapheme. Correlations among the predictor variables were moderate to strong; however, they were not at levels that would be problematic for multiple regression analyses. Both Tolerance (range .284-.850) and VIF (range 1.177-3.617) values for all predictors were within acceptable ranges according to Menard (1995) and Myers (1990), indicating that collinearity was not a problem.

By-Items Regression Analyses

We first conducted a simultaneous regression analysis predicting Time 1vowel spelling scores aggregated across subjects for each of the 95 items. The predictors were unconditional probability of vowel spellings, conditional probability of vowel-given-coda spellings, log word frequency, log rime frequency, presence of canonical letter sound, and the simplicity of the vowel grapheme. The results are reported in the left half of Table 4. The model accounted for 86% of the between-item variance and all of the predictors except for rime frequency and conditional probability accounted for significant unique variance. A relatively weak but significant predictor was word frequency. The two variables pertaining to the complexity of the vowel grapheme–the presence of the canonical letter sound and the number of letters in the vowel grapheme–each accounted for unique variance (3.6% and 1.5% respectively). The strongest predictor, accounting for 5.1% of unique variance, was the unconditional probability of the target vowel. Thus, at this early stage of learning, spelling performance was affected by several variables specific to vowel spelling.

We conducted an identical analysis predicting the accuracy of the vowel spellings at Time 2 (the right half of Table 4). The model accounted for 87% of between-item variance. As can be seen, by mid-Year 1, all of the predictors except the coda-conditioned probability of vowel spellings and rime frequency accounted for unique proportions of variance in vowel spelling. It is also evident that between Time 1 and Time 2 the size of the effect of most unique predictors remained relatively stable, with the strongest effect (6.7%) still exerted by the presence of the unconditional probability of the vowel, although the strength of the canonical letter sound variable decreased slightly (1.8%) while the variable of vowel grapheme simplicity increased (2.1%).

Within-Subject Regression Analyses

The by-item correlations in Table 3 and by-item multiple regressions in Table 4 show the magnitude of associations between mean spelling outcomes and the array of predictors that are fixed stimulus attributes. However, analyses that average across subjects and only analyze the variability across items may be misleading because they overestimate the percentage of variance accounted for by the predictors and the statistical significance of such effects. We therefore conducted within-subject regression analyses, following the methods recommended by Lorch and Myers (1990), which compute variability across items that is separate from variability across subjects, giving more accurate assessments of the significance of predictors.

The outcome variable to be predicted was dichotomous, with the vowel in a word either being represented by the correct grapheme (1) or not (0). We therefore conducted a simultaneous regression analysis predicting vowel spelling of the 95 items from our six predictors separately for each of the 78 children at Time 1 and at Time 2. One-sample *t* tests were used to assess whether the standardized regression coefficients for each predictor, averaged across the 78 participants, was significantly different from zero. The results of these regression analyses are shown Tables 5 and 6 which give the average within-subject standardized regression coefficients together with their 95% confidence intervals.

As can be seen from Table 5, at Time 1, all variables in the model except the probability of the vowel spelling given the coda were significant predictors of vowel spelling accuracy. By far the most powerful predictor of correct vowel spelling was the unconditional probability of the vowel. In addition, the presence of the canonical vowel letter and the simplicity of the vowel grapheme were both significant but weaker predictors. Finally, both word and rime frequency were relatively weak predictors of variations in vowel spelling.

The same model predicting the accuracy of the vowel spellings at Time 2 is presented in Table 6. The pattern of predictors and their relative magnitude at Time 2 was very similar to the pattern found at Time 1, and by far the strongest effect was again exerted by the unconditional probability of the vowel. As in the by-items analyses, the canonical letter sound and vowel grapheme simplicity variables remained significant predictors, although their relative strengths altered slightly over time.

Summary

At both Time 1 and 2, by far the strongest unique predictor of children's success in spelling vowels was the probability with which a vowel phoneme is represented by the target vowel grapheme in English words encountered by Reception and Year 1 children. Vowel spelling accuracy was also moderately predicted by the extent to which a target vowel grapheme contained the canonical sound that children learn for that vowel in school, and by the number of letters in the vowel spelling. Finally, weak but significant effects of word frequency and rime frequency emerged in both analyses, although rime frequency, the consistently weakest predictor, was only marginally significant at Time 2. In no analysis was the effect of the probability of vowel spellings conditioned by the coda significant.

Discussion

This study assessed when, how, and to what extent children's vowel spelling accuracy is influenced by the degree of consistency in the English orthography, and more specifically, by the effects of conditional versus unconditional vowel consistency. We found that the unconditional consistency of vowel spellings influenced children's spelling accuracy very early, by the end of the first year in school, and it remained the strongest predictor of correct vowel spelling six months later. Children are not explicitly taught about the probabilities with which particular vowel graphemes occur in English words, and therefore we ascribe children's sensitivity to this aspect of the writing system to implicit learning through exposure to print. The two other variables that exerted an important influence at both test times were the extent to which the target vowel contained the canonical letter sound explicitly taught for the vowel and the number of letters contained in the vowel grapheme (vowel simplicity). Although the relative weighting of the latter two variables changed somewhat over time—perhaps reflecting children's diminishing reliance on simple letter-sound associations as their spelling ability increased—our findings are consistent with previous research that has shown that one of the best predictors of children's early spelling ability is letter-sound knowledge (e.g., Caravolas et al., 2001). Thus, our results indicate that, in the first two years of schooling at least, learning to spell vowels in English depends on both implicitly and explicitly acquired knowledge about vowel–grapheme correspondences.

In contrast, our assessment showed that in the first two years of schooling, children were not sensitive to vowel–coda interdependencies, and the effect of written rime frequency was extremely weak. Thus, in the early stages of spelling development, sensitivity to small-grain phoneme-level units in spelling is stronger than sensitivity to larger sublexical rime units, the latter exerting only a marginal influence on vowel spelling performance. These results are not compatible with earlier reports that children initially more likely to spell words on the basis of onset and rime units rather than using links from phonemes to letters (Goswami, 1988). The present findings do support the English-language findings of Treiman and colleagues (Treiman, 1993; Treiman & Cassar, 1997) and the French-language findings of Pacton et al. (2001) that children become sensitive to certain statistical properties of the orthography, such as positional constraints and word frequency, even while their own spelling productions are only partially phonologically accurate. Our results extend previous findings to show that beginner spellers are sensitive to the subtle effects of vowel-spelling consistency.

We were also interested in the effects of lexical frequency, which presumably reflect the effect of sight word learning on children's emerging spelling skills. Word frequency had a significant effect on children's vowel spellings at both test times (cf. Martinet et al., 2004). This is consistent with models of spelling development that ascribe an important role to reading ability in the development of conventional spelling, because children are most likely to become sensitive to lexical (and sublexical) frequency through reading experience (Ehri, 1995, 1999; Frith, 1985).

Together, the results of this study suggest that, over and above the explicitly learned foundation skills required for a phonological encoding strategy (such as letter-sound knowledge), the development of orthographic representations in spelling is shaped from the earliest stages by a complex combination of information about the properties of the orthographic and lexical input, acquired to some extent through implicit learning. These representations are primarily small-grained and context-independent, although they seem to be influenced to some extent by frequency information about higher order units such as words, and rimes. However, at least during the first two years of schooling, they appear not to include information about the vowel–coda interdependencies that increase the predictability of English vowel spellings. It is important to note that this study reflects the performance of approximately 50% of the five-and-a-half year old children from our original sample, those who produced above-floor levels of spelling ability. Thus our study confirms that vowel spelling ability in English develops slowly indeed and children would need to be assessed at later stages, perhaps in years 2 and 3, in order to examine when sensitivity to larger unit information emerges and how it interacts with other factors.

Our results are broadly compatible with the theoretical view expressed in Cleeremans's connectionist model, which assumes that small-unit, context-independent learning precedes learning about inter-letter contingencies such as those observed in English rime spellings (Cleeremans, 1993). They also resonate with the position of Hutzler et al. (2004), who have demonstrated that the most valid accounts of alphabetic literacy development ascribe important roles to both explicitly taught rules about letter–sound correspondences and implicit learning through exposure to print.

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Appendix

Samples of Children's Spelling Productions at Time 1 and Time 2

	Child 1		Child 2		Child 3		Child 4	
Word	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
bag	pax	bnlg	pag	bag	dolo	bag	bag	bag
ten	tne	ten	ten	ten	ten	ten	ten	ten
pear	ca	per	per	per	plep	per	pj	pare
cake	cac	cnel	cec	keyk	clailt	cack	cakc	cack
train	e	trn	retn	treyn	tnon	tain	tran	triyn
pin	a	pmeu	pin	pin	paon	pin	pin	pin
brick	pnd	brrs	brcs	brik	blit	brik	brics	brik
peach	ehe	pienhb	qit	pich	plo	pitch	pict	peth
root	pp	ransa	ros	ruwts	plal	roat	root	root
wood	c	wend	ueo	wod	wl	wood	wood	wood
book	mmm	boc	bick	book	baplooli	book	boc	book
nut	o	nont	cik	nut	noi	nit	nut	nut
coat	ppa	katso	kcot	kowt	cl	cate	Cot	cote
cod	cac	cou	cdo	cod	cord	kod	cod	coa
door	dnm	door	dor	boor	dal	door	doaw	door
ball	pmp	ball	bol	ball	blel	ball	boll	ball
yawn	yoy	yoen	yon	yon	yoloit	yone	yon	yorn

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Table 1

Descriptive Statistics of Children's Literacy and Related Skills at Time 1 and Time 2

	Time 1		Time 2	
Measure	Mean	S.D.	Mean	S.D.
Letter Sound Knowledge (max = 31)	25.42	2.89	26.91	2.27
Letter Name Knowledge (max = 26)	10.94	9.12	17.04	8.05
Word Recognition (raw score)[a]	16.38	12.89	30.78	16.66
Word Spelling (% correct)[b]	31.14	19.75	55.26	18.69
Vowel Spelling (% correct)[b]	51.81	30.00	73.82	30.97

[a]Raw score on British Abilities Scales–Basic Reading test. [b]Percent of words and vowels spelled correctly on 95-word spelling test.

Table 2

Values on the Independent Variables for a Sample of Test Words

Word	Probability of phoneme–letter mapping		Canonical letter sound	Simplicity of vowel grapheme	Word frequency (log)	Rime frequency (log)
	Unconditional	Given coda				
book	.070	.389	2	1	2.81	35.46
door	.027	.095	1	1	2.91	12.22
ball	.123	.900	2	2	2.77	51.30
coat	.208	.800	1	1	2.08	17.20
ten	.942	1.00	0	2	2.30	25.50
brick	.986	1.00	0	2	1.00	47.38

Table 3

Bivariate Correlations Between Each Predictor Variable and Spelling Accuracy at Time1 and Time 2

	T2 vowel spelling accuracy	Uncond. probability	Cond. probability	Log word frequency	Log rime frequency	Canonical Letter	Number of letters in vowel spelling
T1 vowel spelling accuracy	.936**	.845**	.580**	.214*	.331**	.823**	.838**
T2 vowel spelling accuracy	—	.855**	.580**	.227*	.352**	.800**	.846**
Unconditional probability		—	.666**	-.016	.271**	.728**	.766**
Conditional probability			—	-.018	.281**	.467**	.619**
Log word frequency				—	.229**	.061	.191
Log rime frequency					—	.197	.309**
Canonical letter						—	.754**

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

Table 4

By-Items Regression on Vowel Spelling Accuracy

	Time 1 (end reception)			Time 2 (mid-year 1)		
Predictors	β	r^2	p	β	r^2	p
Unconditional probability	.424	.051	.001	.484	.067	.001
Probability given coda	-.007	.000	n.s.	-.035	.001	n.s.
Log word frequency	.145	.018	.001	.152	.020	.001
Log rime frequency	.051	.002	n.s.	.066	.004	n.s.
Canonical letter sound	.319	.036	.001	.255	.018	.001
Number of letters in vowel spelling	.233	.015	.005	.278	.021	.001

Table 5

Within-Subjects Logistic Regression on Conventional Vowel Spelling Accuracy at Time 1

Predictors	Average beta (95% CI)	1-sample *t* value[a]	*p*
Unconditional probability	6.21 (4.33 – 8.09)	6.573	.001
Probability given coda	0.29 (-1.88 – 2.45)	.268	n.s.
Log word frequency	0.61 (0.36 – 0.85)	4.97	.001
Log rime frequency	0.03 (0.01 – 0.44)	3.28	.005
Canonical letter sound	4.72 (2.85 – 6.59)	5.02	.001
Number of letters in vowel spelling	1.17 (0.25 – 2.09)	2.56	.05

[a]Degrees of freedom: 77.

Table 6

Within-Subjects Logistic Regression on Conventional Vowel Spelling Accuracy at Time 2

Predictors	Average Beta (95% CI)	1-sample *t* value[a]	*p*
Unconditional probability	6.12 (2.01 – 10.23)	2.96	.005
Probability given coda	-1.78 (-3.72 – 0.14)	0.19	n.s.
Log word frequency	1.09 (0.33 – 1.85)	2.86	.005
Log rime frequency	0.05 (0.00 - 0.10)	2.00	.052
Canonical letter sound	1.48 (0.58 – 2.37)	3.29	.005
Number of letters in vowel spelling	2.97 (1.64 – 4.30)	4.47	.001

[a]Degrees of freedom: 77.