Oral Vocabulary and Reading New Words:

Examining the Mispronunciation Correction Process

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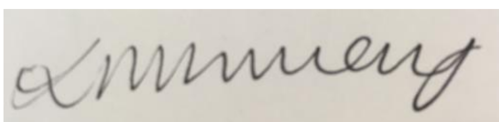
Summary

The irregularity of many words in English (e.g., *yacht*) can present problems for developing readers as they encounter new printed words. It is thought that when children cannot decode words easily, they use their oral vocabulary to help adjust a mispronounced word and that they may draw on other sources, such as sentence context, to assist. This thesis reviewed the literature on connections between oral vocabulary and word reading and on the process of *mispronunciation correction* to examine how children adjust partially decoded words. An empirical study then sought evidence for a mispronunciation correction mechanism operating dynamically as children read novel words in text. Year 5 children were orally trained on a set of novel words and then read them silently in sentences. Oral familiarity, regularity, and context were manipulated and children's eye movements were monitored. The findings revealed that when children see orally known words for the first time in text, irregular words undergo additional processing compared to regular words, and are subsequently read aloud more accurately compared to untrained irregular words. These results are consistent with a mispronunciation correction mechanism being applied as children read novel words.

Statement of Originality

I, Lyndall Murray, certify that this thesis titled “Oral Vocabulary and Novel Word Reading” is an original piece of research that has been written by me and is entirely my own work except where I have given full documented references to the work of others. All the help and assistance that I have received in the preparation of this thesis has been properly acknowledged. The materials of this thesis have not previously been submitted for a higher degree or as part of requirements for a degree to any university or institution. In addition, I certify that all information sources and literature used are indicated in the thesis. This project was approved by the Macquarie University Human Ethics Committee, reference number: **5201500098**



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Chapter 1

Oral Vocabulary and Novel Word Reading:

A Literature Review

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Abstract

The purpose of this literature review is twofold. The first aim is to summarise the current research that explains how readers learn to associate novel words they see in print with words in their oral vocabulary. A second aim is to explore what is known about how children resolve discrepancies for words that are represented in unexpected ways, specifically when the letters or letter strings corresponding to sounds in the word are atypical. This process is thought to be particularly important for children learning to read in orthographically inconsistent languages such as English (Venezky, 1999), although some researchers believe it influences learning in all languages (Elbro, de Jong, Houter, & Nielsen, 2012). One mechanism for this process, termed *mispronunciation correction*, will be reviewed whereby children adjust sounds in written words until they make a match with one they know orally. Correlational evidence and training studies that teach mispronunciation correction as a strategy to read orally familiar words are considered. Finally, future directions for this area of research are suggested.

The fundamental task faced by the child learning to read is to link the printed form of words with knowledge about those words' pronunciations and meanings (Castles, Rastle, & Nation, 2018). For readers learning alphabetic languages, the ability to match letters or letter strings (graphemes) to their correct sounds (phonemes), known as *phonological decoding*, is an essential skill that underpins children's ability to make these links (e.g., Share, 1995, 1999). Children learn that graphemes link to phonemes, that the phonemes can be blended to make intelligible words, and that the blended result can be matched with a word stored in their lexical memory (Venezky, 1999).

However, children learning to read in languages such as English face additional complexities when learning to link printed words with their spoken form and meaning, over and above children learning to read in many other alphabetic languages (e.g., Seymour, Aro, & Erskine, 2003; Ziegler et al., 2010; Ziegler & Goswami, 2005). This is because English is considered to have an inconsistent orthography due to the complexities in the relationships between graphemes and phonemes (e.g., Venezky, 1999). When children are decoding words in English it is common to produce a blended unit that does not sound like a real word. This is because individual graphemes can match to several sounds; for example, in English the grapheme *a* has divergent pronunciations in words such as b*a*by, c*a*t, wh*a*t, f*a*st and zebr*a*. When children phonologically decode novel words by applying standard grapheme-phoneme mappings, they therefore will often face a challenge in linking the output of their decoding with that word's correct pronunciation and meaning.

Children's success in overcoming this challenge is likely to be integrally linked with their oral vocabulary knowledge. Several studies have demonstrated clear associations between oral vocabulary and success in word reading (Nation & Cocksey, 2009; Ricketts, Nation, & Bishop, 2007), and children with vocabulary impairments are more likely to struggle when learning to read (e.g., Nation & Snowling, 1998; Oullette, 2006). As well, experimental training studies have shown that, when children encounter a new word in print, they are more likely to read it accurately and they will recognise it more quickly when it is already part of their oral vocabulary (McKague, Pratt, & Johnston, 2001). One theory is that oral vocabulary is important to accurate reading partly because of its role in assisting children to resolve the inconsistency in conversion between graphemes and phonemes for words in English (Venezky, 1999).

The broad aim of this review is to explore what is currently known about how readers learn to associate novel words they see in print with words in their oral vocabulary. A more specific aim is to review the research on how children resolve discrepancies for words that violate typical grapheme-phoneme mappings, known as *irregular words*. It will first consider an influential theory of learning to read new words - the self-teaching hypothesis – and its limitations for accounting for the learning of irregular words. Research on the impact of word regularity on word learning will then be considered. Following this, research linking oral vocabulary with accurate word reading, and interactions with regularity, will be outlined. Correlational and intervention studies that have looked in detail at the process of *mispronunciation correction* will then be examined. Lastly, the review will consider gaps in the current literature and suggest ways that these might be addressed.

1. The self-teaching hypothesis

A skilled adult reader can effortlessly recognise between 50,000 and 100,000 individual words within a few tenths of a second of exposure, linking these printed forms almost instantly with their pronunciations and meanings (Dehaene, 2009). If every word needed to be memorised in its entirety, the process of learning to read would be impossibly onerous. An influential theory for how children initially develop their enormous repositories of orthographic knowledge is the self-teaching hypothesis (Jorm & Share, 1983; Share, 1995). This theory proposes that children start reading through a process of phonological decoding, whereby they translate words on a page into spoken form.

Share (2008) proposed that phonological decoding is the key foundation of word learning as it allows children to link the printed form of a word with one in their oral vocabulary. The outcome is that children "self-teach" new words independently over time and through experience as they engage in the phonological decoding process. In one study, Share (1999) tested this idea with second grade Hebrew reading children (Share, 1999). The children were asked to learn novel words presented in short stories (e.g., ''Yait is the hottest town in the world''). In subsequent testing, the children were more likely to choose the target words (e.g., *yait*) than to choose distractors that were spelled differently but with the same pronunciation (e.g., *yate*) or words that looked similar (visual distractors, e.g., *yoit*, *yoyt*).

Self-teaching seems to operate for children reading consistent languages but the process in inconsistent languages is likely to be impeded (Share, 2008). For children learning to read in these languages, additional support may be needed to make the link from a partially successfully decoded written word to one that they know orally. Share (2004) posited that for developing readers, and especially for those decoding irregular words, the sentence context in which it appears may confer an advantage for reading accuracy. A study of English speaking children found that, similar to children reading in consistent languages, self-teaching is evident as early as Year 1 (Cunningham, 2006). Notably, the study manipulated the context in which target words appeared. Cunningham found that when the word appeared in a facilitative context, their accuracy for the target word was increased, supporting Share's (2004) suggestion that context was important for readers of inconsistent languages.

Share (1999) established that when beginning readers encounter new words, they go through a process of phonological recoding by matching the letters and letter combinations of the letter string to a word in their oral vocabulary. Share (1999) also provided evidence to suggest that becoming a proficient reader involves an element of self-teaching in that children develop an orthographic representation of words over time and through experience. However, this research largely concentrated on the reading of regular words and this left open questions for researchers interested in how children learn words with irregular letter to sound correspondences. For example, words like *yacht* cannot be read by directly mapping the letters to the most likely sounds. Researchers have since questioned whether phonological decoding can account for all word learning (e.g., Cunningham, 2006) and Share (2008) acknowledges that there are still several research questions awaiting investigation.

2. Word regularity and learning to read new words

Share's (1995) self-teaching hypothesis accounts for word learning across languages with varying orthographic consistency. However, according to this hypothesis it should be harder for children to undertake the phonological decoding process when words are irregular than it is when words are regular. Thus, the hypothesis might predict that learning to read new words should be most efficient in languages with consistent orthographies. Indeed, it seems that children learning to read languages such as English may need twice the amount of time to acquire word reading and phonological decoding skills to the same extent as their peers reading in consistent orthographies (Seymour, Aro, & Erskine, 2003). An alternative view is that inconsistent orthographies necessitate greater attendance to graphemes for early readers when compared to those learning to read a consistent orthography and that this might confer some advantage for accurate word identification (e.g., Ehri & Saltmarsh, 1995; Thompson, Fletcher-Flinn, & Cottrell, 1999) than for children learning to read in more consistent orthographies (see Share, 1999).

Wang, Castles, and Nickels (2012) directly tested the prediction that word regularity would influence the learning of new orthographic representations. Wang et al. (2012) orally taught Year 2 children the phonology and meaning of a set of novel words. They later introduced the words in written stories with half of the words given a regular, predictable spelling. For example, during training children learned the word /fɜːb/ and during testing saw it spelled *ferb*. Another set of words had an irregular, unpredictable spelling, for example, children learned the word /kleɪp/ during training and then saw the word *cleap*. Following orthographic exposure, children's learning of the words was assessed through a spelling test and an orthographic decision task, where they were required to identify the correct orthographic form from distractors were phonologically or visually similar to the target. There was a significant effect of regularity, with words that were spelled regularly being correctly identified more often than words with irregular spellings. Furthermore, the regular words were more likely to be spelled correctly than the irregular words.

In summary, the evidence suggests that the regularity of words does indeed influence the process of establishing orthographic representations, and making links between those representations and the words' pronunciations and meanings. Specifically, irregular words present a particular challenge to children learning to read in inconsistent orthographies such as English. In the next section we examine research which has explored the interaction between oral vocabulary knowledge and children's success in learning new regular and irregular words

3. Oral Vocabulary and learning to read new words

As discussed, strong evidence suggests that children's word reading skill is related to their oral vocabulary (Nation & Snowling, 1998; Oullete, 2006). There are a range of possibilities as to what may underlie this general association. The correlation may occur because having a good vocabulary helps develop phonological awareness skills, which children later use to build better orthographic representations of written words (Ricketts, Nation, & Bishop, 2007). An additional possibility, particularly relevant in the present context, is that the correlation between oral vocabulary and word reading is due to the need to adjust incorrect pronunciations of written words. This second theory would predict a stronger association between oral vocabulary and the reading of irregular words than of regular words.

Nation and Snowling (2004) were interested in exploring these questions. They used a correlational design and tested children on a wide range of reading measures and oral language skills. They used tests that tapped children's spoken, or expressive, language, their language understanding, or receptive language and also on their understanding of word meanings. When tested at age eight, all three measures of oral language explained significant amounts of the unique variance in children's general reading skills. The children were tested five years later and it was found that language ability at age eight accounted for a significant portion of the variance in general word recognition at age 13. Notably, there was a strong relationship between irregular word reading and language, in that children's langauge skills at eight predicted a significant amount of the variance in irrregular, but not regular, words. Thus, Nation and Snowling's findings support the theory that having an extensive oral vocabulary may confer a particular advantage when reading irregular words.

Ricketts et al. (2007) sought to further explore which word reading skills are predicted by oral vocabulary. They tested eight- and nine-year-old children on a range of reading and vocabulary measures and conducted regression analyses to determine the unique variance across the range of reading related skills that could be predicted by vocabulary. They found that vocabulary predicted some aspects of word recognition but not others. There was no relationship between vocabulary and regular word reading but vocabulary accounted for unique variance in irregular word reading. Rickets et al. suggest that one reason for this association could be that word meanings directly influence word recognition. For example, a child might read the word *blood* and decode it using the most likely conversion of graphemes to phonemes as /bluːd/. Children with good vocabulary knowledge have an advantage over children with poor vocabulary as they suspect that this word may not exist. They are then able to recall the proximate word *blood* and substitute it into the text. Rickets et al. findings were important in suggesting that the correlation between vocabulary and word reading does not simply occur because having a good vocabulary helps develop phonological awareness skills.

Nation and Cocksey (2009) looked at different aspects of oral vocabulary in seven-year-old children to determine which were most important for accurate word reading. They used two constructs: knowledge of a word's meaning, measured through defining words; and phonological familiarity, measured using auditory lexical decisions. They also asked the children to read lists of words with irregular and regular spellings. Nation and Cocksey found that when children saw a previously known word, as indexed through lexical decision and performance on the definitions task, they were two to three times more likely to read the word correctly compared to words that they did not know. Further, the association between word knowledge and reading was significantly stronger for irregular than regular words. In support of Share's self-teaching hypothesis, these findings suggest that when children have some oral familiarity with a word, they use partial decoding attempts to match the word they are seeing with its phonological match.

In an experimental training study, Wang et al. (2011) examined the effects of regularity and context on the learning of written words that had been instantiated in children's oral vocabularies. They orally taught novel words to children in Year 2, describing them as new inventions. Later the children read the words in sentences either in context or from a list. Some of the words that the children read were regular, and others were irregular. Wang et al. found that contextual facilitation for words at first reading was evident when words were irregular but not when they were regular. They suggested that this effect might arise as the irregular words were only partially decoded and the children then drew on contextual support and their oral vocabulary knowledge to help them correct the pronunciation. Wang, Nickels, Nation, and Castles (2013) further explored learning at an item level and tested whether explicitly knowing a word in oral form confers an advantage for orthographic learning. They found that, for the words that children could recall, vocabulary knowledge was a significant predictor of orthographic learning for irregular but not for regular words.

In summary, the evidence clearly points to a link between oral vocabulary and word reading, and also suggests that this association is strongest for irregularly spelled words. These findings support the proposal that having a word in oral vocabulary may assist a child to correct an imperfect phonological decoding attempt and therefore successfully link a word's printed form with its pronunciation and meaning. Further research has turned to exploring the specific mechanism of this mispronunciation correction process.

4. The process of mispronunciation correction

Venezky (1999) posited that the complexity of English orthography makes learning to read a more complex task for English reading children than for those learning through a more transparent orthography, such as Dutch or Finnish. Venezky reasoned that the purpose of explicit reading instruction for English readers was not to teach children the mapping of every grapheme to their potentially multiple phonemes and vice versa. Instead, reading instruction enables children to generate phonological representations that are close enough to the correct pronunciation to approximate a known word. Venezky coined the term *set for variability* to describe the ability to correct an initial mispronunciation when a new irregular or complex word is encountered in text. Recently, researchers have used *mispronunciation correction* (Dyson, Best, Solity, & Hulme, 2017) to describe the process of self-correcting decoding errors when reading, and this is the term that will henceforth be used in this review. One example of mispronunciation correction might be when a young child comes across an irregularly spelled word, such as *was* as he or she is reading text aloud. The child might first mispronounce the word as *wass* to rhyme with *gas*, before applying some flexibility and adjusting the pronunciation and reading the word again as *woz.* This process is illustrated in Figure 1.

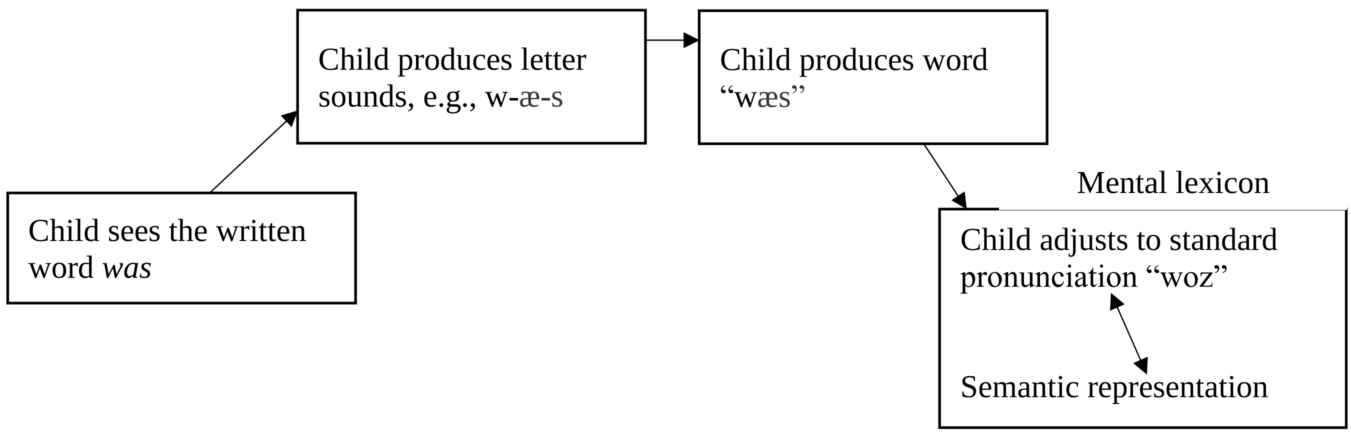

Figure 1. *The process of mispronunciation correction when reading irregular words (from Elbro & de Jong, 2017)*

4.1. Correlational studies of mispronunciation correction. Tunmer and Chapman (2012) conducted a longitudinal study over three years to explore whether vocabulary has an indirect influence on word reading accuracy through mispronunciation correction. They developed a mispronunciation correction task which addressed children’s ability to correct orally mispronounced, familiar words. For example, the word *stomach* was pronounced *stow-match*. The use of real words meant that children could adjust the sounds in a partially decoded word to one existing in their oral vocabulary. This enabled the researchers to assess children’s mispronunciation correction ability. Children at the end of Year 1 listened to words that were mispronounced by an experimenter and were asked if they could modify the pronunciation to make a real word. The study also tested children’s vocabulary, decoding of nonwords, reading of irregularly spelled words, single word reading, and reading comprehension. In line with findings that link oral vocabulary with orthographic learning, Tunmer and Chapman found that Year 1 mispronunciation correction test performance accounted for a small but significant amount of the variance in Year 3 decoding and word recognition, even once skills such as phonemic awareness and vocabulary knowledge were accounted for. They proposed that the ability to correct mispronunciations may play a key role in children's word reading development for languages with irregular orthographies, such as English. Elbro et al. (2012) expanded on Tunmer and Chapman's (2012) study by proposing that the ability to correct mispronunciations might not only be important for children learning to read exception words, but also for regular words. If this is the case, it is likely that even children learning to read in consistent languages engage in a process of mispronunciation correction when reading words. They argued that readers of regular words need to correct pronunciation to some degree because when phonemes are pronounced in words, there is always some adjustment that needs to be made, depending on the place of the grapheme within the word and the adjacent letters (Elbro et al., 2012). One example in English might be demonstrated by the sound */p/*, which is represented by *p* or *pp*. Despite being perceived as having a single, predictable pronunciation, it has different mouth movements and consequent allophonic pronunciations in *pot, spider, nipped,* and *lump*.

Elbro et al. replicated Tunmer and Chapman's (2012) study with Danish and Dutch children, as Dutch orthography is highly consistent and the regularity of Danish orthography falls between English and Dutch. They developed a similar test to the mispronunciation correction task devised by Tunmer and Chapman, using distorted versions of everyday words. For the Danish children, reading through a moderately inconsistent orthography, the ability to adjust pronunciation of spoken words was positively correlated with reading speed and accuracy. Furthermore, the skill of mispronunciation correction was found to be correlated equally with reading of regular and irregular words. For the Dutch children, the ability to correct spoken mispronunciations was also correlated with reading accuracy but not with reading speed. Although the study provides evidence that mispronunciation correction is important for readers of both inconsistent and consistent orthographies, the correlations for the Dutch and Danish children were not as robust as for the English-speaking children. These findings suggest that whilst children may need to make minor allophonic adjustments to regular words, mispronunciation correction ability is more important for irregular words.

Studies have also linked mispronunciation correction with phonological awareness. Kearns et al. (2016) looked at mispronunciation correction as an ability that encompasses semantic and phonological aspects. They suggested that readers initially produce spelling pronunciations that match the most likely letter to sound matches through a phonological process. If this does not elicit a matching word from the known lexicon, a semantic process must occur as the child produces iterative alternatives to locate a matching known word. If mispronunciation correction involves both phonological processing and semantic knowledge then they concluded, like Elbro et al. (2012), that it was a necessary process even for regular words. As such, they posited that it may be an implicit ability demonstrated by children reading in all alphabetic languages.

To test their ideas, Kearns et al. (2016) adapted and developed the mispronunciation correction test to establish its psychometric integrity. Tunmer and Chapman's (2012) original mispronunciation correction test involved contextual and non-contextual exposures to the mispronounced words. However, this raised the possibility that children were using the sentence context to correct pronunciation of words, rather than correctly identifying words through a process of semantic and phonological adjustment. Kearns et al. adapted the test to present mispronounced words in isolation and encompassed a wider age range in their sample. They looked at mispronunciation correction alongside other reading related skills in English speaking children between the ages of seven and eleven. They found that mispronunciation correction appears to be a unique reading-related skill and not merely an aspect of phonological awareness. Consistent with Tunmer and Chapman (2012) and Elbro et al. (2012), they found that mispronunciation correction accounted for a small but significant amount of the unique variance in word reading skills. They suggest, similar to Elbro et al., that these processes are not unique to the reading of irregular words but also are used with regular words.

These studies showed that mispronunciation correction skills and word reading skills are related and that the relationship is stronger for irregular words. In English, vowels tend to be more irregular than consonants, thereby producing the most uncertainty for readers (Elbro & de Jong, 2012). Evidence suggests that skilled readers use consonants that precede or follow an ambiguous vowel representation to interpret the most likely pronunciation of an unknown word (Treiman, Kessler, & Bick, 2003). For example, when asked to read the nonword *mook*, skilled readers are more likely to pronounce it /mʊk/ than /muːk/ because the letter /k/ most frequently follows the /ʊ/ phoneme in words such as book and shook. Steacy et al. (2018) investigated whether children might also use their knowledge of how surrounding consonants predict vowel sounds in words when reading nonwords. They suggested that this knowledge may relate closely to mispronunciation correction. They found that children with better phonological awareness, reading skills and mispronunciation correction abilities were most likely to pronounce nonwords using the most frequently heard vowel pronunciation based on the following consonants.

In summary, the studies reviewed thus far have suggested that mispronunciation correction is a skill that is developed by children reading in alphabetic languages, that it involves semantic and phonological skills, that it appears to predict unique variance in word reading, and that word regularity factors in to its use. However, these studies are primarily correlational, leaving open whether mispronunciation correction can be trained and, if so, whether improvements in mispronunciation correction can improve irregular word reading.

4.2 Training studies of mispronunciation correction. Evidence from correlational studies suggest that the ability to correct mispronunciations in words is important for accurate word reading. However, the gold standard for understanding causation in observed behaviour is through experimental paradigms, which include training studies (Hulme & Snowling, 2013). There have been three training studies that have involved explicit teaching of mispronunciation correction. Two short-term training studies have demonstrated that teaching children to use mispronunciation correction can lead to improved word reading accuracy (Dyson, Best, Solity, & Hulme, 2017; Zipke, 2016).

Zipke (2016) suggested that mispronunciation correction might be a strategy that could be explicitly taught to beginning readers. She posited that if children were taught to alter sounds in mispronounced words, then it should generalise to overall word reading accuracy. Zipke trained 15 first and second graders with delayed reading skills to correct pronunciation of irregularly spelled words over five lessons of 20 to 25 minutes. A matched group of 15 children was allocated to a control group which involved five lessons of 20 to 25 minutes, during which time they practiced reading aloud. Pre-test and post-test measures included tests of word reading and irregular word reading, and the number of self-correction attempts was also recorded. Zipke found that children in the training group made more attempts to read irregularly spelled words compared to children in the control group, but they were not more accurate in reading the test words. Additionally, there were no differences between the groups on post-test irregular word reading tests, suggesting that the mispronunciation correction training did not generalise to non-trained words. However, the study had some methodological limitations in that it employed small sample sizes consisting of poorer readers and training was limited to around 120 minutes.

Dyson et al. (2017) attempted to overcome some of these limitations by using a larger sample of 84 children and conducting training over eight sessions. They taught five- to seven-year-old children a mispronunciation correction strategy in 20-minute sessions. The intervention involved teaching a range of strategies to correct mispronunciation, including adjusting irregular consonants, vowels and silent letters. The children then listened to a puppet incorrectly reading mispronounced irregular words and then corrected the puppet's pronunciation. Dyson et al. conducted standardised word reading and vocabulary tests alongside a mispronunciation correction task both pre- and post-training. They found that when compared to a no-intervention control group, trained children were better at reading the taught words following the intervention. This provides evidence for a causal link between mispronunciation correction and word reading accuracy. However, the skill did not reliably generalise to new irregular words, limiting the conclusions that can be drawn.

Zipke (2016) and Dyson et al. (2017) conducted training over relatively short periods and it may be that mispronunciation correction can be trained, but teaching over a longer time frame is required to impact word reading. Savage, Georgiou, Parrila, and Maiorino (2018) extended on these short-term training studies with a longer-term intervention taking place over six months with three 30-minute intervention sessions per week. The study also improved on some methodological weaknesses of previous studies by using a large sample of nearly 500 children, an active control group, and including a delayed post-test to ascertain if any learning was sustained beyond the intervention. In the study, one group accessed a synthetic phonics scheme alongside explicit teaching of a mispronunciation correction strategy. Children were taught to adjust pronunciation of vowels in irregular words that were introduced in authentic texts. A second group accessed a program that was similar in all ways, except that mispronunciation correction was not a taught strategy, and authentic texts were not matched to taught exception words. The intervention resulted in significant reading, spelling and comprehension advantages for the mispronunciation correction group over the phonics-only control group, suggesting that mispronunciation correction training was an effective learning strategy when implemented over an extended period. Furthermore, these advantages were maintained for six months at delayed post-test. This is an important outcome because it suggests that mispronunciation correction can lead to gains in word reading accuracy. It therefore seems appropriate to explicitly incorporate the teaching of mispronunciation correction techniques into early reading programs. However, teaching children to correct mispronunciations only leads to general word reading improvements when it is implemented over an extended period of time.

5. Summary and Future Directions

Several conclusions regarding the role of vocabulary in children's word reading can be drawn based on the literature reviewed here. Evidence suggests that vocabulary plays an especial role in accurate word reading when words are irregular. Additionally, children use contextual facilitation to read new irregular words accurately. This allows them to bridge the gap from a partially accurate decoding to one that is correct when the word's orthography produces phonological ambiguity. There is evidence to suggest that the ability to correct initial mispronunciations of words is important for developing readers, and that it is a skill that can be trained.

Much less well-understood is the mechanism that drives mispronunciation correction and this offers opportunities for future research. To date there have been no studies that provide direct evidence of mispronunciation correction being applied as children read words they know orally but have not seen before. There are also opportunities to extend the paradigms used to investigate orthographic learning. To date, most studies have used indirect measures such as orthographic choice tasks to measure how children process new words. One disadvantage of orthographic choice is that researchers must infer processing from performance in a secondary task rather than measuring it directly (Joseph & Nation, 2018). A solution might be to use eye movement monitoring to measure word reading implicitly in real time. There are precedents for the use of eye tracking paradigms in word learning research. Joseph, Wonnacott, Forbes, and Nation (2014) used eye movements to index word learning with adult populations. They found that as participants read novel words in sentences over several sessions, they fixated on the new words for shorter times, suggesting that words were becoming more familiar over time. This effect was found even when participants were unable to recall words during a memory task, suggesting that eye movement monitoring taps implicit and partial knowledge, as opposed to measures like orthographic choice (see also Chaffin, Morris, & Seely, 2001; Elgort, Brysbaert, Stevens, & Van Assche, 2018; Lowell & Morris, 2014).

Eye movement measures are becoming increasingly prevalent as a means of measuring aspects of reading in children. (e.g., Blythe, 2014; Joseph & Nation, 2018; Wegener et al., 2018). Advances in technology mean that eye tracking is now accurate, reliable, and portable. It also allows for monitoring of reading behaviour in a relatively unobtrusive and naturalistic manner, thus allowing greater ecological validity than indirect measures such as orthographic decision tasks. Recent studies looking at eye movements to measure real-time reading behaviour in children show similar results to those seen in adults. Joseph & Nation (2018) found that as children were exposed to novel words presented in context over several sessions their fixation times decreased, indicating that the words were becoming familiar. With these findings in mind, it may be that eye movement monitoring can provide a means of observing mispronunciation correction occurring dynamically as children read. Directly observing children as they perform a mispronunciation correction may clarify the relationships that exist between oral vocabulary, word reading accuracy when regularity varies, and context. In turn, this may inform researchers on how mispronunciation correction might best be taught.

Chapter 2

Mispronunciation Correction During Novel Word Reading: An Eye Movement Study

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Abstract

It has been proposed that children may link words in their oral vocabulary with novel printed word forms through a process termed mispronunciation correction, which enables them to adjust an imperfect phonological decoding. Additional evidence suggests that sentence context may play a role in helping children to make this link. We aimed to provide evidence for a mispronunciation correction mechanism operating as children independently read novel words in sentences. Four groups of Year 5 children were orally trained on a set of novel words but received no training on a second set. Half the words were designated irregular spellings and half regular spellings. Children later read both trained and untrained words in sentences that provided a supportive or neutral context while their eye movements were monitored. Fixations on regular words were significantly shorter than on irregular words, and those on trained words were shorter than for untrained words. There was a larger regularity effect for words viewed in a supportive context compared to words viewed in contextually neutral sentences. In subsequent testing, children demonstrated a higher likelihood of reading both regular and irregular words accurately when they had been orally trained, and irregular words were read more accurately when they had previously appeared in a supportive context. These results suggest that when words are present in oral vocabulary and irregular, they undergo additional processing when viewed in text for the first time, which is consistent with the online operation of a mispronunciation correction mechanism.

Learning to read in English involves difficulties over and above that for children learning to read in many other alphabetic languages (e.g., Ziegler et al., 2010; Ziegler & Goswami, 2005). Developing readers of all alphabetic languages must learn that spoken words are composed of sounds and that these sounds systematically map to specific letters or letter combinations in written words (Castles, Rastle & Nation, 2018). Children reading in some alphabetic languages have an added burden in that this mapping of letters to sounds is not always straightforward. Consider the word *busy*. Early readers might recode the first three letters to make the word *bus*. The letter /y/ is problematic because it maps to several sounds in English, depending on its placement in the word. If the child recognises that in the end position /y/ is most likely to make an *ee* sound, then they may come up with *bussy* to rhyme with *fussy*. How then do children adjust this mispronunciation to say the word correctly? It is thought that knowing the pronunciation of the word before reading it is important and that other factors such as context may play a role in making the connection between *bussy* and *busy*. The question of how children adjust imperfect pronunciations of new words with irregular spelling patterns is explored in this study.

Oral Vocabulary and Reading New Words

Research demonstrates a link between children's vocabulary and their ability to read words (e.g., Nation & Snowling, 1998; Nation & Snowling, 2004; Oullette, 2006; Ricketts, Davies, Masterson, Stuart, & Duff, 2016; Ricketts, Nation, & Bishop, 2007). However, the precise nature of this association has yet to be clarified (Wegener et al., 2018). It seems clear that having a good oral vocabulary contributes to later word reading ability. Nation and Snowling (2004) tested a group of children at age eight and then five years later on a broad range of oral language and reading skills. They looked at children's expressive vocabulary, a measure of their spoken vocabulary; their receptive vocabulary, a measure of their understanding of spoken language; and their semantic skills, which measures understanding of word meanings. They found that the three separate measures of oral language each explained significant amounts of the unique variance in reading comprehension and word reading skills at age eight. They also found that language skills at age eight accounted for significant unique variance in word recognition at age 13. The same relationship was even stronger when Nation and Snowling considered recognition of words with an irregular spelling pattern (such as *busy*).

Ricketts et al. (2007) explored the relationship between vocabulary and irregular word reading further. They tested a group of eight- and nine-year-old children on measures of reading and oral language. They found that although oral vocabulary accounted for significant variance in reading comprehension and text reading skills, there was no significant association between oral vocabulary and word reading. However, when they looked specifically at irregular words, they found that vocabulary predicted irregular word reading but not regular word or nonword reading. Later studies have also found this relationship between vocabulary and irregular, but not regular, word reading (e.g., Nation & Cocksey, 2009).

Ricketts et al. (2007) account for the association between vocabulary and irregular word reading by suggesting that semantic factors are particularly important for irregular words. Children with strong vocabulary skills may be better able to resolve inconsistent mappings between written and spoken word forms because their oral language allows them to use context more proficiently than children with poor vocabulary skills (Nation & Snowling, 2004). The self-teaching hypothesis (Share, 1995) proposes that word reading skills are largely developed through experience as children learn to sound out new words. As children encounter words that are difficult to decode solely using letter to sound knowledge, they need to draw on their vocabulary to map a partially, or incorrectly, decoded word to one that exists within the oral lexicon. Children with strong oral language skills are thus advantaged as they are likely to recognise that their decoding attempt has resulted in something that is not a real word. They can then adjust some elements of the word's phonology to produce an item that they recognise from their oral lexicon as being appropriate (Elbro & de Jong, 2017).

Contextual Facilitation in Irregular Word Reading

The adjustment in pronunciation that is necessary for reading irregular words is a particular problem for early readers who have yet to encounter many words in text that they know orally. The process of moving from the methodical, letter-by-letter decoding strategies used by beginning readers to the rapid recognition of words for skilled readers is known as orthographic learning (Castles & Nation, 2006). Irregular words might be substantial stumbling blocks to successful orthographic learning by young readers. Wang, Castles, Nickels, and Nation (2011) posited that if children can only partially decode a word, then they might need to draw on other factors, such as the sentence context in which the word appears. This might be of greater importance for irregular words that cannot easily be read through decoding.

One way to test this idea is through using nonwords, pronounceable novel items such as "cleap" or "vack", because researchers can be assured that children have not encountered the words previously in print. Wang, Castles, Nickells, and Nation (2011) taught children eight nonwords alongside an explanation that these were names of specific inventions. Later children were exposed to the words in print, however, the spelling of some of the words was irregular. For example, the children learned the word "clape" during oral training and later saw it spelled as *cleap*, which is a plausible but unexpected representation of the word. Some of the words were presented in a list and others as part of a story. Wang et al. found that children were more likely to identify the irregular spelling of target words when they had seen them presented in context than when they had seen them in a list. Furthermore, the effect of contextual facilitation was stronger for irregular than regular words. This finding aligns with the conclusions drawn from research that links irregular word reading with oral vocabulary. The implication is that when words are irregular, children draw on semantic features and the sentence context to produce the correct pronunciation (Wang et al., 2011).

Mispronunciation Correction in Word Reading Accuracy

Venezky (1999) coined the term *set for variability* to describe the strategy of making phonological adjustments to incorrectly pronounced words. This strategy is also referred to as *mispronunciation correction* (e.g., Dyson, Best, Solity, & Hulme, 2017), and it is this term that will be used henceforth in this study. Tunmer and Chapman (2012) argued that mispronunciation correction may mediate the relationship between vocabulary and word reading. They conducted a longitudinal study in which they tested a range of reading related measures alongside a test of oral mispronunciation correction. In this test, experimenters read out real irregular words as if they were regular, for example, the word “spinach” was pronounced “spy-natch”, and children adjusted the mispronounced word to produce the corrected pronunciation. The mispronounced words were presented in isolation during an initial testing session and in a sentence context during a later session. Tunmer and Chapman found that the ability to correct orally mispronounced real words in Year One was correlated with later decoding ability in Year Three for irregular words, nonwords, and regular words.

Although Tunmer and Chapman (2012) emphasised the importance of mispronunciation correction in irregular words, Elbro, de Jong, Houter, and Nielsen (2012) argued that it is an important step in reading for all words in alphabetic languages. They replicated Tunmer and Chapman’s study with Dutch and Danish children. Dutch orthography is highly regular, and Danish lies in between Dutch and English in terms of orthographic complexity. Elbro et al. adapted Tunmer and Chapman’s oral mispronunciation correction task and found that both Dutch and Danish children’s performance in the task also correlated with later decoding skills, although not as strongly as for the English readers in Tunmer and Chapman's study. Elbro et al. argued that even when words are regular, children adapt mouth movements and consequent pronunciation of words to pronounce specific sounds. This may reflect a second step in word reading, whereby children move from a regularised "spelling pronunciation" to the correct form through mispronunciation correction.

A third study examined the role of semantic and phonological factors in mispronunciation correction. Kearns, Rogers, Koriakin, and Al Ghanem (2016) used an oral mispronunciation correction task that removed contextual cues and correlated ability to perform mispronunciation correction with a range of oral language and reading tasks. They found that mispronunciation correction was associated with measures of word reading accuracy after controlling for other reading related variables such as oral language and attention. Kearns et al. theorised that when children decode novel words, they check the result against items in the phonological lexicon using their semantic knowledge of words and word parts, but note that confirming this will require additional research. Kearns et al. found that mispronunciation correction might be more important for irregular words, however, they argue like Elbro et al. (2012) that the ability to correct mispronounced words is likely to affect reading of all words to some extent.

Supporting evidence for the idea that semantic processing is required at a word level in mispronunciation correction (Kearns et al., 2016) can be found in a study looking at how nonwords are processed based on word-level knowledge. Although English is known to have an inconsistent orthography, it is the vowels, rather than the consonants that are most troublesome (Elbro & de Jong, 2017). Steacy et al. (2018) suggested that ambiguous associations between orthography and phonology, particularly in vowel sounds, lead readers to lean on context. They reasoned that this might occur even in the absence of sentence level support. They explain that specific phonological representations are more frequent in some contexts than in others, for example *oo* is more likely to make a long sound when the following letter is /m/ or /n/, for example *room* and *soon*, and a short sound when the following letter is /k/, such as in *book* or *shook.* This kind of context might be even more important when the representation of the sound is less common. Steacy et al. introduced children to nonwords that might be pronounced in either of two possible ways, for example the nonword *mook* might be pronounced with the /ʊ/ as in *book* or the /uː/ as in *room*. They found that children with better mispronunciation correction skills were more likely to read the word using the higher frequency vowel sound within the context of that word, that is, to pronounce *mook* to rhyme with *book*.

More powerful conclusions about mispronunciation correction might be drawn from training studies. Three studies, two short-term and one long-term, suggest that teaching children a mispronunciation correction strategy leads to more accurate word reading. Zipke (2016) and Dyson et al. (2017) conducted interventions designed to teach children to adjust mispronunciations of irregular words. Both studies utilised short term interventions and explicitly instructed children how to adjust pronunciations of words in their reading. Each separately concluded that, when compared to control groups, children in the intervention groups were more able to correct mispronunciations post-training. However, the children were unable to generalise their learning to encompass words that they had not encountered during training.

It may be that mispronunciation correction is an important skill to teach but that short term-training approaches are not sufficient for children to utilise the strategy effectively in their own reading. Savage, Georgiou, Parrila, and Maiorino (2018) conducted a longer intervention over six months. They found that children in the mispronunciation correction group made greater gains in reading, spelling, and comprehension when compared to an active control group. Furthermore, these advantages were maintained six months later at delayed post-test. This finding suggests that mispronunciation correction can be taught and that it contributes to reading development. This has implications for teaching as it demonstrates that children's reading skills might be enhanced by explicitly teaching children how to adjust pronunciation of irregular words.

The Aims of the Current Study

Previous research has established evidence of the links between oral vocabulary and reading skills. There is strong evidence that oral vocabulary and word reading accuracy are tied to an ability that enables readers to adjust pronunciations of words that are irregular. There is additional evidence that sentence context may play a role in children's ability to correct mispronounced words. Additionally, training studies have demonstrated that mispronunciation correction ability can be improved through training and that this may help develop general reading skills in developing readers. However, to date, no research has reported direct evidence for the mispronunciation correction mechanism being applied by children as they attempt to read new words for the first time. The purpose of the current study was to provide such evidence. We did so by manipulating the children's familiarity with novel words (nonwords) in oral form, the regularity of the novel words' spellings, and the context in which they were read.

To examine children's dynamic processing as they read the novel words for the first time, we used eye movement monitoring. Eye movement monitoring is often used in reading research due to its ability to track reading behaviour in real time (Rayner, Pollatsek, Ashby, & Clifton, 2012) and has been used extensively in the study of adult reading behaviour (for reviews, see Rayner, 1998; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001; Rayner et al., 2012). Advances in technology mean that eye tracking is now accurate, reliable, and portable, allowing for monitoring of reading behaviour in a relatively unobtrusive and naturalistic manner. Because of this, eye monitoring is gaining momentum as a tool for answering questions about dynamic processes in reading in children (e.g., Blythe, 2014; Joseph, Nation, & Liversedge, 2013; Wegener et al., 2018).

In the present study, children's eye movements were monitored during silent reading as they read both orally trained and untrained novel words within sentences. The spelling regularity of the words was manipulated to include words with an irregular relationship between their spoken and written form (e.g., "clape" - *cleap*), and words with a regular relationship between spoken and written forms (e.g., "cleap" - *cleap*). Untrained irregular words were expected to be regularised. As mispronunciation correction is thought to be facilitated by contextual cues, sentence context was also manipulated so that children either read words within a sentence with a supportive context, or within a sentence that was neutral. When a word was familiar in oral vocabulary and its spelling was irregular, we expected that children would lengthen their viewing times, and would be more likely to regress back, when silently reading the word, relative to when the word was orally unfamiliar. In contrast, when the words were familiar and regular, we expected viewing times to be shorter, and that children would be less likely to regress back to the word, than for irregular trained and untrained words. Sentence context was proposed to confer an additional advantage, such that differences in viewing times between irregular and regular words in a supportive context would be larger than the differences in the neutral condition.

Following monitoring of eye movements during silent reading, the children read both trained and untrained words aloud from a list. We expected that children would be more likely to read the regular words accurately than the irregular words and that training would confer an advantage for accuracy, with better reading of orally trained items than untrained items. We further expected the training advantage to be particularly strong for irregular words, with a larger training effect for these items than for regular words. The advantage of training for irregular words was predicted to be particularly strong for words that were read in supportive, rather than neutral, sentences during eye tracking.

Method

Design

Four classes of children were each trained on an oral vocabulary of 16 novel nonwords, with two of the classes learning one list and the other two learning a second list. Half the words were pronounced in such a way that the orthographic form they were later exposed to was regular. The other half were pronounced such that the orthographic form of the vowel sound would be irregular, with this being counterbalanced between classes. The children were then exposed to the printed form of all the words, both orally trained and untrained, embedded in either contextually supportive or neutral sentences and read silently whilst their eye movements were monitored. Following this, they read all the words aloud from a list and accuracy was recorded. The study utilised a two (regularity: regular, irregular) by two (training: trained words, untrained words) by two (context: supportive, neutral) mixed design with orthography and training as within-subjects factors and context as a between-subjects factor.

Participants

Following approval by Macquarie University's Social and Behavioural Research Ethics Committee, 78 Year 5 students participated in the study, all of whom were recruited through a boys' independent school in Sydney. All children who returned a consent form participated, however, data from two children were excluded: one for a child whose eye movements could not be calibrated by the eye tracker and a second that occurred because of mid-experiment software failure. The final sample therefore consisted of data from 76 male participants (M_{age} = 130 months; SD_{age} = 4.10 months). All children had normal or corrected-to-normal vision and 75 out of the final sample of 76 reported their primary spoken language as English. One child spoke French as his primary language, having learned to speak English at the age of six. A second child learned Mandarin as his first language but had English as a second language since birth. For all participants, English was the first language they reported learning to read and write. Summary data for reading and oral vocabulary measures are presented in Table 1.

Table 1

Participants' Age and Performance on Standardised Tests.

	M	*SD*	Min	Max
Age (years; months)	10;10	4.10	10;1	11;7
Reading aloud (CC2)				
Regular	37.61	3.33	16	40
Irregular	26.29	3.87	13	33
Non-words	32.86	6.90	4	40
Reading aloud (TOWRE-2)				
Sight words	73.82	9.35	42	93
Nonwords	43.45	11.06	9	61
Oral Vocabulary				
Adapted PPVT-III	35.25	2.84	29	40
Mispronunciation Correction Test	20.03	3.77	7	25

Note. CC2 = Castles and Coltheart 2, max. score 40; TOWRE-2 = Test of Word Reading Efficiency, 2nd Edition, score is number correct in 45 seconds; PPVT-III = Peabody Picture Vocabulary Test, Third Edition, max. score 40; MCT = Mispronunciation Correction Task, max. score 25. All scores are raw scores.

Materials

Participants completed two standardised measures of word reading proficiency. These were the Test of Word Reading Efficiency, 2nd ed. (TOWRE-2; (Torgeson, Wagner, & Rashotte, 2012) and the Castles and Coltheart, 2nd ed. (CC2; Castles et al., 2009). Two oral vocabulary measures to were also administered: an adapted Peabody Picture Vocabulary Test, a test of receptive vocabulary breadth; and the Mispronunciation Correction Task (Kearns et al., 2012), which tests children's ability to make phonological adjustments to correct words that have been mispronounced.

TOWRE-2 (Torgeson, Wagner, & Rashotte, 2012). The TOWRE is used extensively in reading research and has been normed for Australian school children (Marinus, Kohnen, & McArthur, 2013). As it is timed, the TOWRE-2 provides information about fluency of reading as well as accuracy. The test is composed of two subtests: a sight word efficiency (SWE) subtest and a phonemic decoding efficiency (PDE) subtest.

The SWE subtest comprises 104 items that are a mix of orthographically regular and irregular words increasing in difficulty, and participants are asked to read as many words as possible in 45 seconds. The PDE subtest consists of 63 nonwords that are decodable for English readers but are not real words. These nonwords also increase in difficulty, and participants read as many words as possible in a 45 seconds. For both subtests, the number of correctly read words are recorded. If participants read all words in either subtest before the 45 second time limit, their time is recorded alongside the number of correctly read words.

Castles and Coltheart, Second Edition (CC2; Castles et al., 2009). The CC2 comprises 120 items, presented on individual cards. These consist of 40 words that have a regular orthography (e.g. *chicken*), 40 nonwords (e.g. *framp*), and 40 words that are orthographically irregular (e.g. *couple*), increasing in difficulty. The tester presents the participants with word cards one at a time with regular, irregular, and nonword classes being **interleaved**. Once a participant makes five consecutive errors for an item class, it is discontinued and only other cards with other word classes are presented. Administration is discontinued when children make five consecutive errors on all three word classes, or all words are read. Accuracy scores for each item class are calculated separately.

Adapted Peabody Picture Vocabulary Test, Third Edition (PPVT-III; Dunn, 1997). The adapted PPVT-III is a shortened version of the PPVT-III, comprising 40 items. For each item, participants are shown four pictures presented on a single page and asked to select which picture best matches a given orally presented word. The items increase in difficulty. Participants are not given feedback and all items in the test are administered. The adapted form of the PPVT-III demonstrates strong equivalency to the original PPVT-III with a Pearson product-moment correlation of 0.93 between the two versions (Australian Institute of Family Studies, 2015).

Mispronunciation Correction Task (MCT; Kearns et al., 2016). The MCT is comprised of 25 items derived from the Set for Variability Task (SVT; Tunmer & Chapman, 2012). Participants are told that they will hear words that will be pronounced in a strange way. Their task is to guess the word that the tester is mispronouncing. Children are orally presented with words that contain mispronounced vowel and/or consonant sounds. The mispronounced vowel sounds are usually matched to the most likely grapheme-phoneme correspondence when reading the word. For example, *kind* is pronounced to rhyme with *pinned.* The participant then attempts to correct the word that has been mispronounced. No feedback is provided and all items in the task are administered. The MCT uses recorded words which are played to participants, however these are North American accented. Consequently, during this experiment the tester read the words aloud using an agreed pronunciation.

Experimental Materials

Experimental words. Two lists of 16 nonwords were created. All items were single syllable, between four and six letters in length, and structured with a consonant or consonant cluster at the beginning and end (e.g. *vaik*). The word lists were matched on length and bigram frequency and Table 2 presents means and standard deviations. Independent-samples t tests determined that there were no overall differences in length, bigram frequency, or neighbourhood size between words in List A and List B (all ps >.05).

Table 2

Means (and Standard Deviations) of Matched Variables for Word Lists A and B.

	List A	List B
Length in characters	4.63 (0.50)	4.63 (0.62)
Bigram frequency	28.14 (13.52)	24.50 (13.06)
Neighbourhood size	3.81 (2.95)	3.87 (2.83)

Two classes received oral vocabulary training on the words in List A and two classes received training on the words in List B, with the other list becoming their untrained items. Within each list, eight of the words were pronounced in a way such that the orthographic form the children would subsequently be exposed to would be regular. The remaining eight were pronounced such that the orthographic form of the vowel sound would be irregular. For example, the first class learned that *vaik* was pronounced with the vowel sound to rhyme with *bake*. The second class learned that *vaik* was pronounced with the vowel sound pronounced as in the word *bike*. During the subsequent orthographic exposure phase and oral reading, the word was spelled *vaik* for participants in both classes. Both regularity and word lists were counterbalanced between the four classes. Appendix A presents all 32 words accompanied by their alternative phonological forms.

The experimental paradigm was based on that developed by Wang et al. (2011), in which the words represented the names of inventions. Each word was accompanied by a corresponding illustration of the invention it represented. An example of an illustration is shown in Appendix B. The illustrations comprised the eight original illustrations developed by Wang et al. (2011), a further 12 added by Mimeau, Ricketts, and Deacon (2018), and an additional 12 that were created for this experiment.

Apparatus

Eye movement monitoring was conducted using a remote Eyelink 1000 eye tracker (SR Research; Mississauga, Canada), sampling at 1000 Hz at a viewing distance of 950mm on a 27" AOC monitor. Eye tracking was conducted in head stabilised mode to minimise children's head movements during testing. Eye movements of the right eye were monitored while children read binocularly. Sentences were presented using Experiment Builder software (SR Research Experiment Builder; Mississauga, Canada) in black Courier New font, on a single line and on a white background. Characters covered 0.36˚ of visual angle.

When testing children's word reading accuracy, target words were displayed in random order on a MacBook Pro 15" laptop computer using DMDX software (Forster & Forster, 2003). The words were presented individually for 3000 ms in white Courier New font in size 36 on a black background.

Procedure

The experimental procedure consisted of three phases. Firstly, in the *oral exposure* phase, children were orally introduced to the words accompanied by illustrations of inventions that they represented. Then, in the *orthographic exposure* phase, the children read the words in sentences from a computer screen whilst their eye movements were monitored. Lastly, in the *post-exposure phase*, children read the words in isolation from a computer screen as their accuracy was recorded. The standardised reading and oral vocabulary measures were also administered during this phase.

Phase one: Oral exposure. Oral vocabulary training was delivered at a class level. The children were told that an inventor called Professor Parsnip had devised a range of gadgets and that they would be learning the names of these inventions and their functions. They saw pictures of each invention, and repeated the names of each as it was introduced. The names and pictures were accompanied by two pieces of descriptive information. For example, the tester told the children, "Professor Parsnip invented the *vaik*. The *vaik* is used for cleaning fish tanks. The *vaik* has a sponge and is shaped like an arm".

The training took place across four sessions administered over eight days. On the first day, eight inventions were introduced and rehearsed. In the second session, participants were introduced to and rehearsed a further eight inventions. In the third and fourth sessions, participants rehearsed all 16 inventions. Each session lasted around 20 minutes. If participants missed any sessions due to illness or withdrawal from class during training, they were trained separately to ensure everyone received the same exposure to the invention names.

Picture naming task. Following the four training sessions, each participant was individually asked to recall the names and functions of the 16 inventions they learned about during oral training. Participants viewed pictures of the inventions one at a time and were asked to name them and to recall their functions. If children named the invention correctly, the experimenter delivered feedback by acknowledging the correct response and repeating the name and the function. If children made an incorrect response or could not remember, the experimenter provided the correct name and asked the children to repeat the name and function of the invention.

Phase two: Orthographic exposure. Testing took place between one and five days following oral training. Children's eye movements were recorded as they read all the words, both trained and untrained, presented within sentences on a computer monitor. The children were informed that the experiment would involve reading sentences in their head and that some of the sentences would be about inventions they learned about in class and some of them would be about inventions they had not learned about.

Prior to the experiment commencing, participants' eye movements were calibrated. Following calibration, three practice sentences were administered followed by the experimental sentences. A fixation dot, placed at the sentence reading onset point, preceded presentation of each sentence. After silently reading the sentence, children fixated on a rectangle set to the right of the sentence, causing it to disappear. Sentences were presented in four blocks of eight and were fully counterbalanced. Each block ended with a short break, during which children were told to remain in the head rest and indicate when they were ready for more sentences. Some sentences were followed randomly by a question requiring a yes or no response to ensure children were maintaining attention as they read. The questions did not refer to the target words or to the inventions' functions and responses were not analysed.

All 32 words (List A and List B) were presented to participants within sentences, such that half of the words children read were trained and half were untrained. Sentences were designed to provide either semantically supportive or semantically neutral information preceding the target word. For example, referencing an invention that encourages birds to sing, half of the children saw the word *leam* in the sentence ‘The bird flew down to the *leam* in the garden’. The other half saw *leam* in the sentence ‘The boy ran down to the *leam* in the garden’. A full list of sentences is provided in Appendix C. All sentences were matched as closely as possible, and words immediately pre- and post-target were matched. Context was counterbalanced between participants, such that children read sentences in which all the trained words were in contextually supportive sentences and untrained words were presented in neutral sentences, or all trained words were in neutral sentences and untrained words in contextually supportive sentences.

Phase three: Post-exposure word reading. The children were asked to read each word aloud as quickly and accurately as possible as it appeared on a laptop monitor. They were told that some of the words were the names of inventions that they had learned about in class and some were the names of inventions they had not learned. The experimenter hand scored children’s accuracy during the task and scoring was cross-checked with Check Vocal (Protopapas, 2007). Following this, the experimenter administered the tests of reading and oral vocabulary.

Results

Pre-exposure Picture Naming

Children were able to recall a mean of 10.95 (SD = 3.70) of the 16 orally trained invention names. A one-way ANOVA revealed no significant differences in the number of inventions recalled by each class, $F(3, 72) = .24$, $p = .87$. Means and standard deviations of invention naming by class are shown in Table 3.

Table 3

Means and Standard Deviations (SD) for Target Word Recall by Class

	Mean recall	*SD*
Class One	11.09	4.08
Class Two	11.35	4.43
Class Three	11.00	3.65
Class Four	10.33	2.57

Eye Movements

Eye movement data were analysed in the R computing environment (R Core Team, 2018) and employed linear mixed effects models using the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). Training (trained, untrained), regularity (regular, irregular), and context (supportive, neutral) were fixed factors, while participants and items were treated as random factors. Separate models were run for each of the dependent variables of interest: first fixation time, gaze duration, total reading time, and regressions back to the target words (regressions in). If a participant skipped any of the predefined interest areas (target word, pre-target text, or post-target text), the trial was removed prior to analysis. This resulted in the removal of 5.18% of trials overall. Consistent with other recently reported eye movement studies (Joseph & Nation, 2018; Taylor & Perfetti, 2016; Wegener et al., 2018), reading time data were log transformed prior to analysis.

All models included the full fixed structure, as well as random intercepts for participants and items. The random slopes structure was derived via model comparisons using a data driven approach (see Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017; Zuur, Ieno, Walker, Saveliev, & Smith, 2009) and a forward selection heuristic. See Appendix D for results of omnibus models. To test our specific hypotheses, we undertook planned contrasts which were implemented using the *lsmeans* package (Lenth, 2016). We predicted: (a) a training effect for irregular items (reflecting attempts to adjust mispronunciations of orally known items such that trained items should be fixated for longer with a higher probability of regression than untrained items); (b) a training effect for regular items (reflecting a processing advantage for orally known items apparent in shorter fixation times for trained words and a lower probability of regression); (c) a regularity effect for orally known items (reflecting the operation of both processes mentioned above and resulting in longer fixations on irregular items and a higher probability of regressions to them); (d) the regularity effect for orally known items would be larger when situated in contextually supportive, rather than neutral sentence frames (because context may enhance mispronunciation correction attempts); and (e) no regularity effect for orally untrained items (reflecting the lack of any difference in expected looking times for the regular and irregular items in the absence of oral familiarity). Regression coefficients, standard errors, *t* values (for time data) or *z* values (for binomial data), and corresponding *p* values are reported for these planned contrasts. The Holm-Bonferroni correction for multiple comparisons was used to adjust the *p* values. Arithmetic means and standard deviations for each dependent variable are presented in Table 4 For clarity, these data are also represented as separate figures in the analyses of each of the eye movement indices below.

Table 4

Mean Reading Times and Regressions In Probabilities on the Target Word for Each Factor

		Contextual sentence		Neutral sentence	
Training	Eye movement measure	Irregular	Regular	Irregular	Regular
Trained words	First fixation	285 (152)	260 (117)	271 (123)	266 (121)
	Gaze duration	497 (320)	397 (220)	474 (277)	400 (214)
	Total reading time	799 (548)	559 (370)	714 (434)	611 (422)
	Regressions in	0.31 (0.46)	0.20 (0.40)	0.26 (0.44)	0.26 (0.44)
Untrained words	First fixation	270 (122)	275 (131)	287 (147)	283 (124)
	Gaze duration	456 (295)	463 (287)	455 (278)	429 (241)
	Total reading time	736 (505)	675 (424)	781 (573)	743 (454)
	Regressions in	0.27 (0.44)	0.25 (0.43)	0.30 (0.46)	0.29 (0.45)

Note. Reading time measures are expressed in milliseconds. Regressions in are expressed as a probability. Standard deviations are in parentheses.

When the planned contrasts were applied to the selected model for first fixation duration (see Table 5) none reached statistical significance (all *p*s > .05). These findings were consistent with only one of our predictions: that there would be no effect of regularity for orally untrained targets.

Table 5
Linear Mixed Model Planned Contrasts for First Fixation Duration

	b	***SE***	*t*	*p*
Training effect for irregular items	0.003	0.023	0.12	1.00
Training effect for regular items	-0.052	0.02	-2.20	0.14
Regularity effect for trained items	0.047	0.02	2.01	0.18
Regularity effect for trained items: context vs. neutral	0.018	0.023	0.755	1.00
Regularity effect for untrained items	-0.007	0.023	-0.32	1.00

Contrary to our predictions, there was no training effect for irregular or regular targets and no regularity effect for trained targets; nor did the regularity effect for trained targets differ when items were read in contextually supportive compared to neutral contexts. Figure 1 demonstrates means and standard deviations.

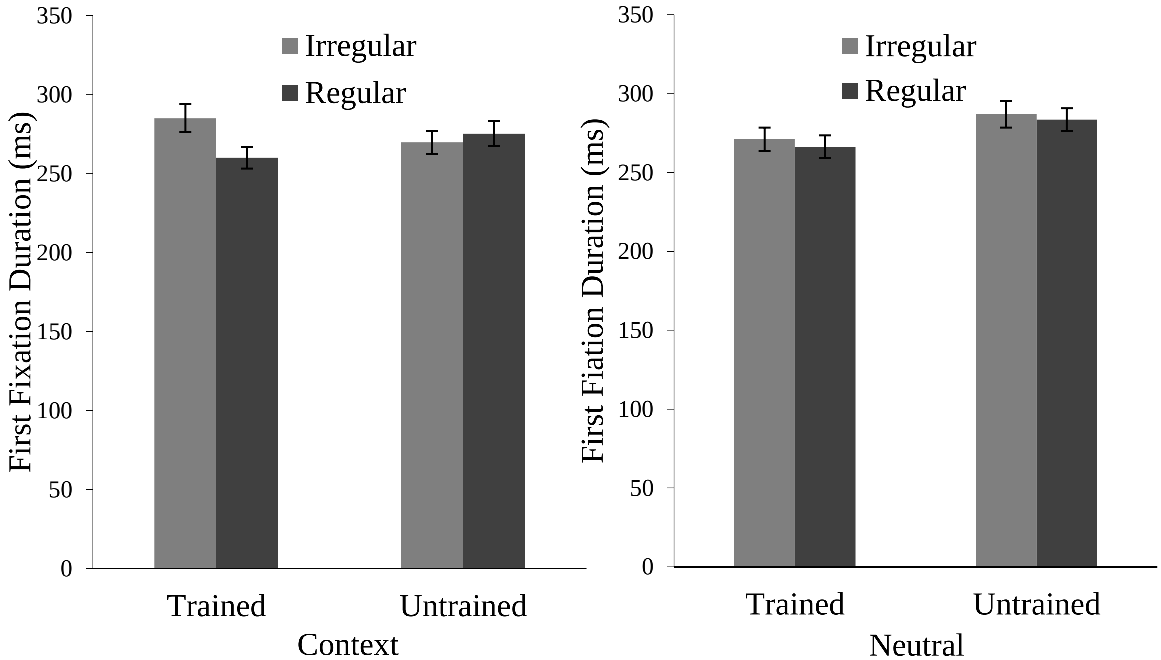

Figure 1. *Means and standard errors of first fixation duration times for target words. First fixation duration is measured in milliseconds.*

When the planned contrasts were applied to the selected model for <u>gaze duration</u> (see Table 6), as expected, there was no difference in fixation durations for regular and irregular targets that were orally untrained. Also, in line with expectations, there was a significant training effect for regular items such that orally trained targets were fixated for shorter periods than orally untrained targets; and there was a significant effect of regularity for trained items such that regular spellings of orally known words were fixated for shorter periods than irregular spellings of orally known words. However, contrary to expectations, the regularity effect did not vary with the sentence frame in which it was embedded (contextual vs. neutral). Also contrary to expectations, fixation times on trained irregular targets did not differ from fixations on untrained irregular targets. These results are represented graphically in Figure 2.

Table 6
Linear Mixed Model Planned Contrasts for Gaze Duration

	b	*SE*	*t*	*p*
Training effect for irregular items	0.06	0.03	2.04	0.13
Training effect for regular items	-0.09	0.03	-2.83	0.02
Regularity effect for trained items	0.15	0.03	5.12	<.001
Regularity effect for trained items: context vs. neutral	0.025	0.03	0.85	0.79
Regularity effect for untrained items	0.003	0.03	0.12	0.91

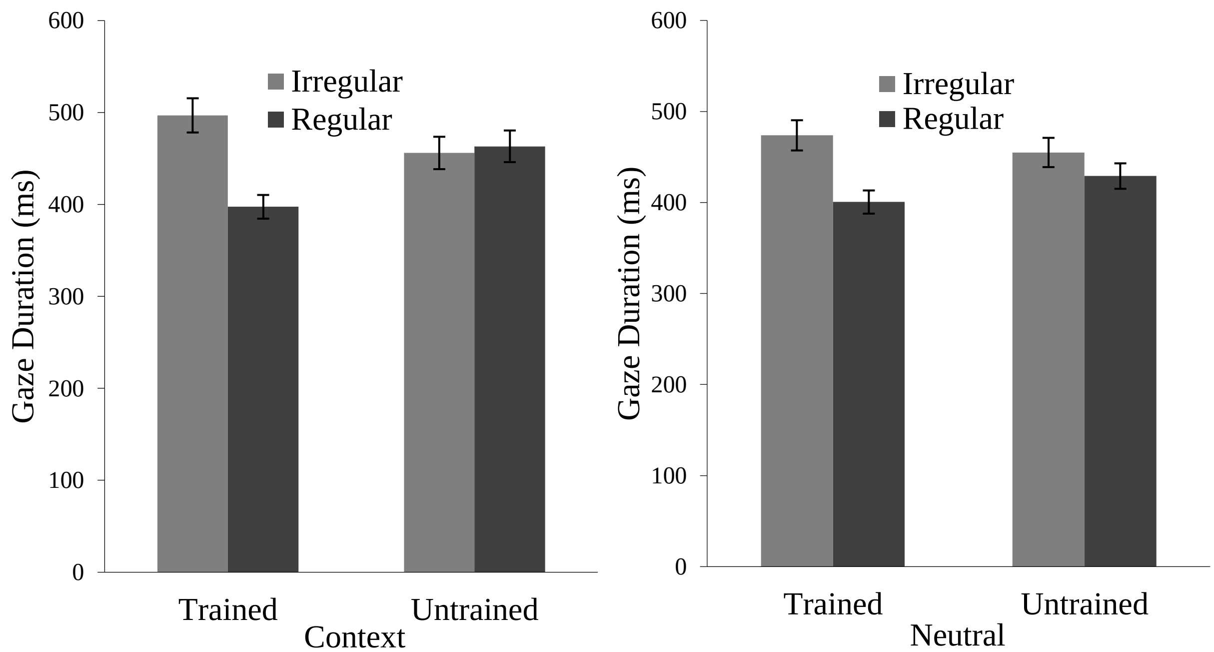

Figure 2. *Means and standard errors of gaze duration times for target words. Gaze duration is measured in milliseconds.*

When the planned contrasts were applied to the selected model for <u>total reading time</u> (see Table 7), four out of the five predictions were supported. As expected, there was once again no significant difference in fixation durations for regular and irregular targets that were orally untrained. Also consistent with predictions, there was a significant training effect for regular items such that orally trained targets were fixated for shorter periods than orally untrained targets; and there was a significant effect of regularity for trained items such that regular spellings of orally known words were fixated for shorter periods than irregular spellings of orally known words.

Table 7
Linear Mixed Model Planned Contrasts for Total Reading Time

	b	*SE*	*t*	*p*
Training effect for irregular items	0.0009	0.03	0.03	0.98
Training effect for regular items	-0.18	0.03	-5.62	<.001
Regularity effect for trained items	0.23	0.03	7.05	<.001
Regularity effect for trained items: context vs. neutral	0.09	0.03	2.82	0.02
Regularity effect for untrained items	0.05	0.03	1.62	0.21
Regularity effect for trained items in the context condition	0.32	0.045	7.09	<.001
Regularity effect for trained items in the neutral condition	0.14	0.05	2.96	0.01

On this late measure of fixation time, the regularity effect for trained items did vary as expected according to the sentence frame in which it was embedded, with a larger regularity effect observed when sentences were contextually supportive compared to when they were neutral. When this interaction was unpacked, the regularity effect was present for trained items in both supportive and neutral contexts. However, contrary to predictions, fixation times on trained irregular targets did not differ from fixations on untrained irregular targets. These results are represented in Figure 3.

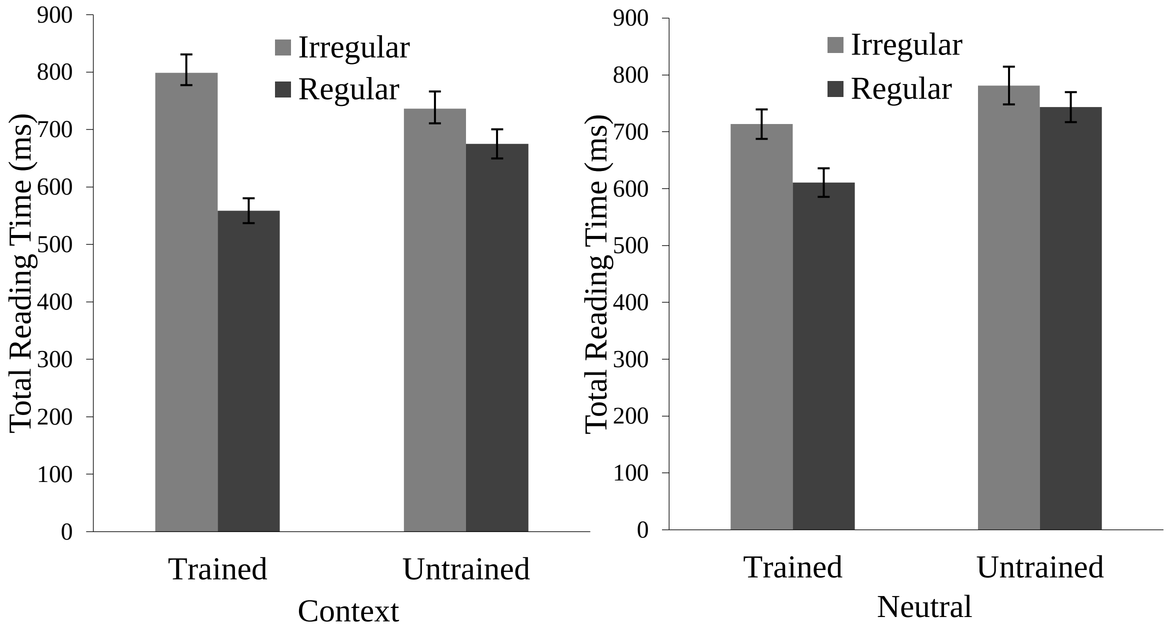

Figure 3. *Means and standard errors of total reading times for target words. Total reading time is measured in milliseconds.*

When the planned contrasts were applied to the selected model for regressions in (see Table 8), none reached statistical significance. These findings were only consistent with our prediction that there would be no impact of regularity for orally untrained targets on the probability of rereading. Contrary to our predictions, there was no training effect for irregular or regular targets and no regularity effect for trained targets; nor did the regularity effect for trained targets differ when items were read in contextually supportive compared to neutral contexts.

Table 8

Linear Mixed Model Planned Contrasts for Regressions In

	b	*SE*	*z*	*p*
Training effect for irregular items	-0.001	0.14	-0.01	0.99
Training effect for regular items	-0.23	0.14	-1.6	0.33
Regularity effect for trained items	0.34	0.14	2.40	0.08
Regularity effect for trained items: context vs. neutral	0.34	0.14	2.38	0.08
Regularity effect for untrained items	0.11	0.14	0.82	0.83

We conducted exploratory contrasts to examine these results further. We found that when considering the context condition in isolation there was a simple effect of regularity for trained words. Whilst these findings cannot be considered confirmatory, there was a clear effect of regularity for trained words in the context condition but not the neutral condition, suggesting that regressions in for irregular words are driven by contextual cues. These differences are represented in Figure 4.

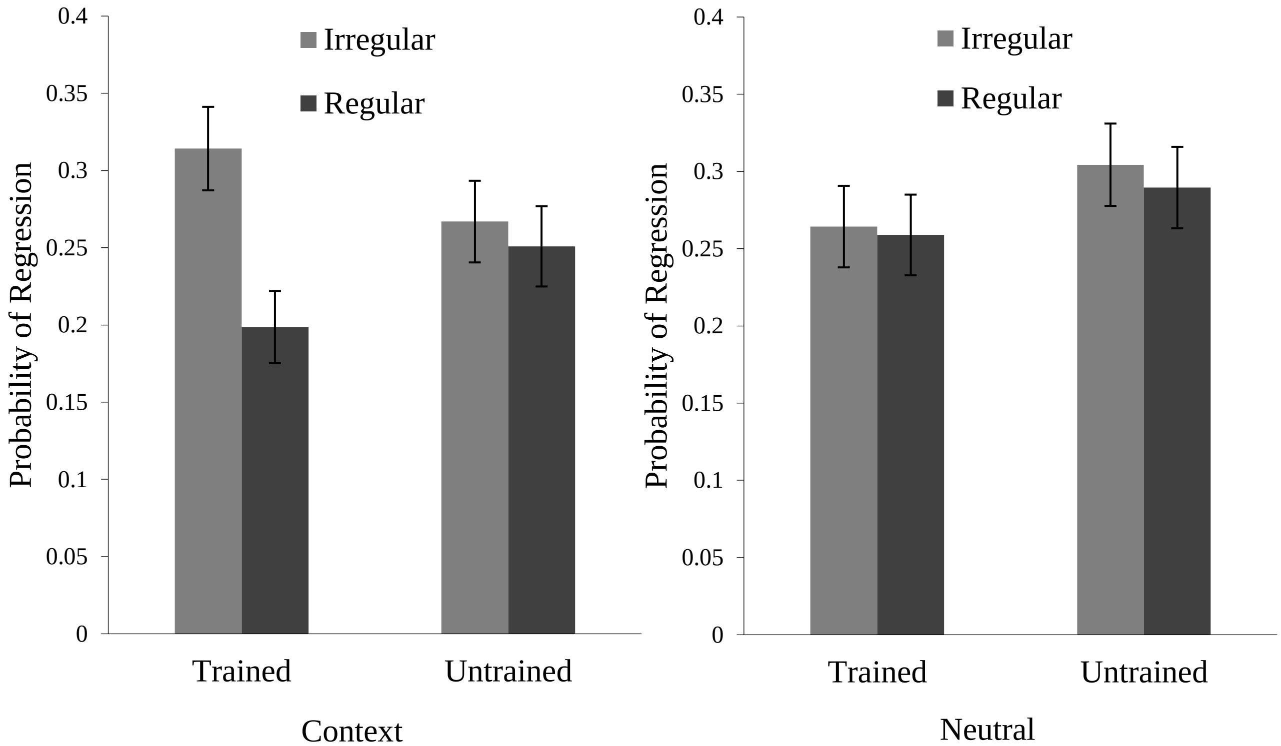

Figure 4. *Means and standard errors of regressions in for target words. Regressions in is expressed as a likelihood of regression.*

Reading Aloud

Reading aloud accuracy was analysed using a logistic linear mixed effects model. Model selection was performed in the manner described above. the omnibus test appears in Appendix D and planned contrasts were again implemented in *lsmeans* (Lenth, 2016) to test our specific hypotheses. We predicted that training would benefit reading accuracy for both regular and irregular items; that regular spellings would benefit reading accuracy for both orally trained and untrained items; and that the benefit of training for the reading accuracy of irregular words would be larger when sentences were contextually supportive than when they were not. Means and standard deviations of reading aloud accuracy are presented in Table 9.

Table 9
Reading Aloud Accuracy Expressed as Proportion Correct

	Contextual sentence		Neutral sentence	
Training	Irregular	Regular	Irregular	Regular
Trained words	0.46 (0.50)	0.98 (0.14)	0.26 (0.44)	0.97 (0.16)
Untrained words	0.33 (0.18)	0.92 (0.27)	0.04 (0.20)	0.91 (0.29)

Note. Standard deviations in parentheses.

When the planned contrasts were applied to the selected model for reading aloud accuracy (see Table 10), all hypotheses were supported. Orally trained regular and irregular items were both more likely to be read correctly than orally unfamiliar items; regular items were more likely to be read correctly than irregular items both when items were orally trained and when they were not; when spellings were irregular, oral training boosted reading accuracy more when the words had been previously seen in contextually supportive sentences in the eye tracking task.

Table 10
Linear Mixed Model Planned Contrasts for Naming Accuracy.

	b	*SE*	*z*	*p*
Training effect for irregular items	3.73	0.62	6.03	<.001
Training effect for regular items	1.95	0.83	2.35	0.038
Regularity effect for trained items	-5.89	0.81	-7.32	<.001
Regularity effect for untrained items	-7.68	0.72	-10.67	<.001
Training effect for irregular items: context vs. neutral	0.71	0.35	1.20	0.046

Exploratory correlational analyses

The relationship between children's reading accuracy on the orally trained but irregularly spelled items (which are the items that should be subject to mispronunciation correction processes) and their performance on standardised tests of vocabulary, reading, and mispronunciation correction was explored. To do so, by-participant Pearson product-moment correlations were performed (see Table 11). Data from one outlier was removed and thus test scores for 75 participants were examined. Scores on the CC2 nonword and regular word tests were moderately negatively skewed. These data were transformed using a square root transformation and showed no differences in significant results from non-transformed data. Thus, correlations for non-transformed data are presented. There was a statistically significant positive correlation between trained irregular word reading accuracy and performance on the mispronunciation correction task, and both irregular and nonword reading on the CC2, and a marginally significant correlation between trained irregular word reading accuracy and nonword reading on the TOWRE-2. Following a Holm-Bonferroni correction, only the correlation between trained irregular word reading and mispronunciation correction remained significant. Correlations between trained irregular word reading accuracy and other measures of reading and vocabulary did not reach significance.

Table 11
Pearson Product-Moment Correlations Between Trained Irregular Word Reading Accuracy and Standardised Measures of Vocabulary, Reading and Mispronunciation Correction.

Correlations	*R*	*p*
Mispronunciation Correction Task	.31	.006*
Adapted PPVT-III[1]	.19	.10
CC2 regular words[2]	.14	.23
CC2 irregular words[2]	.26	.03
CC2 non-words[2]	.26	.03
TOWRE-2 sight words[3]	.06	.60
TOWRE-2 non-words[3]	.22	.05

Note. [1]Adapted PPVT-III = Peabody Picture Vocabulary Test; [2]CC2 = Castles and Coltheart 2; [3]TOWRE-2 = Test of Word Reading Efficiency. * denotes significant results following a Holm-Bonferroni correction

Discussion

The aim of the present study was to find evidence for the presence of a mispronunciation correction mechanism being applied by children as they encounter novel words. To accomplish this, we orally taught children the phonology and meaning of novel words, which they later read silently in sentences. We applied three key manipulations. Firstly, children were exposed to both orally trained and untrained words during silent reading. Secondly, half the trained words were designated a regular spelling and half an irregular spelling. Thirdly, children either saw the words in contextually supportive sentences or in neutral sentences. Following this, children read the words aloud from a list and their reading accuracy was recorded. The eye movement data were used to address five key hypotheses and the findings in relation to each of these will be considered below.

Our first hypothesis proposed that when a word was familiar in oral vocabulary and its spelling was irregular, children might attempt to adjust their pronunciation in real time as they read it silently. If this was the case, it was expected that viewing times for these trained irregular words would be longer, and the likelihood of a regression back to the target word higher, than for orally unfamiliar irregular words; that is, we predicted a training effect for irregular words. Eye movement monitoring has not previously been employed to answer questions about reading and word regularity, but longer viewing times would be consistent with Share's (1999) proposal that processing of irregular words should be impeded. Contrary to expectations, the results showed no training effect for first fixation duration, gaze duration, total reading time, or likelihood of regressions in: Trained irregular words elicited similar viewing times to the untrained words. It may be that time taken to perceive a spelling as irregular is the same as the time taken to process an entirely unknown word of the same length and complexity. Consistent with this idea, several studies that have used eye movement monitoring to track reading have found that novel words are fixated longer than known words (e.g., Joseph, Wonnacott, Forbes, & Nation, 2014; Lowell & Morris, 2014). Future studies may be able to clarify this further.

The second hypothesis proposed that when a word was orally familiar and regular, viewing times would be shorter, and likelihood of regressions lower, than for orally unfamiliar regular items. This hypothesis of a training effect for regular items was based on previous research that has shown that oral familiarity with a novel word confers an advantage in subsequently reading a simple regular spelling of that word (McKague Pratt, & Johnston, 2001). In the present study, when considering first fixation duration and likelihood of regressions in, no differences between viewing times for trained and untrained regular words was found. However, differences emerged in gaze duration and total reading time, with viewing times being considerably shorter for the trained regular words.

Thirdly, it was proposed that differences would emerge in viewing times and likelihood of regressions between orally known regular and irregular words such that the irregular items would elicit longer viewing times, and higher likelihood of regressions, when compared to the regular items. This finding would be consistent with previous literature that has focused on regularity effects and word reading (e.g., Wang et al., 2011; Wang, Castles, & Nickells., 2012). Wang et al. (2012) found that during orthographic decision tasks children were more likely to identify orally trained regular words correctly than irregular words. No differences were seen at first fixation duration, but later measures of gaze duration and total reading time showed that children's viewing times were considerably shorter for trained regular words than for trained irregular words. Surprisingly, there was no regularity effect for trained words when considering regressions in. However, an exploratory comparison revealed that likelihood of regressions in was indeed significantly increased for trained irregular words but only when the target words were seen in contextual sentences. This finding will be discussed further below.

The fourth hypothesis predicted that the regularity effect for orally known words would be larger when children read the words in contextually supportive sentences when compared to reading them in neutral sentences. Context was included as a factor in the experiment based on Share's (1995) proposal that when words are irregular, children may draw on the sentence context to arrive at a correct pronunciation. Supporting this, Wang et al. (2011) found that context is important for the accurate reading of irregular but not regular words: When irregular target words were presented within a sentence frame, children were more likely to correctly identify them during a later lexical decision task than when they were presented in a list. It was thus expected that context would confer some advantage for children reading trained irregular words in the current study. We found that there was no difference in the size of the regularity effect for trained items in the supportive compared to the neutral conditions for first fixation duration, gaze duration, or regressions in. However, differences did emerge for the total reading time measure, indicating an interaction between regularity and context: the regularity effect was significant in both sentence contexts but was larger in the supportive context condition. This finding is suggestive that children do draw on the sentence context to make links between oral vocabulary and novel irregular word forms but follow up studies will be required to clarify the nature of this facilitation.

Consistent with expectations, there were no viewing time differences for the untrained words for any of the eye tracking measures. Untrained words, like trained words, were designated irregular or regular spellings and we expected that children would regularise all words that they had not learned about orally in class. This is useful in confirming that the selected words were processed in a similar way unless allocated to an irregular condition.

Of particular interest is the finding that differences in word regularity did not impact first fixation duration. This is a measure of early processing and longer fixations would indicate that irregular spelling is noted by readers almost instantly. It makes sense that the effects of regularity only appear as children move through the word and beyond into the post-target region. The most striking eye movement results were seen in total reading time, in which all fixations on the word are summed, and in likelihood of regressions in, meaning that children have returned to the word for a second look after passing over it. These are considered measures of later processing (Rayner, 1998), implying that the spelling incongruity produced by irregular words might only be picked up after the child has viewed it for a while or has moved beyond the word altogether. Elbro and de Jong (2017) note that children can only achieve automatized decoding once the written word they see in the text is matched to one in the mental lexicon. Upon first encounter with a written word, readers construct a “spelling pronunciation” prior to linking the word with one they know to produce the standard pronunciation. The late processing measures that drive the differences in viewing times for irregular words may be reflective of this two-step decoding process.

An alternative explanation for the observation that eye-movement signatures of the processing of irregular words appear to be late may be that there are discrepancies between the speed of eye movements and speed of semantic processing. Studies of adult readers suggest that, as they read silently, comprehension is supported by an inner reading voice and this inner reading voice is thought to lag a little behind the eye fixations (e.g., Laubrock & Kliegl, 2015). Returning to the current study, it may be that as children read the sentences, their eye movements were faster than their inner reading voice, which caught up after the eye passed over the word. In this case, the child might only perceive the incongruity after passing over the target, and thus regress back to check that it was a word they learned during training.

In considering the results of the eye movement measures, there is clear evidence that irregular words undergo some degree of additional processing as they are read. If this additional processing indicates mispronunciation correction occurring of the form proposed by Tunmer and Chapman (2012) and Elbro et al. (2012), children should be able to read the trained irregular words correctly following initial orthographic exposure. The current study made several predictions regarding post-exposure reading accuracy. Firstly, it was predicted that children should be more likely to read aloud the orally trained regular and irregular words correctly than the untrained words. Furthermore, if children had undertaken mispronunciation correction during silent sentence reading, then orally trained irregular words should be read more accurately than those that were untrained. It was also predicted that a supportive sentence context would confer an advantage in that the accurate reading of trained irregular words would be more likely if the children had previously seen them in supportive sentences than in neutral sentences. Consistent with Wang et al. (2011) we found that when trained words were presented in supportively contextual sentences, the advantage for reading accuracy was greater for irregular words compared to regular words.

When considered together, results from the eye movement data and the reading accuracy data demonstrate that knowing words orally is advantageous for real time processing and word reading. The results also show that irregular words undergo additional processing as they are read silently, and reading irregular words in contextual sentences makes it more likely that additional processing will occur and that words will later be read accurately. These results are strongly supportive of a mispronunciation mechanism taking place in real time as children read, adding to previous evidence for such a mechanism (Elbro et al., 2012; Kearns et al., 2016; Tunmer & Chapman, 2012). However, more definitive evidence for such a mechanism would be provided if the eye movement data showed that the trained irregular words that were read correctly during post-exposure testing also had longer total viewing times and more regression in than the trained irregular words read incorrectly. To this end, we looked at the total reading times and likelihood of regressions for irregular words that were read correctly. In only looking at this subset of data, there were too few samples to find meaningful results, however the data trended in the expected direction. Thus, we can only suggest that mispronunciation correction was a possible mechanism, presenting opportunities for further research.

For our final analyses, we calculated a number of correlations to explore any relationships between children's word reading accuracy and standardised reading and vocabulary measures. The results showed that scores on a mispronunciation correction test (Kearns et al., 2016) had the strongest relationship with reading accuracy for trained irregular words. This provides additional evidence that mispronunciation correction is a strong predictor for reading accuracy of irregular words and corroborates the findings reported by Tunmer and Chapman (2012), Elbro et al. (2012), and Kearns et al. (2016).

It is important to consider whether our results might originate from alternative explanations. One possibility is suggested by the orthographic skeleton hypothesis (Wegener et al., 2018) which suggests that when children learn a word orally, they form an expectation of how that word might appear in print. When a representation of the word confounds their expectations, viewing times will be longer. However, key differences suggest that the present study taps into different processes. Firstly, Wegener et al.'s target items did not include irregular words, but words with less common, although still regular, spellings. Secondly, they found that words with more predictable spelling patterns had shorter viewing times at first fixation, whereas irregular words in this study were susceptible to late stage processing measures of total reading time and likelihood of regressions in.

The current study provides several novel contributions to the mispronunciation correction literature. Firstly, this is the first study to use eye movement monitoring as a dynamic means of indexing mispronunciation correction. We were able to observe differences in viewing times for words depending on regularity and context and hence this methodology may provide direct evidence for a causal mechanism of mispronunciation correction in the future. Secondly, to our knowledge this is the first study to examine mispronunciation correction using an experimental approach. Previous studies have used correlational and training studies and the current study has provided converging evidence from a different perspective. A particular strength of the design we used was that the orthography of the target words was identical across the trained and untrained, and the regular and irregular manipulations. It was the oral pronunciations that children learned during training that differed between conditions. This meant that any effects must have been driven by that prior knowledge and interactions with the orthography. Thirdly, the study introduced a context factor to disentangle the possible role that semantic processes might play in mispronunciation correction. Consideration of these findings provided some evidence that mispronunciation correction is facilitated through semantic processes, as theorised by Kearns et al. (2016). Future research might look more closely at this association.

Further research should aim to address some of the limitations of the present study. One possible limitation is the age of the children tested. The children were in Year 5 and results on standardised reading tests showed that the sample was made up of relatively skilled readers, reflecting extensive experience with reading. It is possible that the ability to correct mispronunciations changes as children become more experienced readers of text. This was suggested by Elbro et al. (2012) who posited that mispronunciation correction might not have such a strong association with word reading accuracy in older readers. One way to address this possibility is to adapt the current methodology for early readers. In this way comparisons can be drawn between how Year 5 children respond to novel irregular words and how younger children process these items. A second issue is that these findings may not generalise to non-English readers. Kearns et al. (2016) suggested that as English is considerably less consistent than many other orthographies, children may rely more on whole word reading than is typical for children reading in more consistent orthographies. He theorises that mispronunciation correction may show weaker associations with word reading when orthography is consistent. Cross-linguistic studies with a similar methodology to the present study may clarify the nature of these differences.

Questions about mispronunciation correction remain of both theoretical and practical interest to researchers and educators. If readers use mispronunciation correction to adjust phonology of unknown words, it is likely to be most important for early readers, who have smaller vocabularies and who are building their phonological lexicon. If, as suggested by Elbro, et al. (2012), it is a requisite ability for children learning to read in all alphabetic languages, then teachers should understand the nature of mispronunciation correction as it has strong implications for effective teaching strategies. Evidence suggests that when children are trained in mispronunciation correction, it has a direct impact on word reading accuracy (Savage et al., 2018) and further research might explore ways that children can develop this ability most effectively.

Chapter 3

General Summary and Future Directions

General Summary and Future Directions

This thesis set out to clarify the nature of the relationship between oral vocabulary and word reading accuracy in children, with a specific focus on how children process orally known words that have irregular spellings. Although this is of particular relevance for English readers, due to the high degree of inconsistency in grapheme-phoneme correspondences, it has wide reaching implications for children learning to read in any language. A literature review of relevant research was conducted and revealed considerable converging evidence that children use a process, referred to as mispronunciation correction, to correctly read orally known words when first exposed to them in print. Similarly, the role of context in irregular word reading was explored, supporting the view that context might confer an advantage as children undertake mispronunciation corrections.

The literature review generated research questions that could be explored empirically. Consequently, an empirical study was reported, in which evidence for a mispronunciation mechanism operating online during children's independent reading of novel words was sought. It was found that children exhibit longer viewing times for orally known irregular words than for orally known regular words. Children also later read irregular words more accurately when they had been orally exposed to them prior to reading, and their accuracy in doing so was predicted by their scores on a mispronunciation correction test. These findings are strongly suggestive of a mispronunciation correction mechanism operating online as children read novel words, but do not provide incontrovertible evidence. Further studies will seek to clarify the nature of the relationships that were observed.

Implications and Directions for Future Research

The process of mispronunciation correction holds a great many unanswered questions and possibilities for future research. One particular finding from the study reported here deserves further analysis. We hypothesised that trained irregular words would elicit longer viewing times than untrained irregular words; however, in the experiment no differences in viewing times emerged between irregular trained and untrained words. Our hypothesis was based on the idea that if children perform a mispronunciation correction, the two-step decoding process proposed by Elbro and de Jong (2017) would be likely to take additional time. Previous research on eye movements in reading have shown that both adults and children look longer at novel words when compared to known words (e.g., Joseph et al., 2014; Joseph & Nation, 2018) but in the current study all words were novel and only seen once. There are some possible explanations for this unexpected result. Firstly, it may be that the time taken to recognise a word as known but an imperfect phonological match to the learned pronunciation takes the same amount of time as it takes to dismiss it as unfamiliar. In this case, supplementary measures such as word naming accuracy or latency may be most useful in clarifying the different ways that trained and untrained irregular words are processed.

The finding that children do not view irregular trained words for longer than untrained words may arise from methodological issues. It may be that the training was not sufficient to build strong enough familiarity with the novel words to produce this effect. The oral training followed the same format as previous research (e.g., Wang et al., 2011; Wang et al., 2012), but the aims here were different. It may be that word familiarity needs to be more robust to capture mispronunciation correction in action, and that more oral exposures to the words were necessary. Another possibility is that the sentence context provided during orthographic exposure was not strong enough to properly induce the recognition that a word was known but had an irregular spelling. We instantiated the words during oral training with a name, purpose and two descriptive features. For example, during oral training the children learned: “Professor Parsnip has invented the leam. It is used for making birds sing. The leam is round and makes noises.” During testing, children who saw the word in context read: “The bird flew down and landed on the leam out in the back yard.” Thus, children had the single contextual cue “bird” to facilitate recognition of the word. In future studies, further manipulation of context or a different oral training paradigm may provide the answer to the anomolous finding that seeing a known irregular word does not lead to longer looking times than unknown words.

Future work might also focus on looking at the development of mispronunciation correction over time. Our sample comprised children of around 10 years old, who had been reading for several years. By this age, children are largely reading independently and have accumulated a great deal of experience in reading regular and irregular words. For these more skilled readers, irregularity may be less surprising than it would be for younger, developing readers. For early readers at the initial stages of reading, phonological decoding is a primary means of reading new words (Elbro & de Jong, 2017) and children are less likely to draw on higher order processes to read irregular words. It would be interesting to track how children respond to, and correct mispronunciations for, irregular words across development from early to skilled reading.

It also remains possible that mispronunciation correction for English readers looks different than it does for readers of more consistent orthographies and thus the findings here do not generalise to readers in all alphabetic orthographies. It has been observed that English is an outlier in terms of orthographic consistency, and that children reading in other alphabetic orthographies experience fewer difficulties in developing reading accuracy (Seymour, Aro, & Erskine, 2003). Comparative studies of mispronunciation correction using similar methodologies reported in this paper may provide some answers about how readers of more consistent orthographies respond to, and correct mispronunciations of, the fewer irregular words they encounter. Elbro, de Jong, Houter, and Nielsen (2012) found that that an association between mispronunciation correction and word reading accuracy also exists for children reading in Dutch, which is considered a consistent orthography, and in Danish, which has a moderately inconsistent orthography. If mispronunciation correction is a predictor of reading for words in all alphabetic orthographies, it may also be observable in eye movements of non-English readers, and this would be a direction for future studies to take.

Previous research on mispronunciation correction has included training studies to test the utility of explicitly teaching mispronunciation correction as a means of improving word reading accuracy (Dyson, Best, Solity, & Hulme, 2017; Savage, Georgiou, Parrila, & Maiorino, 2018; Zipke, 2016). Eye movement monitoring may be a way of indexing changes in processing of irregular words over time in future training studies. If word reading accuracy can be linked to eye movements, then it may be possible to deduce the extent to which mispronunciation correction is important for the accurate reading of regular compared to irregular words.

Broader Theoretical Implications

The results of the reported study further illustrate how closely language and word reading are linked, and that children's processing of words that they see during their independent reading is likely to be a function of many factors, including their phonological knowledge, knowledge of meaning, and the context in which a word is seen. Although phonological decoding underpins accurate word reading, as reading skill develops diversity of experience with words in both their oral and written form become integrally important to achieving skilled reading. Nation (2017) describes this as a "lexical legacy" and hypothesises that words are embedded in the lexicon only through a range of rich and diverse contextual experiences. Lexical legacy might have especially strong implications for how children learn irregular words. For example, readers can know the phonology and meaning of the word "yacht" in the oral domain but not associate it with the word *yacht*, that they encounter in their reading. The child may comfortably hold two lexical representations of the word: the phonological pronunciation "yot" and the spelling pronunciation "yatch-t" for some time. Making the connection between the two requires time and experience.

In conclusion, the reported findings add to a growing body of research on mispronunciation correction. Consistent with previous research, we found that having a word in oral vocabulary confers an advantage for accurately reading the word, especially when it is irregular (e.g., Wang et al., 2011; Wang et al., 2012). Evidence also suggested that context could enhance accuracy when reading irregular words. As predicted by the theory that mispronunciation correction mediates word reading accuracy, the current findings showed that, compared to orally known regular words, orally known irregular words undergo some additional processing when they are viewed for the first time. This is important converging evidence for the theory. Additionally, to our knowledge this represents the first study to utilise eye movement monitoring to index online processing of novel regular and irregular words, and adds to a growing trend of employing eye tracking studies to acquire information about what happens at a cognitive level during reading development.

Chapter 4

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Appendices

Appendix A

Word Lists with Matched Random Letter Strings

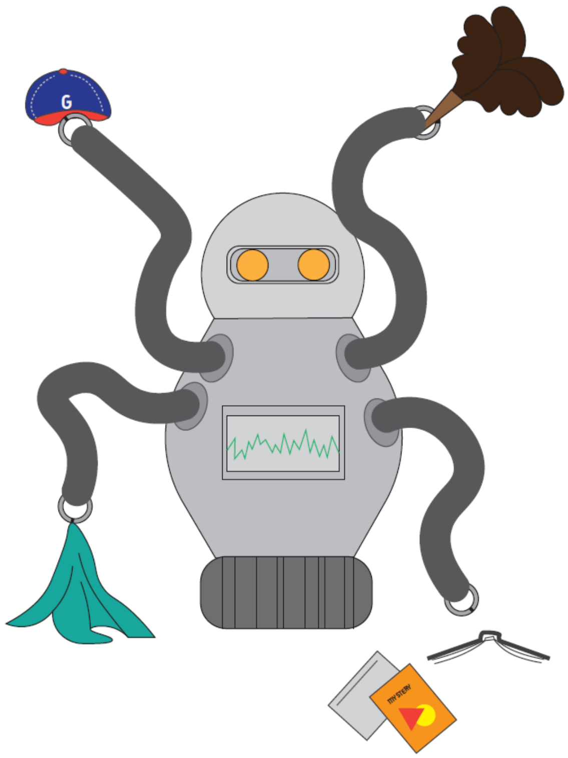
Table 12

Novel word targets presented with orthographically regular and irregular pronunciations

List	Orthography	Regular Pronunciation	Irregular Pronunciation
List A	praif	/preɪf/	/praɪf/
	shab	/ʃæb/	/ʃɒb/
	trome	/trəʊm/	/trɒm /
	hoab	/həʊb/	/hɔːb/
	frone	/frəʊn/	/frʌn/
	forch	/fɔːʧ/	/fɜːʧ/
	glert	/glɜːt/	/glɑːt/
	leam	/liːm/	/lɛm/
	drine	/draɪn/	/drɪn/
	cleap	/kliːp/	/kleɪp/
	broon	/brʊn/	/brʌn/
	plim	/plɪm/	/pliːm/
	clait	/kleɪt /	/klæt/
	ferb	/fɜːb/	/fɑːb/
	vaik	/veɪk/	/vaɪk/
	scrug	/skrʌg/	/skrʊg/
List B	theak	/θiːk/	/θɛk/
	jert	/ʤɜːt/	/ʤɑːt/
	chaim	/ʧeɪm/	/ʧæm/
	shog	/ʃɒg/	/ʃʌg/
	prile	/praɪl/	/prɪl/
	creab	/kriːb/	/kreɪb/
	grud	/grʌd/	/grʊd/
	mife	/maɪf/	/miːf/
	vodd	/vɒd/	/vʌd/
	taith	/teɪθ/	/tɑːθ/
	joat	/ʤəʊt/	/ʤɔːt/
	slersh	/slɜːʃ /	/slɑːʃ/
	jash	/ʤæʃ/	/ʤɑːʃ/
	prine	/praɪn/	/prɪn/
	borve	/bɔːv/	/bɜːv/
	skote	/skəʊt/	/skʌt/

Appendix B

Example of illustration used during oral training



Appendix C

Table 13

Experimental Sentences.

	Semantically Congruent Sentences	Semantically Neutral Sentences
1.	Max's hands were wet so he made a phone call with his borve to help him.	Max's day was over so he left everything with his borve to walk home.
2.	Nick put the deck of cards into the broon to sort them.	Nick sat down in the chair beside the broon to watch it.
3.	The boy with the dog took balls to the chaim on the ground.	The boy in the park ran over to the chaim on the ground.
4.	Joe took his dry texta to the clait when he needed it again.	Joe took his friends to see the clait when they came to visit.
5.	Alice was thirsty and used her cleap to not miss any play time.	Alice was playing and used her cleap to not miss any more time.
6.	Ben made his toast very quickly when he used the creab on school days.	Ben saved a lot of time when he used the creab on school days.
7.	Ella’s ice cream was dripping so the drine was very useful.	Ella's old tool was broken so the drine was very useful.
8.	Jan took her dull flowers over to the ferb to clean them.	Jan stood and ate cake by the ferb to have a rest.
9.	Abdi had very cold feet and needed the forch when he came home.	Abdi had a good idea to use the forch when he sat down.
10.	Ali fell over but the frone made sure it was all okay.	Ali's good friend with the frone made sure he was there to help.
11.	The girl put a plate with some food under the glert as she waited.	The girl put a heavy box down on the glert as she waited.
12.	Kate was getting rained on so she used her grud while she was walking.	Kate was getting bored so she used her grud while her father waited.
13.	John and his dog talked using the hoab and then went for a walk.	John and his son talked and used the hoab and then went out.
14.	Peter was sweating and he used his jash when he went outside.	Peter was busy and he used his jash when he left home.
15.	Mia wanted some orange juice so she got the jert from the cupboard.	Mia wanted to be quick so she got the jert from the cupboard.
16.	Charlie wanted crispy fries and he used the joat to make them better.	Charlie pushed the buttons and used the joat on the playground.
17.	The bird flew down and landed on the leam out in the back yard.	The boy jumped down and landed by the leam out in the back yard.
18.	Lucy had a pebble in her shoe so she used the mife when she was running.	Lucy had a bag in her house where she put the mife when she went out.
19.	Sam dropped his soaking wet hat onto the plim and went inside.	Sam dropped his shopping bags next to the plim and went inside.
20.	Jay forgot the girl’s name and wanted a praif to help find out.	Jay forgot his school bag and wanted a praif to help him out.
21.	She put all her school books in the prile and she left the room.	She put all her bags by the prile and she left the room.
22.	Rose sorted the socks with her prine when she was doing her jobs.	Rose wanted to keep using her prine when she finished the job.
23.	Jack’s room was messy so he used the scrug in the cupboard.	Jack's house was huge so he put the scrug in the cupboard.
24.	Abby climbed a wall with her shab to have fun.	Abby liked to play with her shab to have fun.
25.	Zoe’s soup was too hot so she found her shog to finish it quickly.	Zoe needed to be quick so she found her shog to save some time.
26.	Tom did not want sunburn so he used the skote when he went outside.	Tom wanted to go shopping and he used the skote when he went there.
27.	Liam’s bed was unmade and he used his slersh before mum came home.	Liam was running too fast and dropped his slersh before he used it.
28.	Josh put all the rubbish in the taith when he wanted to be tidy.	Josh opened up the cover on the taith when he wanted to fix it.
29.	James rode in the river with his theak to get to work.	James set off for work with his theak to use later on.
30.	Harry did not like the dark so the trome helped him very much.	Harry did not like feeling sad but the trome helped him very much.
31.	The fish in the dirty tank swam around the vaik as it worked.	The boy in the blue shirt walked around the vaik as it worked.
32.	Ben needed help with his homework so he used the vodd and lay down.	Ben needed help to get things done so he used the vodd and sat down.

Appendix D

Table 14

Results of omnibus models examining the effects of regularity, context and training and their interactions on eye movement measures

		Regularity (regular, irregular)	Training (trained, untrained)	Context (neutral, context)	
Main effects	First fixation	*b* = 0.02, SE = .017, *t* = 1.20, *p* = .23	*b* = -0.02, SE = .017, *t* = -1.47, *p* = .14	*b* = -0.01, SE = .017, *t* = -0.89, *p* = .37	
	Gaze duration	*b* = 0.086, SE = .002, *t* = 3.64, *p* < .001*	*b* = -0.01, SE = .002, *t* = -0.53, *p* = .60	*b* = 0.02, SE = .023, *t* = 0.71, *p* = .48	
	Regressions in	*b* = 0.23, SE = 0.10, *z* = 2.29, *p* = .02*	*b* = -0.12, SE = .099, *z* = -1.16, *p* = .24	*b* = -0.12, SE = .099, *z* = -1.24, *p* = .21	
	Total reading time	*b* = 0.14, SE = .025, *t* = 5.63, *p* < .001*	*b* = -0.09, SE = .024, *t* = -3.74, *p* < .001*	*b* = -0.03, SE = .023, *t* = -1.37, *p* = .17	
		Training x Regularity	Training x Context	Regularity x Context	Training x Regularity x Context
Interactions	First fixation	*b* = 0.05, SE = .033, *t* = 1.65, *p* = .09	*b* = 0.02, SE = .081, *t* = 0.72, *p* = .48	*b* = 0.02, SE = .033, *t* = 0.74, *p* = .46	*b* = 0.02, SE = .066, *t* = 0.33, *p* = .74
	Gaze duration	*b* = 0.15, SE = .041, *t* = 3.68, *p* < .001*	*b* = -0.01, SE = .120, *t* = -0.05, *p* = .96	*b* < -0.01, SE = .041, *t* = -0.09, *p* = .93	*b* = 0.11, SE = .086, *t* = 1.26, *p* = .21
	Regressions in	*b* = 0.22, SE = .199, *z* = 1.15, *p* = .25	*b* = 0.12, SE = .372, *z* = 0.32, *p* = .75	*b* = 0.36, SE = .199, *z* = 1.82, *p* = .07	*b* = 0.63, SE = .397, *z* = 1.60, *p* = .11
	Total reading time	*b* = 0.18, SE = .042, *t* = 4.26, *p* < .001*	*b* = 0.07, SE = .145, *t* = 0.47, *p* = .64	*b* = 0.11, SE = .042, *t* = 2.70, *p* = .007*	*b* = 0.14, SE = .100, *t* = 1.43, *p* = .15

Note. * denotes statistically significant results

Table 14

Results of models examining the effects of regularity, context and training and their interactions on post-exposure reading accuracy.

	Regularity (regular, irregular)	Training (trained, untrained)	Context (neutral, context)	
Main effects	*b* = -6.35 SE = .041 *z* = -14.74 *p* < .001*	*b* = 2.50 SE = .034 *z* = 7.60 *p* < .001*	*b* = 0.32 SE = .031 *z* = 1.39 *p* = .17	
	Training x Regularity	Training x Context	Regularity x Context	Training x Regularity x Context
Interactions	*b* = 0.96 SE = 0.525 *z* = 1.83 *p* = .07	*b* = 0.65 SE = 0.572 *z* = 1.13 *p* = .26	*b* = 0.11 SE = 0.425 *z* = 0.27 *p* = .79	*b* = 1.16 SE = 1.216 *z* = 0.95 *p* = .34

Note. * denotes statistically significant results.