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Children reading spoken words: Interactions between vocabulary and orthographic expectancy

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Research Highlights

- Oral vocabulary training benefits children's processing of novel written words, as indexed by eye movements on first exposure.
- This effect interacts with spelling predictability: children benefit more from oral familiarity when the spellings of words are predictable from their phonology than when they are not.
- Findings indicate that children "read" spoken words, forming expectations about their written form even before seeing them in print.
- Findings provide the first direct evidence for a new and developmentally plausible mechanism via which oral vocabulary knowledge may assist reading acquisition.

Abstract

There is an established association between children's oral vocabulary and their word reading but its basis is not well-understood. Here, we present evidence from eye movements for a novel mechanism underlying this association. Two groups of 18 Grade 4 children received oral vocabulary training on one set of 16 novel words (e.g. "nesh", "coib"), but no training on another set. The words were assigned spellings that were either predictable from phonology (e.g., *nesh*) or unpredictable (e.g., *koyb*). These were subsequently shown in print, embedded in sentences. Reading times were shorter for orally familiar than unfamiliar items, and for words with predictable than unpredictable spellings but, importantly, there was an interaction between the two: children demonstrated a larger benefit of oral familiarity for predictable than for unpredictable items. These findings indicate that children form initial orthographic expectations about spoken words before first seeing them in print.

Children's oral vocabulary skills are known to be strongly associated with their word reading. This association has been demonstrated in cross-sectional studies (Nation & Snowling, 2004; Nation & Cocksey, 2009) and also within longitudinal and training designs (Lee, 2011; Duff, Reen, Plunkett, & Nation, 2015; McKague, Pratt & Johnson, 2001; Duff & Hulme, 2012), suggesting a causal role for oral vocabulary in reading development. Given that children typically have many words established in oral vocabulary prior to seeing them in print, understanding the mechanism by which this influence occurs is critical, as it offers the potential to create language learning conditions that maximise reading outcomes for children. Here, we present novel evidence from eye movements in support of one such mechanism: that children build initial representations of the written forms of words present in their oral vocabulary prior to first encountering them in print.

Most accounts of the way in which oral vocabulary enhances children's word reading propose that it assists in the process of forming representations of new written words – or *orthographic learning* (Castles & Nation, 2006) – and that this assistance occurs at the point of first seeing the printed word. According to the self-teaching hypothesis (Share, 1995), the presence of a word in oral vocabulary furnishes top-down support during the process of phonological decoding, assisting a child to resolve partially successful attempts. Specifically, if a child's initial decoding attempt does not match the phonology of any word present in their oral vocabulary, they may modify their decoding so as to align it with a phonologically similar word that they do know. In a similar vein, the lexical quality hypothesis (Perfetti, 1992) proposes that the presence of a word in oral vocabulary assists children to form and strengthen links between phonological and orthographic representations, and that when only partial orthographic or phonological information is available reliance on vocabulary knowledge increases. Thus, both of these theories propose a causal mechanism in which oral vocabulary influences orthographic learning upon visual exposure.

A less widely canvassed possibility is that the presence of a word in oral vocabulary assists the orthographic learning process even *before* a child has seen the word in its printed form. That is, a child who is orally familiar with a word, and who has an adequate knowledge of sound-letter mappings, may form an expectation as to how that word might be spelled, a suggestion first made but not tested by Stuart and Coltheart (1988). Indeed, children may, without intention, establish an initial orthographic representation of the word, which we refer to here as an *orthographic skeleton* (see Figure 1). This would aid reading when the word was first seen in print, particularly for words with highly predictable spellings.

Insert Figure 1 about here

Evidence from skilled readers is consistent with this alternative causal hypothesis. McKague et al. (2008; see also Johnston et al., 2004) conducted a learning study in which they taught adults the pronunciations and meanings of sets of novel words. Critically, they manipulated the spelling consistency of the words; that is, the extent to which their spellings could be predicted from their phonology (Stone, Vanhow, & Van Orden, 1997). In a condition in which the initial training was in oral form only, the participants' subsequent visual word recognition was disrupted by spelling inconsistency, suggesting that they had generated some kind of orthographic expectancy about the words based on their phonology. This is consistent with reports from a range of studies of skilled readers of pervasive effects of orthography on spoken word processing (e.g., Chéreau, Gaskell & Dumay, 2007; Rastle, McCormick, Bayliss & Davis, 2011; Taft, Castles, Davis, & Lazendic, 2008).

If spoken word learning leads to the formation of initial orthographic representations in children, this would inform the mechanisms by which oral vocabulary influences reading acquisition. We know that children make tight mappings between orthography and phonology from very early in reading development (Rack, Hulme, Snowling & Wightman, 1994; Savage & Stuart, 2006; Savage, Stuart & Hill, 2001; Ventura, Morais & Kolinsky, 2007; Perfetti, 1992). Given this, it seems likely that, as they build their proficiency in rapidly and automatically converting sounds into their written form, children would increasingly form expectations about the spellings of words present in their oral vocabulary. Here, we report on the first direct test of the orthographic skeleton hypothesis in developing readers. We reasoned that if children generate orthographic skeletons for orally familiar words, then two experimental manipulations might reveal this. Firstly, a training study design enables the manipulation of oral familiarity. Accordingly, Year 4 children received oral vocabulary training on a set of novel words (e.g. "nesh", "coib"), but received no training on a second set. Both the trained and untrained items were subsequently presented to the children in printed form, and it was at this point that the second manipulation was applied: spelling predictability. By assigning half of the items spellings that were highly predictable from their phonology (e.g., *nesh*) while the other half were assigned unpredictable spellings (e.g., *koyb*), we sought to create conditions in which the orthography of the orally trained novel items was either in line with children's likely expectation (predictable) or incongruent with it (unpredictable). To index the children's online processing when first seeing the novel words in print, their eye movements were monitored as they read the words, embedded in sentences. Eye movement monitoring is a sensitive measure of dynamic reading processes in children (Blythe, 2014; Blythe & Joseph, 2011; Joseph, Nation & Liversedge, 2013), and is an ideal methodology for indexing the effects of training on aspects of word representation (Taylor & Perfetti, 2016).

Based on the orthographic skeleton hypothesis, we predicted an interaction between oral vocabulary training and spelling predictability in eye movement indices of looking time, with the children showing a larger effect of spelling predictability for those items that had been orally trained. The logic for this was as follows: if children generate orthographic skeletons for orally familiar words, when a trained item is shown in print with a predictable spelling, the match between the child's orthographic skeleton and the presented orthography should facilitate processing. In contrast, when a trained item with an unpredictable spelling is presented, a mismatch would occur between the orthographic skeleton and the presented orthography, creating a "surprise" that takes time to resolve. Since no orthographic skeletons are created for untrained items, the effect of spelling predictability should be smaller or non-existent, reflecting only any baseline difference in processing time between the more common spelling patterns of the predictable words and the more unusual patterns of the unpredictable words.

Orthographic expectations, should they exist, might be expected to exert a very early effect on lexical processing. As such, the interaction between oral vocabulary training and spelling predictability was anticipated for eye movement measures thought to reflect the operation of initial lexical identification processes; namely first fixation duration and gaze duration (Rayner & Liversedge, 2011). Persistence of the interaction on the later processing measure of total reading time, which reflects the sum of all fixations on a target word including any time spent rereading, was also anticipated. Expectations regarding the probability of rereading were different: consistent with findings showing that novel words are associated with a greater likelihood of rereading (Chaffin, Morris & Seely, 2001), we anticipated that untrained items would be more likely to be refixated than trained items. Because all the items were phonologically decodable, irrespective of the predictability of their spellings, we did not anticipate an effect of spelling predictability or an interaction with training.

Because the orthographic skeleton hypothesis proposes that children draw on their knowledge of sound-letter mappings to form expectations of the spellings of orally known words, we reasoned that children with a higher level of reading and language proficiency would be more capable of forming robust orthographic expectations of orally trained items than children with a lower proficiency level. This in turn would lead them to be more surprised when shown an unexpected orthographic form for an orally familiar word than children with weaker orthographic expectations. Therefore, we hypothesised that there would be a positive correlation between children's level of reading and language proficiency, particularly their ability to convert novel phonology into orthography (as indexed by nonword spelling) and the size of spelling predictability effect, with more able children showing a larger effect of spelling predictability than their less able peers.

Method

Participants

Participants were 36 Year 4 children from two parallel classes at a primary school in the metropolitan region of Sydney, Australia (N = 18 in each group; 17 female; mean age:10y;1m; range: 9y;2m -10y;11m). No child who returned a consent form was excluded. Children of this age were selected because they were expected to have well-developed knowledge of the mappings between sounds and letters (such that they would be capable of forming orthographic skeletons) and to be at the stage where they were rapidly acquiring orthographic representations through instruction and independent reading. The sample size was informed by previous investigations of orthographic learning (e.g., Wang et al., 2011; Share, 2004). Moreover, we employed inferential statistics (linear mixed-effects models) that are recognized to reduce error variance, and thereby increase power, as a consequence of treating both participants and items as random effects (Baayen et al., 2008).

Standardized tests

Standardized measures of reading, spelling, and oral vocabulary were administered to characterise the sample, and so that associations with the eye movement indices could be examined. Regular, irregular and nonword reading were assessed with the Castles and Coltheart 2 (CC2; Castles, Coltheart, Larsen, Jones, Saunders & McArthur, 2010), word and nonword spelling with the Diagnostic Spelling Test (DiST; Kohnen, Colenbrander, Krajenbrink & Nickels, 2015) and oral vocabulary with the Naming subtest from the Assessment of Comprehension and Expression 6-11 (ACE 6-11; Adams, Cooke, Crutchley, Hesketh & Reeves, 2001). Summary data are presented in Table 1 and show that mean performance was within the average range across all measures.

Insert Table 1 about here

Experimental materials

Two sets of 16 three-phoneme monosyllabic nonwords, matched for consonant/vowel structure, were constructed. Half of the items in each set were assigned spellings that contained frequent phoneme to grapheme mappings and thus were highly predictable from their phonology (e.g. “f” for /f/). The other half were assigned spellings that were unpredictable due to containing less frequent mappings (e.g. ‘ph’ for /f/). The spelling predictability manipulation was confirmed through pilot testing on five adults and five children: When presented orally for dictation, the predictable items were spelled in the same way by all pilot participants (e.g., *nesh*, *coib*) while the unpredictable items were not spelled in that way by any participant (e.g., *veme, koyb*). Despite the variation in spelling predictability, all items were regular for reading in that they could be read aloud correctly using the most common grapheme to phoneme correspondences. The strong spelling predictability manipulation meant that the predictable and unpredictable items could not be matched for number of letters (varying from 3 – 5 letters) or bigram frequency, although items were matched on these properties across the two training sets. The full item sets appear in Appendix A.

Procedure

Oral Vocabulary Training. Each group was trained on one set of 16 novel words, with the other set constituting their untrained items and the sets being counterbalanced across groups. The children were told that they would be learning about "Professor Parsnip's Inventions" (procedure following Wang, Castles, Nickels & Nation, 2011; additional inventions from Mimeau, Ricketts & Deacon, in preparation) and engaged in a range of activities to learn about the names of the inventions as well as their function and two perceptual features. For example they learned that a "nesh" is "used to shuffle cards" and "is made of metal and has two hands". Each invention was paired with a picture demonstrating its features, such as shown in Figure 2. The written form of the words was never shown.

Insert Figure 2 about here

Training took place in four 20-minute sessions over four days, with eight items (four from each spelling predictability condition) being introduced in the first session and the remaining eight in the second session. If a child was absent, a catch-up session was provided. A detailed description of the training protocol is provided in the Supporting Information.

After completion of training, and immediately prior to their initial orthographic exposure (see below), the children's oral vocabulary learning was assessed with a picture-naming task. They were individually shown the pictures of the inventions one at a time and asked if they remembered what the invention was called and what it was used for. Accuracy was recorded but, to ensure that the number of phonological exposures to the novel words was controlled, feedback was given regardless of accuracy.

Initial Orthographic Exposure. The children were exposed to the words in written form for the first time between one and four days after their final oral vocabulary training session, with the mean delay being equivalent across groups, $t(34) = -1.017$, $p = .316$ (group 1: $M = 1.89$, $SD = .900$; group 2: $M = 2.22$, $SD = 1.060$). They silently read interleaved sentences referring to the 16 inventions they had learned about and the 16 inventions learned by the other group. There were also an additional four pairs of filler sentences that included novel words not learned by either group. The carrier sentences were designed to be contextually rich, such that as the children read them, they would expect to see the word they had learned about during oral vocabulary training, if they had been trained on that item. For example, *Nick picked up the cards and put them into the nesh to shuffle them*. All experimental sentences can be found in Appendix B.

The children's eye movements were recorded using a remote Eyelink 1000 eye tracker (SR Research; Mississauga, Canada) sampling at 500 Hz as they read the sentences on a computer monitor at a viewing distance of approximately 70cm. Each character covered 0.36˚ of horizontal visual angle. Sentences were presented in black, Courier New font on a white background. Participants read binocularly but only the movements of the right eye were monitored. An initial calibration of the eye tracker was performed, followed by three practice trials, and then the experimental sentences. The experimenter triggered the beginning and end of each trial after the children looked at a fixation cross to indicate their readiness. To promote attention to task, they were required to answer a (yes/no) question after each trial.

Eye movement dependent variables were: first fixation duration (the duration of the initial fixation on the target word); gaze duration (the sum of all fixations made on the target word before the eyes move past the target to a subsequent word within the sentence); total reading time (the sum of all fixations on the target word, including any regressions back to it); and regressions in (the probability of making a regression back to the target word from a later portion in the sentence).

Results

Oral Vocabulary Learning: Picture Naming

Children were able to name a mean of 10.67 out of 16 words of the pictures of the orally trained nonwords (*SD* = 4.13), with no differences between those subsequently assigned predictable or unpredictable spellings, $t(35) = .236$, $p = .815$ (predictable: *M* = 5.36, *SD* = 1.93; unpredictable: *M* = 5.31, *SD* = 2.41). In addition, the difference in the number of items learned by children in each group (group 1: $M = 10.78$, $SD = 3.49$; group 2: $M = 10.56$, $SD = 4.79$) was not significant, $t(34) = .159$, $p = .875$.

Orthographic Exposure: Eye movements

The eye movement data were analysed in the R computing environment (R Development Core Team, 2015), using the package lme4 (Bates, Maechler, & Bolker, 2013) and employing linear mixed-effects models (Baayen, 2008; Jaeger, 2008; Quene & van den Bergh, 2008). Following Baayen (2008), to normalize the distributions of residuals, reading time data were log transformed prior to analysis.

Separate models were run for each dependent variable: first fixation duration; gaze duration; total reading time; and regressions in. Models were Gaussian with the exception of the model for the probability of rereading, which was logistic. All data were checked to ensure that no participant skipped either the target interest area, or the text preceding or following the target. If any interest area (target, pre-target or post-target) was skipped, the trial was removed for the analysis (5.1% of trials removed). Arithmetic means and standard error values of the four target word dependent variables are depicted in Figure 3.

The area of interest was the name of an invention (target word). Fixed effects included training (trained vs. untrained), spelling predictability (predictable vs. unpredictable) and their interaction. Group (group 1 vs. group 2) was included as a fixed covariate. Random factors were participants and items. A data driven approach to model selection was employed in view of findings suggesting that this offers the best balance of protection against Type 1 error and power (Matuschek, Kliegl, Vasishth, Baayen & Bates, 2015; see also Perez, Joseph, Bajo & Nation, 2015; Zuur, Ieno, Walker, Saveliev & Smith, 2009). Briefly, the full fixed structure was kept initially along with random intercepts for participants and items to take into account the possibility that both could have different baseline levels of performance. Next, the optimal random slopes structure was found using data driven model comparison with a forward-selection heuristic (see Supporting Information). For each analysis the *t* or *z* statistic is reported. When a model produced one or more significant fixed effects, *p* values were obtained using *lsmeans* (Lenth, 2016). When a significant interaction was identified the testInteractions function from the phia package (De Rosario-Martinez, 2015) was used to compute contrasts. Mean and standard error values for significant model predictions are reported in the Supporting Information, with time data back-transformed from log fixation durations for display in ms using *predictSE.SR* (Robidoux, S., 2017).

All three dependent measures reflecting looking time produced the same pattern of results: a fixed effect of vocabulary training such that trained items were fixated for shorter periods than untrained items (first fixation duration: β = -0.101, *SE* = 0.036, *t* = -2.797, *p* = 0.011; gaze duration: β = -0.106, *SE* = .032, *t* = -3.314, *p* = .001; total reading time: β = -0.250, *SE* = 0.059, *t* = -4.203, *p* < .001); a fixed effect of spelling predictability such that items with predictable spellings were fixated for shorter periods than unpredictable spellings (first fixation duration: β = -0.211, *SE* = 0.063 , *t* = -3.340, *p* = 0.007; gaze duration: β = -0.348, *SE* = 0.062, *t* = -5.624, *p* < .001; total reading time: β = -0.419, *SE* = 0.064, *t* = -6.572, *p* < .001); and critically, an interaction between the two factors such that the effect of spelling predictability was larger for orally familiar than unfamiliar items (first fixation duration: β = -0.085, *SE* = 0.036 , *t* = -2.348, *p* = .0191; gaze duration: β = -0.126 , *SE* = 0.032, *t* = -3.967, *p* < .001; total reading time: β = -0.186, *SE* = 0.047, *t* =-3.979, *p* < .001).

Interaction contrasts showed that items with predictable spellings benefited from training (first fixation duration: χ^2 = 13.001, p <.001; gaze duration: χ^2 = 26.046, p <.001; total reading time: χ^2 = 33.257, p <.001) whereas items with unpredictable spellings did not (first fixation duration: χ^2 = 0.103, p =.749; gaze duration: χ^2 = 0.217, p =.642; total reading time: χ^2 = 0.732, p =.392). The effect of spelling predictability was present for items that had received oral training (first fixation duration: χ^2 = 16.525, p <.001; gaze duration: χ^2 = 46.467, p <.001; total reading time: χ^2 = 53.346, p <.001). For items that had not received oral training, the effect of spelling predictability was marginal for first fixation (χ^2 = 2.997, p =.083) and significant on both other measures (gaze duration: χ^2 = 10.127, p = .001; total reading time: χ^2 = 9.691, p = .002).

For regressions in, the model showed an effect of training (β = -0.604 , *SE* = 0.143*, z* = 4.237, *p* < .001) such that children were more likely to return to the target word if they had not been trained in its phonology and semantics. There was no main effect of predictability, and no interaction between training and predictability.

Insert Figure 3 about here

Relationship between the spelling predictability effect and standardized reading and language measures

We conducted exploratory by-participant Pearson product-moment correlational analyses to investigate the relationship between children's raw scores on standardized assessments of vocabulary, reading, and spelling and the size of their spelling predictability effect [(trained unpredictable/trained predictable)-(untrained unpredictable/untrained predictable)]; see Table 2). Correlations with vocabulary were not significant for the early processing measures of first fixation duration and gaze duration, but the correlation with the later processing measure of total reading time was significant. Correlations with reading were significant or approaching significance across all eye movement measures. Correlations with spelling were significant or approaching significance for early processing measures, but not for the later measure of total reading time. The overall pattern suggests that reading, spelling and language skills are positively correlated with the effect of spelling predictability. However, these exploratory results should be read with some caution. When correcting for multiple comparisons (using the Holm-Bonferroni method with a family-wise error rate of

.05), only the largest correlation (between nonword reading and first fixation duration) remains significant.

Insert Table 2 about here

Discussion

This experiment provides the first direct evidence that children generate initial orthographic representations of words present in their oral vocabulary prior to seeing them in print. When Year 4 children were taught novel words in oral form, they responded differently to those words on first encountering them in print depending on whether their spellings were predictable or not from their sound: they spent less time looking at the words whose spellings were predictable, consistent with the idea that these spellings matched their expectations. Importantly, this effect was much less pronounced when the children had not previously received oral training on them, ruling out an account based simply on differences in the orthographic complexity of the predictable versus unpredictable words. This interaction between training and spelling predictability, providing key evidence for our *orthographic skeleton* hypothesis, was consistently observed across the early processing measures of first fixation duration and gaze duration, and the later measure of total reading time. Further support for the hypothesis comes from correlational analyses revealing that children with relatively stronger language and literacy skills, including phonological decoding, tended to experience a greater spelling predictability effect than those with weaker skills.

These findings have important implications for theories of reading acquisition, providing evidence for a plausible but little-explored mechanism by which oral vocabulary may influence written word learning. Theories of orthographic learning such as the self-teaching (Share, 1995) and lexical quality (Perfetti, 1992) hypotheses, presume that oral vocabulary knowledge exerts an effect that commences at the point of exposure to the printed form of a word. Our findings build on these accounts to suggest that oral vocabulary knowledge may further confer an advantage prior to initial visual exposure, via a mechanism that explicitly allows for a flow of information from phonology to orthography.

More broadly, and in line with previous work that has shown an accuracy advantage for reading orally known words over unfamiliar words (McKague, et al., 2001; Nation & Cocksey, 2009; Duff & Hulme, 2012), we found that training in a word's sound and meaning was associated with a general processing advantage across all eye movement measures, and with a reduced likelihood of rereading. These findings are compatible with the view that oral vocabulary knowledge benefits reading at an item level (McKague et al., 2001; Nation & Cocksey, 2009; Duff & Hulme, 2012); they also confirm the utility of eye movement monitoring for addressing questions about reading development (Taylor & Perfetti, 2016; Blythe & Joseph, 2011).

Much remains to be learned about how the orthographic skeleton influences ongoing orthographic learning: future studies should address the issue of its precise form and its impact on the retention and consolidation of orthographic representations in long-term memory. A further key question is whether the orthographic expectancy is stimulated by knowledge of the sound of the spoken words alone, by a combination of knowledge of the sound and meaning of words, or by semantic support provided by contextual factors. We did not seek to differentiate these alternatives in the present study, but it is important to do so to maximise the potential benefits of vocabulary knowledge for ongoing reading development.

We viewed it as critical for the initial test of the orthographic skeleton hypothesis that our manipulation of spelling predictability be as strong as possible, such that there was a high likelihood that the orthographic expectancy children generated matched the predictable items and was incongruent with the unpredictable ones. A limitation of adopting this strong manipulation was that items with predictable and unpredictable spellings, although regular for reading, could not be matched on number of letters or bigram frequency. We therefore expected to observe an effect of spelling predictability across all items, including those that had not been trained orally, and this was consistently found. Importantly though, this cannot account for the interaction we observed between oral training and spelling predictability. Future studies might nevertheless seek to replicate these findings in more closely matched stimuli.

An alternative account of our results might continue to attribute the observed interaction to the operation of processes that occur from the point of visual exposure, based on the idea that oral familiarity in combination with a more typical spelling might facilitate phonological decoding. However, we suggest that the pattern of results is more in line with the view that the interaction arises as a result of processes that operate prior to visual exposure. Under the alternative hypothesis, both predictable and unpredictable spellings would be expected to benefit from training, with possibly a larger advantage for predictable items. While the orthographic skeleton hypothesis also predicts a benefit of training when items have predictable spellings, in contrast to the alternative account, the effect of training is expected to be *reduced* when an unpredictable spelling is presented; because its incongruence with the child's orthographic expectation is surprising to them. Consistent with the orthographic skeleton hypothesis, interaction contrasts showed that items with predictable spellings benefitted from oral familiarity, whereas unpredictable items did not. However, further research is needed to the disentangle the complex interactions that appear to be occurring between the children's processing of phonology and orthography.

In summary, we provide the first direct evidence for a new and developmentally plausible mechanism via which vocabulary knowledge benefits reading acquisition, at least once children have some prerequisite literacy level. As well as contributing to theories of the nature of the association between oral vocabulary and reading, it has important implications for practice in the teaching of reading. Our findings clearly support the inclusion of oral vocabulary instruction as part of a comprehensive teaching program, and, with further elaboration, may provide direction as to the nature, level, and timing of this instruction.

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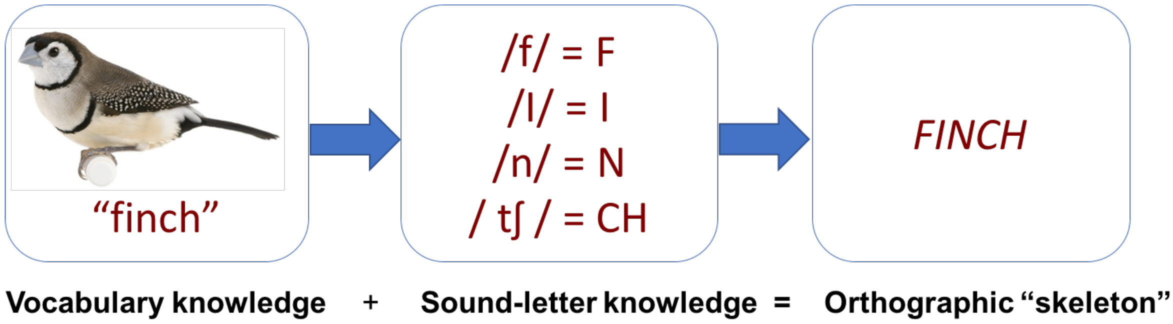

Figure 1. *The orthographic skeleton hypothesis*

Table 1

Children's performance on standardized tests of vocabulary, reading and spelling.

	M	SD	Min	Max
Oral Vocabulary (ACE)[a]	8.08	2.20	4.00	12.00
Reading aloud (CC2)				
Regular [b]	0.08	1.17	-2.03	2.99
Irregular [b]	-0.02	0.85	-1.82	1.14
Nonwords [b]	-0.42	0.82	-2.27	2.03
Spelling (DiST)				
Nonwords [c]	-0.54	0.82	-2.00	2.00
Irregular [c]	0.00	0.64	-1.20	1.58

Note: ACE, Assessment of Comprehension and Expression 6-11; CC2, *Castles & Coltheart 2;* DiST*, Diagnostic Spelling Test.* [a] *Age scaled score (M = 10, SD = 3);* [b] *Age-based z scores (M = 0, SD = 1);* [c] *Grade-based z scores (M = 0, SD = 1)*

Figure 2. Sample picture: A “nesh” which is used to shuffle cards.

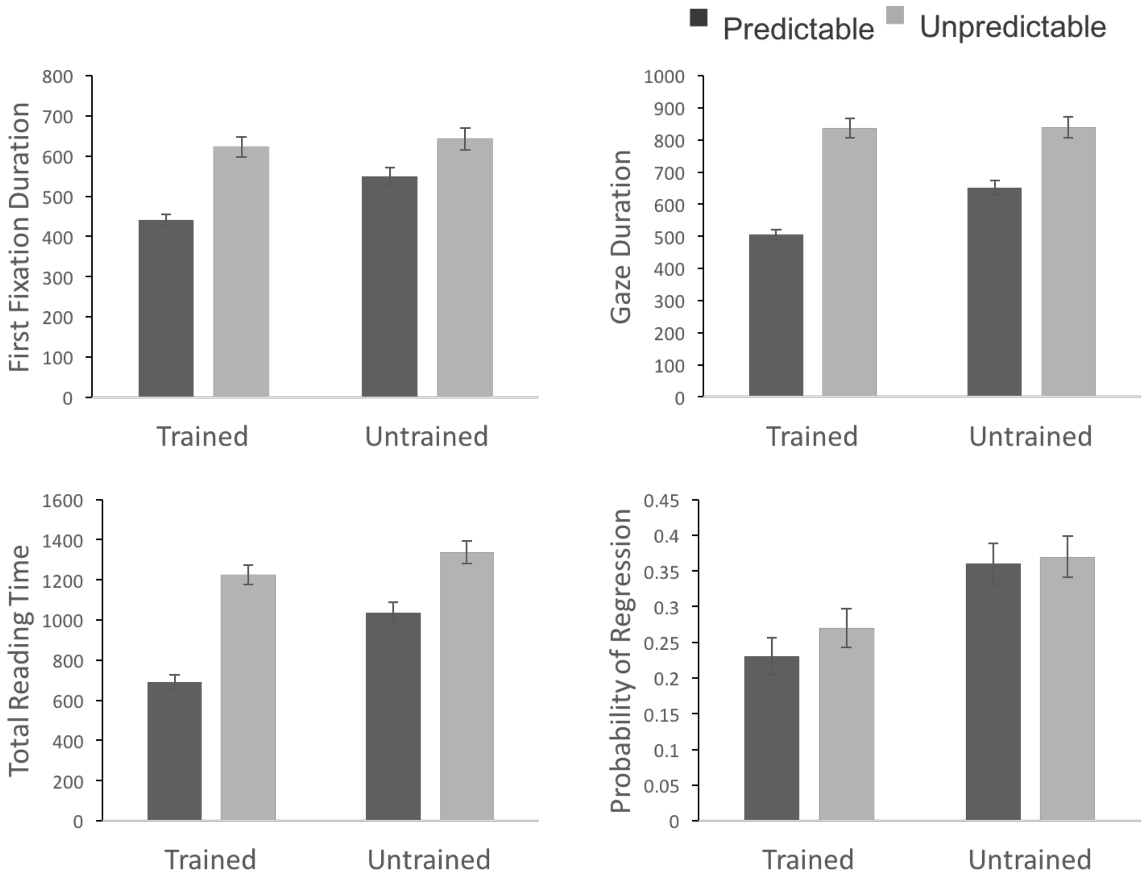

Figure 3. *Arithmetic (untransformed) means and standard errors of eye movements in the target word interest area. First fixation duration, gaze duration and total reading time are all expressed in milliseconds. Probability of regressions reflect the likelihood of occurrence.*

Table 2

Correlations between the spelling predictability effect and vocabulary, reading and spelling ability

	First Fixation	Gaze Duration	Total Reading Time
Vocabulary (ACE)	0.25	0.24	0.36*
Nonword Reading (CC2)	0.53**	0.43**	0.42*
Irregular Word Reading (CC2)	0.41*	0.40*	0.29^{+}
Nonword Spelling (DISTn)	0.33^{+}	0.28^{+}	0.21
Irregular Word Spelling (DISTi)	0.36*	0.37*	0.24

$^{+}$*p<.10, *p<.05, **p<.01 (uncorrected)*

Appendix A

Experimental target words

	Set 1		Set 2	
	Phonology	Orthography	Phonology	Orthography
Predictable	/dʒev/	jev	/tem/	tem
Items	/jæg/	yag	/nId/	nid
	/vIb/	vib	/dʒIt/	jit
	/tʌp/	tup	/jæb/	yab
	/neʃ/	nesh	/vIʃ/	vish
	/tʃɒb/	chob	/ʃep/	shep
	/ʃʌg/	shug	/θɒg/	thog
	/θʌb/	thub	/tʃIg/	chig
Unpredictable	/viːm/	veme	/juːn/	yune
Items	/baɪp/	bype	/kaɪv/	kyve
	/jɜːp/	yirp	/bɜːv/	birv
	/kɔɪb/	koyb	/dʒaɪf/	jayf
	/dʒiːb/	jeabb	/miːf/	meaph
	/fɜːf/	phirf	/gʌz/	ghuzz
	/gæk/	ghakk	/feg/	phegg
	/mɜːb/	mirbe	/veɪp/	vaype

Appendix B

Experimental sentences

	Set 1	Set 2
1.	Rick put his dirty socks into the jev to clean them.	Rick put his dirty socks into the tem to clean them.
2.	Diana put the best orange on the veme to juice it.	Diana put the best orange on the yune to juice it.
3.	Pam put the dirty flowers under the yag to polish them.	Pam put the dirty flowers under the nid to polish them.
4.	Max put his food in the bype to remove the peas.	Max put his food in the kyve to remove the peas.
5.	Sara put her soaking wet hat on the vib to dry it.	Sara put her soaking wet hat on the jit to dry it.
6.	Lucy loaded the rubbish into the yirp to sort it for recycling.	Lucy loaded the rubbish into the birv to sort it for recycling.
7.	Lucas put his sore tummy beside the tup and he felt better.	Lucas put his sore tummy beside the yab and he felt better.
8.	Jennifer put her soggy chips under the koyb to make them crispy.	Jennifer put her soggy chips under the jayf to make them crispy.
9.	Nick put the deck of playing cards into the nesh to shuffle them.	Nick put the deck of playing cards into the vish to shuffle them.
10.	Rex put the tennis ball back into the jeabb to keep playing fetch.	Rex put the tennis ball back into the meaph to keep playing fetch.
11.	James put the girl's picture into the chob to find out her name.	James put the girl's picture into the shep to find out her name.
12.	Jane put her cold and sore feet into the phirf to warm them.	Jane put her cold and sore feet into the ghuzz to warm them.
13.	Matt put his feet into the shug so he could climb up the wall.	Matt put his feet into the thog so he could climb up the wall.
14.	Sam waited for the birds to land on the ghakk to hear them sing.	Sam waited for the birds to land on the phegg to hear them sing.
15.	Ben picked up the fish tank and the thub to clean the dirty glass.	Ben picked up the fish tank and the chig to clean the dirty glass.
16.	Pip waited while the brushes on the mirbe removed the sand from his body.	Pip waited while the brushes on the vaype removed the sand from his body.