Oral Vocabulary and Learning to Read Morphologically Complex Words: Mechanisms of Influence

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Thesis Summary

It is well-established that there is a causal relationship between oral vocabulary and written word reading. However, it is not clear in what ways oral vocabulary facilitates reading and how morphological information interacts with this facilitation. This thesis aims to examine a cognitive mechanism recently proposed to explain the facilitatory role of oral vocabulary on reading and the potential role of morphology on the use of this cognitive mechanism.

Chapter I consists of a literature review in order to present an overview of the relevant evidence for oral vocabulary being causally associated with reading. Possible cognitive mechanisms are discussed. One such mechanism, the *orthographic skeleton* hypothesis, which is tested in the present study, is described in detail. The chapter further overviews the evidence on how readers use their morphological knowledge while reading and how orthographic skeletons could be linked with reading morphologically complex words. The type of morphological complexity (inflection and derivation) as well as their relevance to skeletons and reading in general are discussed.

Chapter II is an empirical investigation of the skeleton hypothesis for two types of morphologically complex novel words (inflected and derived) using a novel oral word learning paradigm, followed by one of two written tasks: self-paced reading or lexical recognition. The first aim was to test whether orthographic skeletons were formed for the stems (i.e., bases) of morphologically complex words upon oral training of these complex words, whereas the second aim was to investigate whether orthographic skeletons were formed independently of affix type. The main findings relate to lexical recognition and indicated that orthographic skeletons are built for the stems of complex words, and this is not dependent on the type of affix. Interactions between phonology, orthography and morphology during the process of reading new words are discussed.

Statement of Originality

*This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself***.**

The ethics clearance for this research project has been obtained from the Human Research Ethics Committee of Macquarie University (Project ID: 6499; 52021649930452 - Tracking children's word learning during independent reading).

(Signed) **Date: 02.06.2022**

Esra Ataman

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CHAPTER I

Literature Review: Interactions between Oral Vocabulary, Orthographic Skeletons and Morphological Complexity

Abstract

Oral vocabulary knowledge has consistently been associated with success in written word reading, but the mechanism of this association is not well understood. Recently, Wegener et al. (2018) proposed that, when words are present in oral vocabulary, skilled readers may form expectations of the spellings of those words (or *orthographic skeletons*) even before they have seen them in print. This then supports their reading when they first encounter the printed words, so long as the expected spelling matches the actual one. Although there is compelling evidence for this mechanism in the case of morphologically simple words, little is known about the extent to which this process applies in the case of morphologically complex words. Furthermore, morphologically complex words come in different types (inflected and derived), and it is not known whether these different word types induce similar or different processing patterns.

The aims of this literature review were: (a) to review the evidence for a causal relationship between oral vocabulary and written word reading coming from various longitudinal, item-level and novel word learning studies; (b) to outline the evidence for an orthographic skeleton mechanism operating on morphologically simple words, and (c) to describe research which suggests that readers are sensitive to morphological information during reading. Finally, we report on studies investigating the similarities and differences between different types of morphologically complex words, all of which motivated the empirical study reported in Chapter II.

1. Introduction

Oral vocabulary refers to knowledge about the pronunciations and meanings of spoken words. Spoken word knowledge has been causally implicated in the process of learning to read new words (Duff et al., 2015; Duff & Hulme, 2012; Hogaboam & Perfetti, 1978; Lee, 2011; McKague et al., 2001) [1]. Recently, there has been an interest in exploring the cognitive mechanisms that might underpin this association. One proposed mechanism suggests that, when a spoken word is known, readers use their knowledge of mappings between spoken speech sounds and letters to make predictions about the likely spellings of words. These predictions have been termed *orthographic skeletons* (Wegener et al., 2018).

Parallel to this is a growing appreciation of the importance of morphological information, and how it contributes to reading new words (Beyersmann et al., 2021). To become proficient readers, children not only need to master the reading of monomorphemic words (e.g., *work*) but also polymorphemic words, including both inflected (e.g., *worked*) and derived (e.g., *worker*) word forms (Brysbaert et al., 2016). Considering that readers use their morphological knowledge to derive form-meaning relationships between words and their embedded constituents (Rastle, 2019), there is a need to understand what happens when readers encounter morphologically complex printed words and how this relates to their existing knowledge of the words in oral form.

Reading or recognising a word requires different cognitive processes to operate in collaboration. These cognitive processes include not only morphological processing but also phonological decoding, grapheme-phoneme mapping, and syntactic and semantic processing (Martin, 2003; Yap & Balota, 2015). Forming orthographic skeletons has been found to be one of the cognitive mechanisms which supports novel word reading by allowing readers to form

[1] Throughout this thesis, APA 7th edition guidelines have been followed. Accordingly, studies with three or more authors were cited with "et al." for all in-text references including their first appearance in text.

expectations of the spellings of words even before these words are seen in print (Beyersmann et al., 2021; Wegener et al., 2018, 2020). However, research on this mechanism has primarily focussed on simple monomorphemic words, and little is understood about how it operates in the case of the many different types of morphologically complex words to which individuals are exposed to in spoken and written form.

In this review, we provide an overview of the research on the association between oral vocabulary and written word reading, which lays the foundation for the introduction of the orthographic skeleton hypothesis. We then move on to considering morphological complexity, and how morphological information is processed by individuals when reading. We consider the distinction between derivational and inflectional morphology, leading us to present the rationale behind the empirical study reported in Chapter II.

2. Interactions between Oral Vocabulary Knowledge and Written Word Reading

2.1.Longitudinal Studies

Longitudinal studies examining the relationship between oral vocabulary and reading development use individual differences in an earlier measured skill (e.g., vocabulary size) to predict later performance on another task (e.g., picture vocabulary, reading comprehension, or reading accuracy). This approach is useful because it identifies factors that could plausibly make a causal contribution to the development of a skill. Two longitudinal studies have assessed the oral vocabulary skills of children and related these to early spoken language skills, with subsequent reading achievement measured during the early school years (Duff et al., 2015; Lee, 2011). Both studies found that a small but highly significant amount of variance in reading ability in later ages could be explained by the vocabulary knowledge of children (especially vocabulary size; .33 for reading accuracy and .43 for reading comprehension in Duff et al.,2015). There is also some evidence for this relationship operating during the early years of formal schooling. For example, Nation and Snowling (2004) investigated the longitudinal relationship between oral vocabulary assessed at 8.5 years of age and subsequent reading achievement assessed at nearly 13, and found a significant relationship between the two skills (but see Muter et al., 2004). Together, these studies provide converging evidence that oral vocabulary could reasonably play a causal role within the process of learning to read.

2.2.Cross-sectional item-level correlational studies

Cross-sectional item-level studies ask whether knowing a particular spoken word is beneficial for reading that word. Accordingly, item-level relationships are examined by relating an individual's knowledge of words in the oral domain (pronunciations and meanings) with their ability to read those same words. Nation and Cocksey (2009) administered three tasks to a sample of 7-year-old children, with each task separated by one week. The children listened to spoken words and decided whether they recognised the pronunciations, heard the same words and provided their definitions, and then read the same words aloud. Half of the words were regular for reading (e.g., *collect*) while the other half were irregular (e.g., *rhythm*). An item-level association was found between oral vocabulary knowledge and reading aloud, with fewer errors found for orally known words than for orally unknown words. This was the case for both regular and irregular words although the relationship was stronger for irregular words. Lexical phonology was found to be essential whereas the presence of semantic knowledge did not appear to convey any additional benefit.

Using a very similar item-level design, Ricketts et al. (2016) required 6- and 7-year-old children to recognise the spoken form of words and define them. Later, the children were asked to read the words aloud. Items included both regular and irregular words, and the words were read both in isolation and within meaningful sentence contexts. The results suggested the presence of an item level relationship between spoken word knowledge and reading for both regular and irregular words. Additionally, the ability to provide word definitions was a stronger predictor of reading accuracy than knowledge of lexical phonology. Thus, the results of Nation and Cocksey (2009) and Ricketts et al. (2016) both support the existence of an item-level relationship between oral vocabulary and word reading, but the former gives more weight to the contribution of lexical phonology to reading while the latter suggests an additional role for semantics.

Kearns and Al Ghanem (2019) attempted to distinguish the roles of item-specific and general semantic knowledge within reading. To this end, they assessed both individual word knowledge and also children's overall vocabulary size as an indicator of general semantic knowledge and sought to evaluate the association between this knowledge and reading performance. Parts of morphologically complex words (e.g., *work* + *-er* in *worker*) also make a semantic contribution to the whole word meaning (*-er* adds the meaning of somebody performing a specific action). For this reason, the authors also included morphological awareness as part of semantic knowledge (see the 'Morphological Complexity' section below for a detailed discussion). Two groups of children – those who were typically developing and those with reading difficulties – took part in both individual item-specific and general standardised tests of their phonological, orthographic and semantic knowledge. Children completed three item-specific tests. First, they chose the target word with the correct spelling from among four options (i.e., orthographic knowledge). Second, they listened to the target word and then were expected to pronounce it correctly (i.e., phonological knowledge). Lastly, they were required to decide on whether the sentences containing the target word made sense (i.e., semantic knowledge). In order to measure general knowledge, one or more standardised tests for each type of knowledge were administered. Items were made up of polysyllabic words (with either one or more than one unit/s of meaning). The authors found that both item-specific and general semantic knowledge accounted for significant variance in children's reading, in addition to their phonological and orthographic knowledge. However, the effect of general semantic knowledge disappeared when morphological awareness was added as a predictor. Taken together, these findings were interpreted as evidence for the presence of an association between item-specific as well as general semantic knowledge, as well as morphological awareness, and reading performance.

In sum, the findings of item-level studies all suggest that knowing the spoken form of a specific word facilitates reading of that word, but the contribution of meaning knowledge to word reading is somewhat less clear.

2.3.Novel Word Training Studies

Each of the experiments discussed to this point have been correlational in nature, and as such cannot provide strong evidence regarding the question of whether the relationship between oral vocabulary and reading might be causal. As noted by Hulme and Snowling (2013), the most persuasive evidence for the existence of causal relationships is derived from training studies. Applied to the oral vocabulary – word reading link, training studies typically use novel word training designs in which participants are first taught the oral form of novel words (pronunciations with or without meanings). Following oral training, participants are exposed to the orthographic form of the same words for the first time in print in the context of a reading task (e.g., reading aloud, silent reading or lexical decision). Importantly, participants also typically read words from a control condition that consists of matched items that are orally untrained, permitting a comparison between the reading of orally familiar and orally unfamiliar items the first time they are seen in print. This design provides tight control over the participants' prior oral vocabulary knowledge when they come to the task of reading.

Several studies have used such a novel word training study design to investigate the relationship between oral vocabulary and word reading. The first such experiment occurred over 40 years ago and was reported by Hogaboam and Perfetti (1978). In their second experiment, Grade 4 children received training in pronunciations alone, or in pronunciations with associated meanings in oral form. There was also an untrained condition in which none of the items had been orally trained. In the pronunciation training condition, children only listened to the experimenter's pronunciation of the word and repeated it. In the pronunciation and meaning training, they were also exposed to the meaning and a picture of the target word. Following training, children saw all the words for the first time in print and were required to read them aloud: items were taken from both oral training conditions and from the untrained condition. Reading aloud latencies were shorter when participants had been given oral training than when they had not, consistent with a benefit of words being in oral vocabulary prior to the first reading encounter. Furthermore, the addition of meaning component into oral training did not affect reading aloud latencies.

Likewise, McKague et al. (2001) examined whether oral training of novel words could help Grade 1 children to read them when they saw the written form of these words for the first time. Children were first trained on the spoken form of novel words. The type of training was also manipulated: either pronunciations alone, or pronunciations with associated meanings. There was also an untrained condition. Following a delay of 2-3 days, children read aloud the trained and untrained novel words. A benefit was found on children's word reading accuracy and latency when words had been taught orally prior to reading, and this benefit was present regardless of the type of training. Using a similar novel word learning study design, in their second experiment, Duff and Hulme (2012) investigated whether the type of oral training (i.e., no training, phonological training only or phonological plus semantic training) affected 5- and 6-year-old children's reading of novel words. The results revealed that both phonological and phonological plus semantic training improved reading accuracy compared to no training. Moreover, no difference was found between two types of oral training conditions. Together, the findings from these three training studies with young children suggest that prior knowledge of spoken word forms is associated with a benefit to reading accuracy and/or efficiency, while knowledge of word meanings does not appear to consistently convey any further benefit.

Taylor et al. (2011) used an artificial orthography paradigm with skilled readers to explore the relationships between oral familiarity, consistency and frequency. The type of oral pre-training participants received prior to reading was manipulated. Participants were taught either the pronunciations alone, or the pronunciations and meanings of a set of words, while another set received no oral training (i.e., untrained condition). Orthographic items were considered to be consistent if there was a character-phoneme correspondence that was pronounced the same way across all items containing that character. Furthermore, vowel frequency was manipulated as high and low based on the number of words the vowels occurred in throughout the experiment. Following oral pre-training, participants then learned to read the items. During this stage, participants were exposed to the orthographic form of the items; they read and repeated them. Following this, participants were asked to decide whether an item was the one they saw in the previous stages and also read aloud some other words formed with the same characters in similar ways to test whether readers could generalize what they had learned. The results revealed that participants found it easier to learn consistent and high frequency novel words. Further, oral pre-training benefited reading accuracy early in the course of learning to read the novel items, compared to the orally unfamiliar untrained items. By the end of the training, however, prior phonological and semantic knowledge only facilitated reading for inconsistent items of low frequency. Thus, these findings were interpreted as showing different roles for aspects of spoken word knowledge within reading, such that phonology plays a role early in learning whereas semantics contributes later with increasing skill, especially when items have inconsistent mappings between written characters and phonemes (Taylor et al., 2011).

3. The Timing of Facilitation: Upon or Prior to Print Exposure?

3.1. Influences arising from the point of visual exposure

Most accounts suggest that oral vocabulary knowledge exerts an influence on reading accuracy and efficiency upon exposure to a novel written word form. For instance, the prominent *self-teaching hypothesis* explicitly makes this assumption (Share, 1995, 2008). In this hypothesis, it is suggested that phonological decoding drives orthographic learning. Vocabulary is thought to provide assistance within this process when readers phonologically decode a word but arrive at an incorrect pronunciation for the word that they do not recognise. Under these circumstances, they might draw on their vocabulary knowledge and the surrounding context, resulting in a revision of their decoding attempt. Thus, oral vocabulary is conceived of as helping readers to refine the mappings between orthographic forms and known spoken words in a top-down manner (Wegener et al., 2020).

The idea that readers might need to revise their decoding attempts in light of their oral vocabulary knowledge is not new. In fact, ideas of this sort can be traced back to a much earlier theory called *set for variability* (Gibson & Levin, 1975). More recently, this process has been termed *mispronunciation correction* (Dyson et al., 2017). Common to all of these descriptions is the basic idea that when readers encounter a new printed word, they apply their knowledge of grapheme-to-phoneme mappings to produce a pronunciation, which then needs to be matched with a word in their oral vocabulary. This trial-and-error process is likely to be more salient for irregular than regular words due to inconsistencies in the spelling to pronunciation mappings for irregular items.

There is some evidence supporting the view that processes such as these, operating from the point of visual exposure, could play a role in reading acquisition. For instance, Tunmer and Chapman (2012) showed that the ability to adjust pronunciations to match known spoken words in Grade 1 correlated with the reading of irregular words in Grade 3 using a longitudinal design. Similar results have also been reported in a longitudinal study in Dutch and Danish (Elbro et al., 2012). More recently, Steacy et al. (2019) tested children in Grades 2 to 5 and found that their ability to orally correct mispronunciations was a significant predictor of irregular word reading at both the item-level and participant-level. Further, several intervention studies have shown that children can be taught to use a mispronunciation correction strategy (Dyson et al., 2017; Savage et al., 2018; Zipke, 2016) although a benefit to reading is typically confined to trained words and does not generalise to untrained irregular words.

3.2. Influences operating prior to visual exposure

While there is support for the existence of a cognitive mechanism that operates from the point of visual exposure, an alternative and complementary possibility exists: oral vocabulary might also exert an influence on reading even before a word is seen in print for the first time. In

1988, Stuart and Coltheart suggested that a child might be able to develop a store of orthographic representations prior to learning to read, provided they were able to segment spoken speech sounds and knew correspondences between letters and their sounds. However, this idea was never tested.

The idea that oral vocabulary might influence reading prior to visual exposure was raised again by Johnston et al. (2004) and tested for the first time. Skilled readers were provided with oral training in the pronunciation and meaning of a set of unfamiliar words. Later, participants completed a masked priming lexical decision task in which primes (identical and all-letters different control) were presented first for a very brief time prior to targets (familiar real words, orally trained novel words and untrained nonwords). The results revealed a processing advantage for identical primes compared to controls for both familiar and novel targets but not for nonwords, suggesting that oral training had given rise to orthographic representations that were discernible on a measure of automatic word recognition. McKague et al. (2008) reported similar findings: following oral training, robust masked identity and form priming effects were observed for orally trained words at their first visual exposure, which were interpreted as being consistent with the idea that partially specified orthographic representations of orally known words were able to be accessed automatically at the first visual exposure.

On this background, Wegener et al. (2018) proposed the *orthographic skeleton hypothesis*. In this hypothesis, when a word is known in spoken form, it is possible to draw on one's knowledge of mappings between phonemes and graphemes to develop orthographic skeletons, or expectations about the spellings of words that have not yet been seen in writing. To test this hypothesis, Wegener et al. (2018) used a novel word training study design in which Grade 4 children were given oral training on a set of novel words (e.g., *vish*). The novel words were presented as Professor Parsnip's inventions (e.g., "*vish*- a machine to shuffle cards"). During training, children were exposed to the picture, name and function of each invention. After training, they participated in an eye-tracking task, in which they saw sentences containing the novel words for the first time. Half of the words were orally trained while the other half were untrained. Spelling predictability was also manipulated. For half of the words, the spelling was predictable (e.g., "vish" was written as *vish*) whereas for the other half, it was unpredictable (e.g., "jaif" was written as *jayf*). Importantly, all of the words were regular for reading (i.e., they all used the most common pronunciation for each grapheme). The results revealed that less time was spent fixating trained compared to untrained words and predictable compared to unpredictable words. Additionally, there was a significant interaction between training and predictability. Specifically, the difference in fixation durations for trained words with predictable versus unpredictable spellings was much larger than the corresponding difference in fixation durations for untrained items with predictable versus unpredictable spellings. This interaction between training and predictability was interpreted as the key indicator that children had formed orthographic expectations.

These findings have recently been replicated: Using the same design, Wegener et al. (2020) also found an interaction between training and spelling predictability at the first and second visual exposure to orally trained and untrained items, supporting the suggestion that children can generate expectations of the spellings of orally known words.

Converging evidence for this mechanism has also recently been reported in the Spanish language, which has shallower orthography than English. Jevtović et al. (2022) taught native Spanish speakers a set of novel spoken words. Subsequently, the readers encountered the trained items and a matched set of untrained items for the first time in print in the context of an online self-paced reading task. The authors took advantage of the fact that many sounds in Spanish can be represented by just a single written letter, whereas other speech sounds can be represented by one of two possible letters. Using this observation, their experiment had three spelling conditions. Consistent items were novel words with only one possible spelling, whereas inconsistent items had two possible spellings. Using a spelling pre-test, the authors established participants' idiosyncratic spelling preferences for the inconsistent items. When participants completed the task, they were shown the words in writing in the context of the self-paced reading task, with half of the inconsistent items in the participant's preferred spelling, while the other half were shown in their non-preferred spelling. The results showed longer reading times for the inconsistent unpreferred condition compared to the consistent and inconsistent preferred conditions, but only for the trained items. There were no differences in reading times for the untrained items. This pattern of findings was interpreted as evidence that participants had formed orthographic skeletons for the trained items, which influenced processing times when there was a mismatch between expectation and form.

Thus, preliminary findings from both English and Spanish provide converging evidence that the formation of orthographic skeletons is a plausible cognitive mechanism through which spoken word knowledge supports written word processing prior to exposure to orthographic form.

4. Morphological Complexity

4.1.The Role of Morphological Information

Studies conducted on orthographic skeletons to date have focused almost exclusively on monomorphemic words; that is, words without any affixes (with the exception of Beyersmann et al., 2021, described below). However, developing and skilled readers' exposure is not limited to monomorphemic words. On the contrary, readers are equally or even more frequently exposed to morphologically complex words in their day-to-day reading. For instance, readers are exposed not only to the word *clip* but also to words such as *clipboard, clipping, clipper* while reading a book or a newspaper, scrolling through the internet or social media. However, although the knowledge base on processes involved in reading morphologically simple words is vast, there is a lack of knowledge or evidence showing how readers benefit from their oral vocabulary when processing morphologically complex words in print. Below we report evidence from two lines of research, both of which are relevant to the current investigation: studies investigating the role of morphological awareness on reading, and masked priming studies examining the automaticity of morphological processing during early visual word recognition.

Before moving onto the details of these studies, it is important to explain why morphological information is important for reading and reading development. First, readers may benefit from morphological processing when pronouncing individual words (pronouncing *react* vs. *reading* where the letter string *ea* marks morpheme boundary in the former but not in the latter; Deacon & Kirby, 2004). Furthermore, morphemes are regarded as the smallest meaningful units in any language (Rastle et al., 2004; Taft & Kougious, 2004). This unit could be a root (e.g., *work* in *working*), an affix (*-er* in *worker* or *un-* in *unhappy*), or a word (e.g., *fly* in *butterfly*) (James et al., 2021). Morphological information is thought to provide regularities for bringing form and meaning together (Rastle, 2019), and skilled readers have been found to show sensitivity to these regularities (Ulicheva et al., 2020). In other words, as readers are exposed to the same form (e.g., *clip*) with the same meaning (e.g., *video clip*, *clipped*, *clipper*) on different occasions (e.g., sentential contexts), they learn to associate this form with this specific meaning, which is in turn transformed into a regularity. Being expert at using these regularities is part of becoming a skilled reader, considering the prevalence of morphologically complex forms in alphabetic languages (Beyersmann et al., 2020; Hasenäcker et al., 2017; Rastle, 2019).

4.2.Studies on Morphological Awareness

Morphological awareness studies show that readers' sensitivity to morphological information predicts their reading skills. Morphological awareness is conceptualised based on whether readers can consciously recognise and manipulate the morphemes within a word (Carlisle, 2000; Deacon & Bryant, 2006; James et al., 2021; Manolitsis et al., 2019). A cautionary note here is that the term "morphological awareness" has been used in a range of different ways in the literature, in relation to both spoken and written words, and employing a wide range of tasks. We have therefore sought to be specific in relation to each study we describe, as these differences may have implications for understanding the processes involved.

A number of studies have examined whether being aware of the morphemic structure and meaning of spoken or written morphologically complex words (i.e., inflected, derived or compound words) predicts the comprehension of those words for children in different ages (e.g., 3-5 or 6-13 years old; Carlisle, 2003; Deacon & Bryant, 2006; James et al., 2021; Kirby et al., 2012). These tasks used included but were not limited to finding and reading aloud the stem of a morphologically complex spoken word (Carlisle, 2000) or making an analogy (i.e., seeing/hearing a morphologically related pair like *walk-walked* and being asked to produce a similar spoken or written pair for another word like *run-?*) (James et al., 2021). The results have provided supporting evidence for morphological awareness as a significant and unique predictor of reading comprehension for children at different ages.

There are also studies conducted with adults focusing on morphological awareness. For example, Guo et al. (2011) examined whether morphological awareness of adults was a significant and direct predictor of reading comprehension. They utilised a task called grammatical application, which was a revised version of the Wug test designed by Berko (1958). In the original Wug test, children were presented with a novel oral word, accompanied by its picture (e.g., This is a *wug*.), and then were required to produce the corresponding inflected form (e.g., Now, there are two of them. There are two ____.). Inflectional affixes were not confined to plural markers. However, in the revised version, only pluralisation, verb conjugation (i.e., different forms of a verb like *works*, *worked* etc.) and comparative/superlative forms of adjectives were tested. Also, unlike the original version, the task was administered in written format without pictures, as the target audience were adults. It was found that the performance on the grammatical application task, as an indication of morphological knowledge, significantly predicted reading comprehension. In other words, recognising morphemes of a word and being able to produce complex forms of that word significantly predicted its comprehension. This result supports the idea that morphological awareness is a direct and unique predictor of reading comprehension, even for skilled readers.

In another line of research, a role for morphological awareness has also been shown in adults with low literacy (Tighe & Binder, 2015; To et al., 2016). To et al. (2016) used two different tasks: one in which participants were expected to decompose the derived words (e.g., *driver*) and come up with the root/stem (e.g., *drive*) to fill in the blanks in the given sentence orally and one where they were expected to say the derived form of a stem. The results of two groups of participants (a group of adults having low literacy and a control group of skilled readers) showed that morphological awareness significantly and uniquely predicted reading comprehension as well as individual word reading not only for skilled readers but also for adults with low literacy. They also showed that phonological (e.g., *major-majority*) but not orthographic change (*happy-happiness*) between the stem and the derived form was more detrimental for adults with low literacy compared to typical readers.

In sum, morphological awareness studies have utilised both spoken and written tasks, and although these studies provide evidence for both developing and skilled readers' recognition of morphemes within morphologically complex words regardless of the task used, the questions of how and under which conditions this recognition takes place remain. More direct evidence to answer these questions comes from masked priming studies.

4.3.Masked Morphological Priming

In the past few decades, masked priming has been widely used, across a variety of languages, to examine morphological processing during the early stages of visual word recognition (for reviews, see Amenta & Crepaldi, 2012; Rastle & Davis, 2008). In a typical masked morphological priming paradigm, morphologically complex words (e.g., *worker*, *working*) are presented as primes. Then, the target word, which is the root/stem of the morphologically complex word (e.g., *work*) appears and participants are asked to decide whether the target word is an existing word in the given language. If the facilitation acquired from this morphologically related prime-target pairs is similar to an identity condition (e.g., *work-work*) and greater than an unrelated control condition (e.g., *door-work*), this indicates that readers decompose complex words into sub-units and gain access to the embedded stem (Rastle & Davis, 2003).

Another prominent debate surrounding these studies is whether morphological decomposition is unique to semantically transparent prime-target pairs (e.g., *worker-work*) or whether it is also possible to observe the same priming effect for semantically opaque (or "pseudo-suffixed") pairs such as *corner-corn* (Rastle et al., 2004; Rastle & Davis, 2003). While some studies have supported the presence of priming in both semantically transparent and opaque conditions (Beyersmann et al., 2016; Heyer & Kornishova, 2018; Kazanina et al., 2008; Rastle et al., 2004), other studies suggest a greater magnitude of priming in semantically transparent condition compared to the opaque condition (Feldman et al., 2009). What all these studies have in common is that they support some kind of a decomposition as a result of which skilled readers can access the constituents of morphologically complex words.

The decomposition not only entails affixes but also embedded stems. For instance, Beyersmann et al. (2019) investigated whether children could use embedded stems in compound words as a facilitatory mechanism in the course of their processing compounds. In order to test this, they designed a masked priming lexical decision task where there were three types of prime-target pairs as in the previously mentioned studies- semantically transparent (e.g., *saucepan-sauce*), semantically opaque (e.g., *honeymoon-honey*) and noncompound (e.g., *sandwich-sand*). Both children and adults undertook the task, and the results revealed the presence of priming in both transparent and opaque conditions but not in the noncompound condition. These results provide supporting evidence for the use of embedded stems to facilitate the processing of morphologically complex words at the early stages of reading development. The findings of this study also highlight that learning morphological regularities is a useful mechanism for assisting readers to guess the meaning of an unknown word. When readers know the meaning of any morpheme constituting the morphologically complex words, they can make use of this knowledge to hypothesise the meaning of the complex word (Bowers & Kirby, 2010; Dawson et al., 2021).

4.4. Word and Affix Model for Complex Word Reading

More recently, it has been suggested that stems and affixes may have a different status in the reading system (Beyersmann & Grainger, in press; Grainger & Beyersmann, 2017). Based on prior findings, Grainger & Beyersmann (2017) and Beyersmann & Grainger (in press) have proposed the *word and affix model* (previously referred to as the Grainger & Beyersmann Model (2017) where stems and affixes are handled by two entirely separate mechanisms, edge-aligned embedded word activation and affix activation. Edge-aligned embedded word activation is a non-morphological process by which whole word forms (*worker, corner, cashew*) and edge-aligned embedded words (*work, corn, cash*) are activated. (Beyersmann et al., 2018) examined the idea of edge-alignedness in a compound masked priming experiment. In their second experiment, they manipulated the position of the embedded string and created three types of prime-target pairs: edge-aligned (*mukecoat-coat*), mid-embedded (*mucoatke-coat*) and outer-embedded (*comukeat-coat*). Priming was only observed for the edge-aligned condition, which in turn has been taken as evidence for the vitality of edge-alignedness. Edge-aligned activation successfully explains why the embedded stem is activated not only in morphologically complex words (*worker*) but also in semantically opaque pseudo-suffixed ones (*corner*) and words with non-morphological endings (*cashew*).

Affix activation, on the other hand, is morphological in nature and conditional upon fine-grained processing (Grainger & Ziegler, 2011; Ziegler & Goswami, 2005), which requires an exact orthographic identity match (*-un* in *unhappy* needs to be seen to activate *-un*) in the correct position (as a prefix in case of *unhappy*). This, in turn, provides less flexibility to activate other words except the target word.

4.5. Integrating this research with work on orthographic skeletons

Both morphological awareness and morphological processing studies conducted with the masked-priming paradigm provide compelling evidence for readers' sensitivity to and recognition of morphemic parts (i.e., stems and affixes). Following the same logic, it is not implausible to assume that readers could form orthographic expectations for embedded stems within morphologically complex words.

Beyersmann et al. (2021) examined whether skilled readers formed orthographic expectations for morphologically complex forms similar to those for monomorphemic words found by Wegener et al. (2018). They orally trained three inflected forms (e.g., "*vishing*", "*vished*", and "*vishes*") of novel stems used in Wegener et al. (2018) and presented the embedded stems for the first-time in print within a sentence reading task with eye-movements being monitored (e.g., *vish*). They also manipulated the spelling predictability of the items and added untrained items as control condition. The procedure used was the same as the one in Wegener et al. (2018). It was revealed that adult readers spent less time fixating trained items compared to untrained items, and less time fixating predictable items compared to unpredictable items. Furthermore, a significant interaction between spelling predictability and training was found such that there was a larger difference in looking times for orally trained items with predictable and unpredictable spellings than orally untrained items with predictable and unpredictable spellings The significant interaction clearly supported the idea that orthographic skeletons could be formed for embedded stems in inflected novel words. However, no research to date has explored whether skeletons are also formed in the case of derived words.

4.6. Type of Morphological Complexity

There are good reasons to suppose that inflected (e.g., *swims, cleaned*) and derived (e.g., *happiness, worker*) words may be processed differently, reflecting the underlying linguistic differences between the two types of morphological complexity. While inflection denotes grammatical relations, derivation can change meaning as well as the syntactic category of the stems (e.g., whether it is a verb or a noun; Jacob et al., 2018; James et al., 2021). For example, the past tense marker *-ed* in *played* does not change the meaning of the stem *play* but just adds the meaning of the past into it. Also, the verb status of *play* remains as is when it becomes *played*. This, however, is not the case for the nominalizer suffix *-er* in *player*. In addition to turning a verbal stem into a noun, this derivational suffix also transforms the meaning of the item from the action itself to the person carrying out the action.

Several studies have revealed different behavioural and neuro-cognitive morphological processing patterns for inflected and derived words (Álvarez et al., 2011; Leinonen et al., 2008; Leminen et al., 2011; Prins et al., 2019). For instance, with three repetition priming experiments in Serbian adults, Feldman (1994) compared the processing of inflected and derived words. Targets were preceded by three types of primes: identity primes; (*brod – brod* meaning *boat* in Serbian), inflected primes (*brodu – brod*; with *-u* that is the instrumental case marker) and derived primes (*brodi - brod* with *-i* that is the derivational marker). The results revealed greater facilitation when the primes were identical or inflected compared to derived word condition.

In a review paper, Leminen et al. (2019) showed that the evidence coming from neuro-imaging studies for inflected words was more consistent in that they all supported a specific account (i.e., dual mechanism account suggesting the use of both whole-word listing as well as decomposition into morphemic parts) used while processing inflected words. The evidence concerning derived words, however, was indicated to be less consistent because there was a great variation in terms of the time course of activation and the brain areas activated from study to study).

Similarly, Álvarez et al. (2011) examined possible differences between inflectional and derivational suffixes in Spanish adult speakers. The ERP paradigm was used, and participants undertook a lexical decision task. Two types of prime-target pairs were used. In the related condition, prime-target pairs were morphologically related, and both were morphologically complex. Namely, in the related condition, primes and targets were either inflected or derived words. This related condition was compared with an unrelated condition where the primes were orthographically, morphologically and semantically unrelated to the target inflected or derived words. The findings indicated differences between the brain areas associated with the processing of inflection and derivation. For inflected words, the activated brain area was the same as the areas used for visual word recognition (e.g., right cuneus and lingual gyrus) while for derived words these were right anterior and left medial areas. Also, the decrease in N400 effect (the brain's reaction to lexical stimuli) continued longer in inflected words than derived ones (Álvarez et al., 2011).

Raveh and Rueckl (2000), on the other hand, found similarities between inflection and derivation in their second experiment in English adults. They tested identity (e.g., *bake*), inflected (e.g., *baked*), and derived (e.g., *baker*) primes using a long-term morphological priming paradigm with a lexical decision task. It was long-term since there were ten intervening trials between primes and targets. There was also an unprimed condition as the baseline. A priming effect was found both for inflectional and for derivational prime conditions and no significant difference was found between priming effects for inflection and derivation.

Similar to the experimental conditions of Álvarez et al. (2011), Kirkici and Clahsen (2013) compared morphologically related (either inflectionally or derivationally) and completely unrelated (orthographically, morphologically and semantically) prime-target pairs in two separate masked-priming experiments with adults. They also used morphologically complex primes (inflected or derived words). However, unlike Álvarez et al. (2011), targets were morphologically simplex (stems) in the inflection experiment while they were derived words (stem + derivational suffix) in the derivation experiment. They found similar priming for verbal inflection and nominal derivation testing native speakers of Turkish.

Raveh and Rueckl (2000) listed some possible reasons behind the inconsistent results, in which there have been similarities in some studies between inflection and derivation but differences in others. One of the reasons provided was that there was great variability in the studies, with inflection and derivation often being compared across separate experiments with different targets. Jacob et al. (2018) raised similar concerns and tested inflection and derivation in L1 German adults in a masked-priming experiment. They used the same morphologically simplex targets for both derivation and inflection. Primes, on the other hand, were inflected and derived forms of the stems. The results showed similar facilitation for both inflection and derivation.

In sum, although a considerable number of studies have investigated processing differences between inflected and derived words, the findings are not conclusive.

5. Summary and Future Directions

Evidence from novel word training studies suggests that oral vocabulary is causally related to word reading. Two complementary accounts have been outlined which seek to explain how oral vocabulary might influence word reading. One of these accounts, the orthographic skeleton hypothesis, is proposed to operate even before written words are seen in print for the first time. Specifically, it is proposed that individuals can draw on their knowledge of mappings between spoken speech sounds and letters to generate expectations of the spellings of orally known words that have not yet been seen in print. Evidence for the operation of such a mechanism has been reported with English speaking children (Wegener et al., 2018, 2020) and Spanish speaking adults (Jevtović et al., 2022).

However, studies examining the orthographic skeleton effect in morphologically complex words are scarcer. Recent evidence from a novel word training study showed that skilled readers form orthographic expectations during oral exposure to inflected word forms (Beyersmann et al., 2021). The aim of the study reported in Chapter II was to further test the robustness of the orthographic skeleton effect by directly comparing inflected and derived novel words within the same study.

CHAPTER II

Oral Vocabulary and Learning to Read Morphologically Complex Words: Mechanisms of Influence

Abstract

The potential causal role of oral vocabulary knowledge within written word reading has been documented with various study designs. *Orthographic Skeleton* formation has recently been proposed as one of the cognitive mechanisms used to link oral representations of words with their written forms via formation of orthographic expectations about what the written form of an orally exposed word would look like. This skeleton effect has been tested with morphologically simple novel words (e.g., *vish*). Studies testing complex words. however, are rare. Considering that readers' daily exposure is not confined to simple words and the ability to link form and meaning via the use of morphological knowledge is one part of skilled reading, it is of great importance to understand whether the skeleton mechanism operates over different types of complex words.

This study aimed to investigate whether adult readers form orthographic skeletons for the stems of novel words (e.g., *vish*) upon oral training of derived (e.g., *visher*) and inflected (e.g., *vished*) forms of these words using a training paradigm followed by (a) a self-paced reading task (Experiment 1) and (b) a lexical recognition task (Experiment 2). Novel words were allocated to either a trained or untrained condition and divided into predictable and unpredictable groups depending on their spelling predictability. The results of the self-paced reading task did not reveal any significant effects. The findings of the lexical recognition task, on the other hand, indicated shorter latencies for trained words than for untrained ones, as well as shorter latencies for predictable compared to unpredictable words. Moreover, a significant interaction was found between training and predictability, which is an indication of an orthographic skeleton effect. However, the effect of morphological complexity was absent. The results are discussed in the light of the orthographic skeleton hypothesis and its relation to the learning of morphologically complex words.

1. Introduction

Oral vocabulary is proposed to play an important role in word reading, and this has been supported with evidence drawn from various study types, including cross-sectional, longitudinal, item-level, and training study designs (Duff et al., 2015; Duff & Hulme, 2012; Hogaboam & Perfetti, 1978; Lee, 2011; McKague et al., 2001; McKay et al., 2008; Nation & Cocksey, 2009a; Wang et al., 2011, 2013). Despite the prevalence of morphologically complex words (e.g., *studied, swimmer*, *swimsuit*) in the daily exposure of skilled readers (Brysbaert et al., 2016), the effect of oral vocabulary on reading these words has received much more limited research attention. Understanding the cognitive mechanisms supporting complex word reading is vital because learning the regularities between form (e.g., the orthographic representation of the affixes *-ed* or *-er*) and meaning (e.g., that it happened in the past for *-ed* or involved somebody doing the action for *-er*) is an essential part of skilled reading, especially in alphabetic languages such as English (Rastle, 2019; Ulicheva et al., 2020). Furthermore, complex words come in different types (e.g., *worked* is an inflected word but *worker* as a derived word), as outlined in detail below, but it is not clear whether skilled readers use the same cognitive mechanisms and are equally successful when learning to read both word types. Thus, the present study aimed to investigate the link between oral vocabulary knowledge and the learning of complex written words in skilled readers.

It has been shown that early oral vocabulary knowledge is a significant predictor of later written word reading (Duff et al., 2015; Lee, 2011; Nation & Snowling, 2004). Item-level studies have supported the existence of a direct relationship between knowing the spoken form of a particular word (its pronunciation with or without its meaning) and being able to read it (Kearns & Al Ghanem, 2019; Nation & Cocksey, 2009a; Ricketts et al., 2016). Novel word training studies further suggest that this relationship between oral vocabulary and written word reading is likely to be causal (Castles & Nation, 2006; Duff & Hulme, 2012). In these novel word training studies, participants are first taught the spoken form of a set of novel words. After oral training, participants see the written form of the novel words for the first time in the context of a reading task (e.g., reading aloud, silent sentence reading, or lexical decision) along with another set of items for which they have received no oral training, and are thus entirely new. Such studies with both child (Duff & Hulme, 2012; Hogaboam & Perfetti, 1978; McKague et al., 2001) and adult (Taylor et al., 2011) participants have shown that knowing the oral form of a word facilitates the reading of that word when it is first seen in print. This facilitation is observable in reading accuracy and/or reading efficiency measures, compared to untrained items.

One cognitive mechanism that has been proposed to explain how oral vocabulary might support the process of learning to read new words is based on the idea that orthographic representations of words might begin to be formed on the basis of oral vocabulary knowledge even before these words are seen in print (Stuart & Coltheart, 1988). According to this idea, readers can potentially draw on their knowledge of sound-letter correspondences to come up with an expectation about how the written form of an orally known word might be spelled. Preliminary data from skilled readers was consistent with this idea. For instance, Johnston et al. (2004) taught a set of obscure words in oral form only. When the words were subsequently encountered in the context of a masked priming task, lexical decisions to the orally trained words exhibited a pattern of facilitation that was commensurate with that observed for familiar written words, a finding potentially consistent with the idea that orthographic representations had been established prior to visual exposure. Using a similar design, McKague et al. (2008) also found robust masked identity and form priming effects for orally trained words at their first visual exposure, supporting the idea that training in the phonology and semantics of novel words reflected automatic access to partially specified orthographic representations of those words.

Building on these ideas, Wegener et al. (2018) proposed and tested the *orthographic skeleton hypothesis*. Using a novel word training study conducted with children in Grade 4, participants were taught the pronunciations and meanings of a set of novel words, while another set were untrained. Following oral training, participants encountered the written form of the novel words for the first time in the context of an eye-tracking task. Importantly, half of the words had spellings that were highly predictable on the basis of their pronunciations (e.g., the spoken word 'vish' was written as *vish*), whereas the other half had spellings that were unpredictable on the basis of their pronunciations (e.g., the spoken word 'jaif' was written as *jayf)*. At the first orthographic exposure, less time was spent fixating trained compared to untrained words and predictable compared to unpredictable words. Critically, there was also a significant interaction between training and predictability: the difference in fixation durations for trained words with predictable versus unpredictable spellings was much larger than the corresponding difference in fixation durations for untrained items with predictable versus unpredictable spellings. This interaction was interpreted as suggesting that readers had formed expectations about what a word's spelling should look like when they heard its oral form. Further evidence for this causal mechanism has been reported with English speaking children (Wegener et al., 2020) and adults (Beyersmann et al., 2021) using eye movements during reading as the outcome measure. Recently, the effect has also been conceptually replicated within the shallow Spanish orthography (Jevtović et al., 2022), using self-paced reading as the outcome measure.

1.1.Extension to morphologically complex words

Although previous studies suggest that orthographic expectations can be formed during oral vocabulary training prior to print exposure, it is less clear if similar processes apply in the context of morphologically complex words. Readers' daily exposure to print is made up of not only words without an affix; that is, monomorphemic words (e.g., *sail*) but also many morphologically complex words (e.g., *sailor, sailing, sailboat*) including inflected (e.g., *sailed*) and derived (e.g., *sailor*) words (Beyersmann et al., 2021; Brysbaert et al., 2016), as outlined in more detail below. Knowledge of morphemic structure within words facilitates the mappings between orthography and phonology (*ea* in d<u>ea</u>n versus d<u>ea</u>ctivate; Deacon & Kirby, 2004).

Morphological information also allows readers to discover form-meaning regularities, which are at the core of alphabetic languages where morphologically complex words are quite common, (e.g., *working, worked, worker, workday, workbook*; James et al., 2021; Matthews, 1991; Rastle et al., 2004; Taft & Kougious, 2004; Ulicheva et al., 2020).

Prior work has shown that readers are sensitive to morphemic components within morphologically complex spoken or written words (see Carlisle, 2000; Deacon & Bryant, 2006; James et al., 2021; Manolitsis et al., 2019 for morphological awareness studies, and Beyersmann et al., 2016; Feldman et al., 2009; Rastle et al., 2004; Taft, 1979; Taft & Forster, 1975 for masked priming studies). Linking these results with those of Wegener et al. (2018) on orthographic skeletons, Beyersmann et al. (2021) tested whether skilled readers could form orthographic skeletons for novel stems (e.g., *vish*) within morphologically complex inflected words (e.g., *vished*). The training by spelling predictability manipulation was similar to Wegener et al. (2018), but importantly, the oral training involved exposure to inflected forms of the target stems (e.g., *vishing*, *vishes*, *vished*). Fixation durations during reading showed significant effects of training and predictability, and an interaction between the two, such that there was a larger predictability effect for trained items than for untrained items. These results suggested that adult readers had formed orthographic skeletons of the embedded stems when they were orally trained with the inflected forms of these words.

1.2.Type of Morphological Complexity

The work of Beyersmann et al. (2021) is the first to link orthographic skeletons with the morphological knowledge base by training participants on inflected novel word forms. However, readers' typical exposure to morphologically complex words also includes exposure to derived words (e.g., *selection, swimmer, florist*). Inflection and derivation linguistically differ from each other in three major ways. First, inflectional affixes denote grammatical relations (past tense -*ed*) and do not change the syntactic category of the word to which they are attached (*work-worked*, both verbs). Derivation, on the other hand, has the potential to change both the category and the meaning of the word (*player* from *play* or a noun from a verb; Jacob et al., 2018; James et al., 2021). Thus, inflectional affixes tend to convey syntactic relations whereas derivational affixes can induce broader changes to the stem's syntactic and semantic functions. Secondly, inflectional affixes tend to be more productive since they can attach to a larger group of words than derivational affixes (Bybee, 1985; Leinonen et al., 2008). Lastly, inflectional affixes are small in number in English (only eight), compared to the much larger range of derivational affixes (Booij, 2007; Matthews, 1991).

The distinction between inflectional and derivational morphology in terms of linguistic properties has captured the attention of many researchers. For instance, several studies have investigated whether different processing patterns are observed for inflected and derived words (Bozic & Marslen-Wilson, 2010; Leinonen et al., 2008; Leminen et al., 2011, 2019) across various languages (Spanish: Álvarez et al., 2011; German: Ciaccio & Jacob, 2019; Serbian: Feldman, 1994; Turkish: Kirkici & Clahsen, 2013; Finnish: Leinonen et al., 2008; Dutch: Prins et al., 2019). Leminen et al. (2019) indicated that evidence on the processing of inflected words is more consistent and in favour of a specific processing account (i.e., dual-route involving both listing of full forms and decomposition), whereas there was still a dispute over the time course and activated brain areas for derived words. In addition to studies revealing similarities (Ciaccio & Jacob, 2019; Feldman, 1994; Jacob et al., 2018; Kirkici & Clahsen, 2013; Raveh & Rueckl, 2000), many other psycholinguistic studies have pointed to differences in the processing of these word types (Álvarez et al., 2011; Feldman, 1994; Leinonen et al., 2008; Leminen et al., 2011; Prins et al., 2019). These differences range from greater facilitation for inflected words compared to derived ones (Feldman, 1994), to the use of different brain areas (i.e., right anterior and left medial areas for derived but not inflected words), and continuation of N400 effect (i.e., reaction of the brain to the lexical items) for a longer duration for inflected than derived words (Álvarez et al., 2011).

In summary, the findings on the effect of the type of morphological complexity on word processing seem to be far from conclusive. In relation to orthographic skeletons, it is possible that orthographic skeletons of stems embedded in inflected forms are more easily formed than those embedded in derived forms considering the linguistic properties of inflectional affixes (i.e., more frequent, productive, and typically not involving a syntactic category change). Previous studies have supported the theory that orthographic skeletons are formed for stems embedded in inflected novel words (Beyersmann et al., 2021) but it is not yet clear whether orthographic skeletons can be formed on the basis of oral training of derived novel word forms.

1.3. The Present Study

The present study aimed to investigate whether adult readers form orthographic skeletons for embedded novel stems upon receiving oral training on inflected or derived forms of these stems, by testing both within the same tightly controlled novel word learning paradigm. As such, we attempted to replicate the orthographic skeleton effect found for inflected words by Beyersmann et al. (2021), but also to extend that finding to derivational items. The training paradigm and procedure were closely modelled on Beyersmann et al. (2021). However, because the pandemic prevented in-person eye movement research, we employed two different outcome measures that could be deployed in a web-based format: a self-paced reading task (Experiment 1), and a lexical recognition task (Experiment 2).

2. Experiment 1

In this experiment, our aim was to examine whether adult readers form orthographic skeletons of the stems of morphologically complex words (either derivational or inflectional). To this end, participants received training in the oral form of either inflected or derived novel word forms. Later, participants read the stems of these novel words for the first time in the context of a self-paced reading task. The outcome measure was reaction time to the target word.

We anticipated observing a two-way interaction between training and spelling predictability, with a larger effect of spelling predictability for orally trained than untrained items. If found, this two-way interaction would support the conclusion that participants had been able to form orthographic expectancies on the basis of their spoken word knowledge. We were also interested in whether we would observe a three-way interaction between training, spelling predictability and oral training type (words with inflectional versus derivational affixes). If found, the three-way interaction would suggest a difference in the ease with which orthographic expectancies can be formed on the basis of training in inflectional versus derivational complex word forms. This experiment was pre-registered (https://aspredicted.org/blind.php?x=91Z_MZB).

2.1 Method

2.1.1. Participants

Ethics clearance for the present study was obtained from the Human Research Ethics Committee of Macquarie University. A group of seventy-five participants (60 female, mean age: 24.6, SD: 8.6) participated in the experiment. They were all native English speakers with no history of learning or reading difficulties. They were either recruited via Macquarie University psychology units, or via *Prolific* (www.prolific.co). Participants recruited via *Prolific* were selected to have the same background as the university students in terms of age. In order to assess word reading performance, the Test of Word Reading Efficiency, (TOWRE; Torgeson et al., 1999) was administered. This standardised test measures word and non-word reading. For both components, participants read aloud as many items as possible within 45 seconds. The number of items that they read aloud correctly within the given time was calculated, and converted into age-based standard scores. The mean standard score for the word reading component was 106 (*SD*: 16.4) and 104 (*SD*: 12.4) for non-word reading, indicating the sample were average readers overall.

2.1.2. Oral training

Two derivational and two inflectional affixes were chosen to investigate the effect of the affix type. The morphologically complex word forms were only ever experienced by participants in spoken form during oral training. In order to replicate Beyersmann et al. (2021), two of the same inflectional affixes (*-ing* and *-ed*) were used. For brevity, the affix *-s*, which was tested before by Beyersmann et al. (2021) was not included in the current study. While choosing the derivational affixes, the aim was to pick the affixes which had the same length (i.e., number of letters) and match as closely as possible the frequency of the inflectional affixes. To this end, the affixes *-er* and *-ist* were chosen.

For the oral training, the affixed versions of the novel words were embedded into oral sentence contexts. To manipulate the effect of training, half of the items were orally trained while the other half were untrained for each participant. Oral training scripts for inflected words were adapted from Beyersmann et al. (2021), and shortened in order to keep the training as brief as possible. For derived words, the scripts had similar structure and length but had to be changed a little to give the meaning of somebody who does an action (See section *7.1*. for full listing of the scripts).

The same storyline created by Wegener et al. (2018) and adapted by Beyersmann et al. (2021) was used. Novel words were presented as inventions created by Professor Parsnip. In the inflected list, the focus was on the actions of the inventions, whereas in the derived list the focus was on the people who were operating the inventions (see *Figure 1*). All training scripts were pre-recorded by the experimenter. Derived words used in oral training changed not only the syntactic category of the target stem (making a noun from a verb: *visher* or *vishist* from *to vish*) but also its meaning (the person who is responsible for the action) (Booij, 2007); however, inflectional affixes (*-ed* and *-ing*) caused change only in grammatical relations (whether the action is happening in the present or has happened in the past). Participants were expected to look at the invention picture, listen to the recording and repeat as well as rehearse the target word to which they had been orally exposed. They recorded their own voice to show that they had learnt the target items. Each participant heard either the inflected or derived form of the novel words.

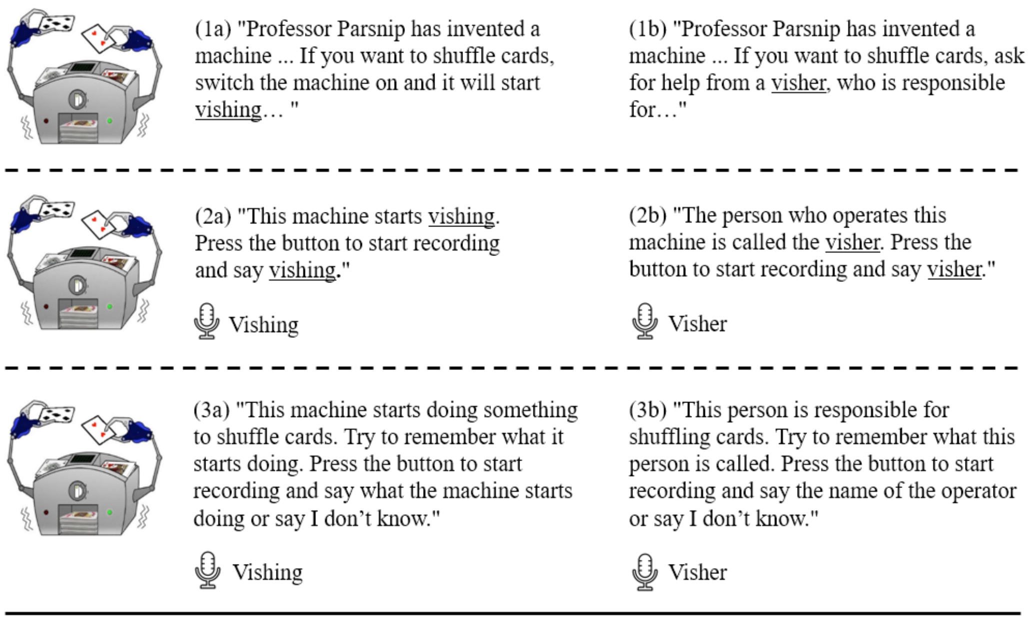

Figure 1. Example of the exposure (1a-1b), feedback (2a-2b) and rehearsal (3a-3b) sessions (a: inflection; b: derivation; picture taken from Mimeau et al., 2018; Wang et al., 2011).

2.1.3. Orthographic exposure

2.1.3.1 Items

The same two sets of 16 monosyllabic novel words previously created by Wegener et al. (2018) were used as the word stems for the present experiment. These were morphologically simple novel words which were piloted in advance so that they could be divided into two groups based on their spelling predictability. Half of the items in each set had spellings that were predictable on the basis of their phonology, while the other half had spellings that were unpredictable on the basis of their phonology. Predictable words used the most frequent grapheme for each phoneme, and thus it was easy to predict their orthography from phonology (e.g., *vish*); this was not the case, however, for unpredictable words because they contained one or more less frequent phoneme-grapheme correspondences (e.g., *jayf*). The CELEX database was used to collect phoneme to grapheme mapping frequencies (Baayen et al., 1993). Pilot testing confirmed the manipulation of spelling predictability. Two sets of items were used to counterbalance trained and untrained items for participants. There was no logarithmic bigram frequency difference between the two item sets (Set 1: mean 1.83 SD: 0.71; Set 2: mean 1.87 SD: 0.44). The full item sets may be found in Section *7.2*. and further details regarding the items may be found in Wegener and colleagues (2018).

2.1.3.2. Self-Paced Reading Task (SPR)

Testing consisted of a non-cumulative, linear self-paced reading task (Jegerski, 2013). This task was chosen for its similarity to eye-tracking in that participants read words at their own pace and reading time data is available for each word.

Thirty-two novel target words were placed into contextually rich sentences in line with the natural reading experience of adult readers. Sentences were the same as those used by Beyersmann et al. (2021). They were 11-15 words long and the target word was in the middle of each sentence (e.g., *Nick put the playing cards into the machine to <u>vish</u> before starting the game.*) There were 6 practice trials to familiarise participants with the task. Of the 32 experimental sentences, 16 contained trained words, while 16 contained untrained words (see Section *7.3.* for the full list). An additional 8 filler sentences were also included which referred to inventions not learned by any participant. In all, there were 46 sentences. To promote attention to task, comprehension questions were included after each sentence. These questions did not pertain to the novel target words in any way and the number of yes and no responses was balanced. Three breaks were added so that participants had time to rest, if required.

Each trial began with a fixation cross displayed in the middle of the screen for 250 milliseconds. After the fixation cross, the first word of the sentence appeared. Participants were instructed to press the spacebar as soon as they read each word. Each word disappeared when the next word appeared. At the end of each sentence, a comprehension question was added. They were asked to press either Y (for Yes) or N (for No) while answering the comprehension questions (see *Figure 2*). Half of the participants were trained on inflected verbs (e.g., *"vishing" or "vished"*) and later encountered its embedded verb stem *vish* embedded in sentences during

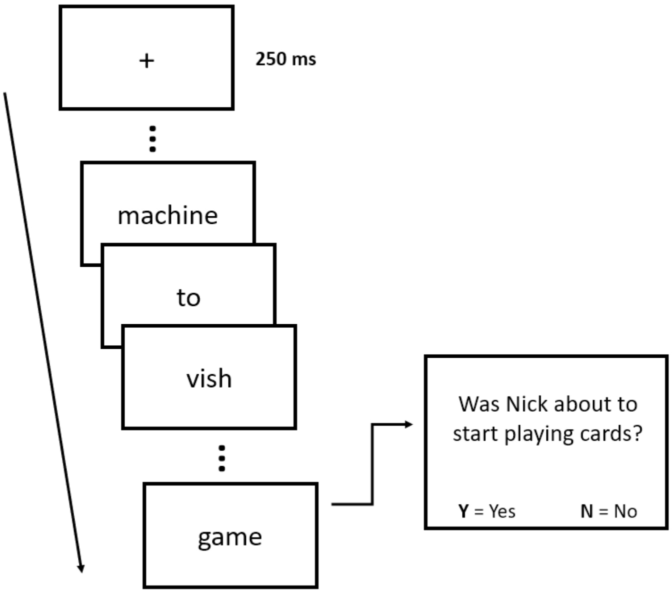

Figure 2. Self-paced reading task procedure.

self-paced reading, while the syntactic category of the trained words was maintained (i.e., verb). The other half of the participants were trained on derived nouns (e.g., *"visher"* or *"vishist"*) and later encountered the stem embedded as verbs in sentences context during self-paced reading. Hence, the embedded stems in this second participant group were assigned a different syntactic category than the items encountered during training.

2.1.4. Procedure

The experiment was programmed in Gorilla Experiment Builder (https://gorilla.sc/) (Anwyl-Irvine et al., 2020). Oral training occurred over three days. The first day always started with the consent form and a demographic questionnaire. Throughout the first two days, participants were orally trained on either inflected or derived words. All items were accompanied by a relevant picture of the invention. Half of the items were trained on Day 1 whereas the other half were trained on Day 2 (i.e., 8 items each day), in sessions lasting approximately 45 minutes. On Day 3, participants rehearsed what they had learnt on previous days. Following oral vocabulary training, participants completed a learning check task in which they were shown the pictures of the items and asked to remember the name of the action or the person who does the action. Next, participants completed the self-paced reading task. Finally, participants completed the TOWRE test. The Day 3 session lasted approximately 60 minutes. The experimental procedure is depicted in *Figure 3*.

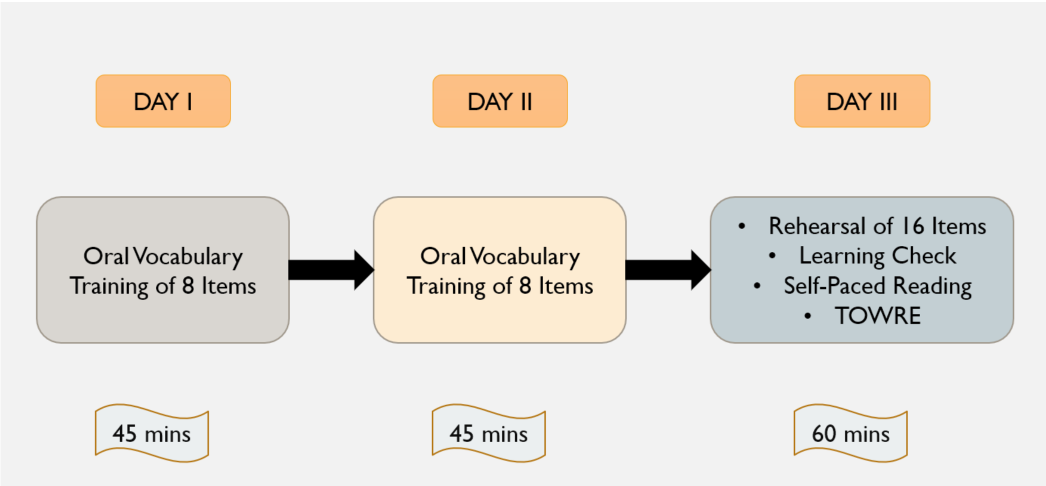

Figure 3. Experimental procedure.

2.2.Results

2.2.1. Learning check

The mean learning check score was 11.70 (SD = 2.83) out of 16 orally trained words. There was no significant difference in the number of items correctly recalled on each of the four lists (derivation 1: M = 12.45, SD = 3.12; derivation 2: M = 11.42, SD = 2.52; inflection 1: M = 11.39, SD = 2.2; inflection 2: M = 11.5, SD = 3.45; F (3, 71) = 0.615, p = .607).

2.2.2. Target word reaction time during self-paced reading

The stem form of the orally trained or untrained words was the area of interest in the self-paced reading task. In line with the pre-registration, we checked whether there was any participant whose error rate for comprehension questions was above 40%. None exceeded this threshold, so no exclusions were required.

Prior to data analysis, several steps were undertaken to prepare the data. First, the data were visually inspected and very long reaction times were excluded (>3000 ms). This resulted in 1.5% data loss. One participant demonstrated consistently long reaction times and so was excluded. Therefore, the following analyses were conducted with 74 participants. Second, the box-cox test (Box & Cox, 1964) was performed to determine whether reaction time data required transformation. Because the result of this test indicated that none was needed, the analyses were conducted with raw RTs. Third, the residual data trimming method described by Baayen (2008) was used to exclude outliers (2.28% of the data). The total data loss was 3.78%.

Analyses were conducted in the R computing environment (R Core Team, 2021). Descriptive statistics for the reaction time data are presented in Table 1. A linear mixed effects models (LME) was constructed using the *lme4* package (Bates et al., 2015), and *p* values were obtained using the *lmerTest* package (Kuznetsova et al., 2017). The dependent variable for all analyses was reaction time in milliseconds. Fixed effects were training (trained vs. untrained), predictability (predictable vs. unpredictable) and affix type (inflectional vs. derivational). The maximal model included random intercepts for participants and items, along with random slopes for training and predictability by participants and items. The maximal model was implemented first (Barr et al., 2013) but it failed to converge and was singular. Thereafter, we used data-driven model selection (Matuschek et al., 2017). We began with the random intercepts model, before adding random slopes incrementally. Because the only nonsingular converging model was the random-intercepts model, that is the model reported here. Table 2 shows the model outputs, which reveal that none of the fixed effects or interactions was significant ($p > .05$ in all cases).

Table 1

Mean reaction times (in ms) and standard deviations (in parentheses) for the self-paced reading task

Affix Type	Inflection		Derivation	
	Predictable	Unpredictable	Predictable	Unpredictable
Trained	371.23 (140.9)	378.57 (165.2)	354.57 (132.6)	359.96 (166.5)
Untrained	379.79 (153.5)	384.79 (168.3)	360.61 (145.7)	362.87 (157.8)

Table 2

Random-intercepts only model outcomes for self-paced reading task

Fixed effects	*β*	*SE*	*t*	*p*
(intercept)	372.221	16.181	23.003	0.00***
training	5.048	4.186	1.206	0.228
predictability	8.900	20.492	0.434	0.667
affix	23.899	25.396	0.941	0.350
training: predictability	-3.468	8.388	-0.413	0.679
training: affix	1.411	8.372	0.168	0.866
predictability: affix	7.696	8.376	0.919	0.358
training: predictability: affix	3.142	16.776	0.187	0.851

2.3. Discussion

We aimed to investigate whether orthographic skeletons are formed for the stems of morphologically complex words upon oral training of these complex words. To achieve this, adult readers participated in a three-day oral vocabulary training in which they were exposed to novel morphologically complex words in either inflected (e.g., *vishing* and *vished*) or derived (e.g., *vishist* and *visher*) forms. Following oral training, participants completed a self-paced reading task in which they saw the target novel stems for the first time, embedded in contextual sentences. In contrast to our hypotheses, the results showed no significant differences between any of the conditions. As such, the results of task are uninformative with respect to the role of oral vocabulary within the reading of morphologically complex words.

The absence of a significant interaction between training and predictability, which has usually been regarded as the primary indication of an orthographic skeleton effect, was unexpected in view of the robustness of the effect in prior eye-tracking studies (Beyersmann et al., 2021; Wegener et al., 2018) and in a recent online self-paced reading experiment conducted in Spanish (Jevtović et al., 2022). We speculate that differences across tasks might explain the failure to observe the orthographic skeleton effect in the current experiment. For instance, decisions about when to move the eyes typically occur implicitly in eye tracking experiments and during natural reading. Self-paced reading tasks, in contrast, are less implicit because they require the participant to perform an action – a button press – before the next word in the sentence is revealed. The explicit button press response has the potential to introduce more strategic responding from participants (Schmitt & Underwood, 2004). In the current experiment, for example, the location of the target word was always highly predictable because it was preceded by the same phrase, "the machine to…". The recent self-paced reading study reported by Jevtovic et al. (2022) varied the location of the target word in their sentences to limit strategic responding related to the sentence position of their target words. Another possibility is that the comprehension questions in the current experiment, which occurred after every trial, and which did not ever require the participant to pay attention to the target word, may have actually served to induce them to adopt a strategy of attending to other parts of the sentence. For these reasons, we conducted a second experiment using a different outcome measure: a lexical recognition task, which has previously been shown to be sensitive to the orthographic skeleton effect in an online testing environment (Wegener et al., under review).

3. Experiment 2

In a recent experiment, Wegener and colleagues (under review) used an online oral vocabulary training study design to investigate the orthographic skeleton effect with skilled readers. Participants received training in the spoken form of a set of novel words over two days. Subsequently, the written forms of the trained and untrained novel words were shown for the first time in the context of a lexical recognition task. The spelling predictability of the novel words was manipulated in the same way as that reported in other studies of the orthographic skeleton (Beyersmann et al., 2021; Wegener et al., 2018, 2020). The results for lexical recognition latency revealed that training and spelling predictability interacted, with a larger effect of spelling predictability for orally trained than untrained items. This finding was consistent with the generation of orthographic expectancies following oral vocabulary training. On this background, we anticipated that if the orthographic skeleton effect could be replicated again using the same online lexical recognition task at test, this might allow us to obtain data that would be informative with respect to our key research question: do skilled readers form orthographic skeletons of the stems of morphologically complex spoken words trained with either derivational or inflectional affixes?

The design of Experiment 2 was identical to that used in Experiment 1, with the exception of the measure used at test (a lexical recognition task as opposed to self-paced reading). The key outcome measure was lexical recognition latency. Predictions for this experiment were the same as the first experiment. If we found a significant two-way interaction between training and spelling predictability on recognition latencies, this would support the presence of a skeleton effect. A three-way interaction between training, spelling predictability and oral training type (inflectional vs. derivational affixes) would suggest a difference in the ease with which orthographic expectancies could be formed on the basis of training in inflectional versus derivational complex word forms. These predictions were pre-registered (https://aspredicted.org/blind.php?x=QND_4TM). Since the primary outcome measure previously used to test the skeleton effect was latency, we had no specific predictions to pre-register for the accuracy analysis.

3.1.Method

3.1.1. Participants

Eighty-one students from Macquarie University (69 female, mean age: 20.8, SD: 5.7) took part in the experiment. Their native language was English, and they did not have any history of learning or reading difficulties. Participants were randomly assigned into one of the four experimental lists. The mean standard score on the TOWRE (Torgeson et al., 1999) word reading task was 101 (SD: 13.7) whereas it was 100 (SD: 14.6) for the non-word reading task.

3.1.2. Oral training

Training was the same as the first experiment.

3.1.3. Orthographic exposure

3.1.3.1. Items

Novel words were exactly the same as those used in the first experiment (see Section *7.2.* for a list).

3.1.3.2. Lexical Recognition Task (LRT)

In this task, participants were shown a fixation cross in the middle of the screen for 250 ms. Then, the fixation cross was replaced with the stems of orally trained complex words one by one in isolation. Participants were instructed to decide whether the shown item was one of the items that they had learned by pressing a button on the keyboard (N for no and Y for yes) as quickly as possible. There were 3 practice trials prior to the experimental trials.

3.1.4. Procedure

The same procedure as in the first experiment was followed (see *Figure 3* for the experimental procedure).

3.2. Results

3.2.1. Learning Check

The mean learning check score was 11.16 (SD = 3.59) out of 16 orally trained words. There was no significant difference in accuracy among the four lists learned by the participants (derivation 1: M = 9.72, SD = 3.98; derivation 2: M = 11.48, SD = 3.56; inflection 1: M = 11.30, SD = 3.5; inflection 2: M = 11.9, SD = 3.27; F (3, 77) = 1.365, p = .260).

3.2.2. *Target word reaction time during lexical recognition*

We pre-registered an error rate of 40% in any experimental condition as a threshold for participant exclusion. However, we instead used a slightly more lenient criterion of a 50% error rate in any experimental condition as a threshold for participant exclusion. We chose to do this to limit participant exclusions, thereby maximising power. This decision also served to bring the threshold in line with that used by Wegener and colleagues (under review). Accordingly, participants who scored 50% and higher in all experimental conditions were included in the analysis. Eight participants who showed more than 50% of error rate in any condition were excluded from the analysis, leaving seventy-three participants whose data were analysed.[2]

Prior to data analysis, several steps were undertaken to prepare the data. Only correct responses were included in these analyses and data loss due to incorrect answers was 16.1% of the data. A box-cox test was conducted (Box & Cox, 1964) on lexical recognition latency to determine whether or not a data transformation was required. It indicated that that inverse transformation was needed, so analyses are reported on inverse RTs. We used the residual data trimming method described by Baayen (2008) for outlier exclusion: RT residuals greater than 2.5

[2] The results were exactly the same with the 40% cut-off point except the absence of the fixed effect of affix type.

standard deviation above or below every condition's mean were trimmed. Data loss due to this trimming was 1.07%.

Analyses were conducted in the R computing environment (R Core Team, 2021). Lexical recognition latency was analysed with a linear mixed effects model, while accuracy was analysed with a generalized linear mixed effects model (Bates et al., 2015). The data analytic approach was identical to that used in Experiment 1. The dependent variable for the latency analyses was the reaction time in milliseconds whereas for lexical recognition accuracy the dependent variable was proportion correct. All other aspects of the analysis were identical to Experiment 1. *emmeans* package (Lenth, 2022) was used to unpack significant interactions.

Descriptive statistics for lexical recognition latency are shown in Table 3 and are shown in graphical form in *Figure 4*. The final model revealed significant effects of training (β =-0.00014, t = -6.768, p =.001), predictability (β =-0.00011, t = -5.284, p =. 001), and affix (β =0.00010, t = 2.418, p = .02), as well as a significant two-way interaction between training and predictability (β =0.00010, t = 4.159, p =. 001).

Table 3

Mean reaction times (in ms) and standard deviations (in parentheses) for lexical recognition task

Affix Type	Inflection		Derivation	
	Predictable	Unpredictable	Predictable	Unpredictable
Trained	967 (431)	1124 (483)	1032. (447)	1269 (534)
Untrained	1126. (682)	1255 (604)	1316 (579)	1413 (659)

The significant training effect was such that trained items were associated with shorter response latencies than untrained items. The significant effect of predictability showed that predictable items were processed faster than the unpredictable items. Also, there was a significant effect of affix; namely, shorter latencies were found for inflected condition compared to derived condition. Considering the significant two-way interaction between training and predictability, there was a larger predictability effect for trained condition compared to untrained condition. The three-way interaction between training, predictability and affix was not significant (p >.05). The two-way interaction between training and spelling predictability was unpacked by computing the simple effect of training for the predictable (t= -7.937, p<.0001) and unpredictable items (t= -3.828, p =.0004), and by computing the simple effect of predictability for both trained (t= -6.565, p<.0001) and untrained (t= -2.635, p =.0113). Results of these contrasts showed that each of these simple effects was significant.

Descriptive statistics for lexical recognition accuracy are presented in Table 4 and are shown in graphical form in *Figure 5*. The final model revealed a significant effect of training (β =0.64088z = 3.849, p =.001), affix (β =0.35650, z = 2.603, p = .009), as well as a significant three-way interaction between training, predictability and affix (β =-1.14034, SE =0.47449, z = -2.403, p =. 016). The significant effect of training showed that trained items were less accurate. Also, there was a significant effect of affix such that derived items were responded less accurately compared to inflected items. The three-way interaction was unpacked by computing contrasts testing whether the two-way interaction between training and spelling predictability was present in each affix condition (inflectional and derivational). These contrasts showed that there was a training by predictability interaction for derivation (z= 2.381, p=.017) but not for inflection (z= -.998, p=.318). The significant two-way interaction in the derivation condition was further unpacked with tests showing that there was a significant fixed effect of training (z= 3.324, p=.003) but no fixed effect of predictability (z= 0.049, p=1). Namely, trained items were less accurately recognised than untrained items. There was a significant simple effect of training in the unpredictable condition (z= 4.023, p=.0002), showing that untrained unpredictable items were responded to more accurately than trained unpredictable items. None of the other contrasts were significant (all p's >.05).

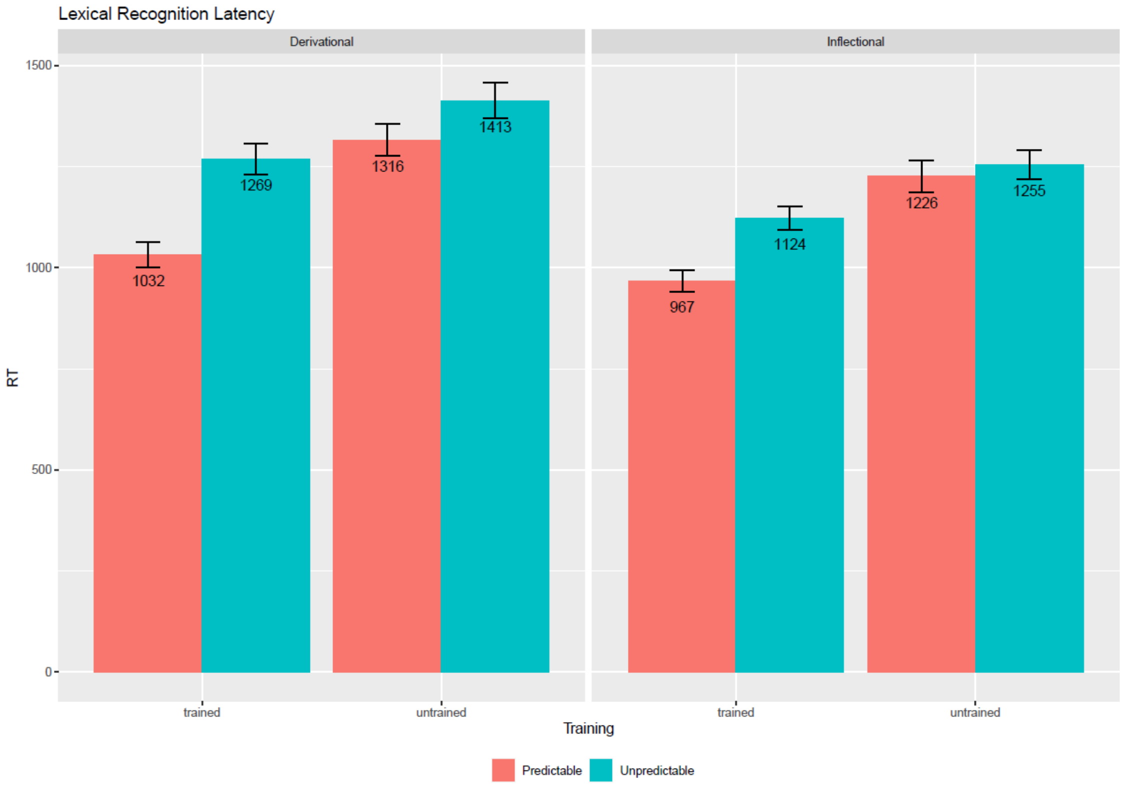

Figure 4. Means and standard errors of lexical recognition latency (in milliseconds).

Table 4

Mean error rates and standard deviations (in parentheses) for lexical recognition task

Affix Type	Inflection		Derivation	
	Predictable	Unpredictable	Predictable	Unpredictable
Trained	.17 (.38)	.15 (.36)	.21 (.41)	.27 (.44)
Untrained	.11 (.31)	.13 (.33)	.17 (.37)	.11(.32)

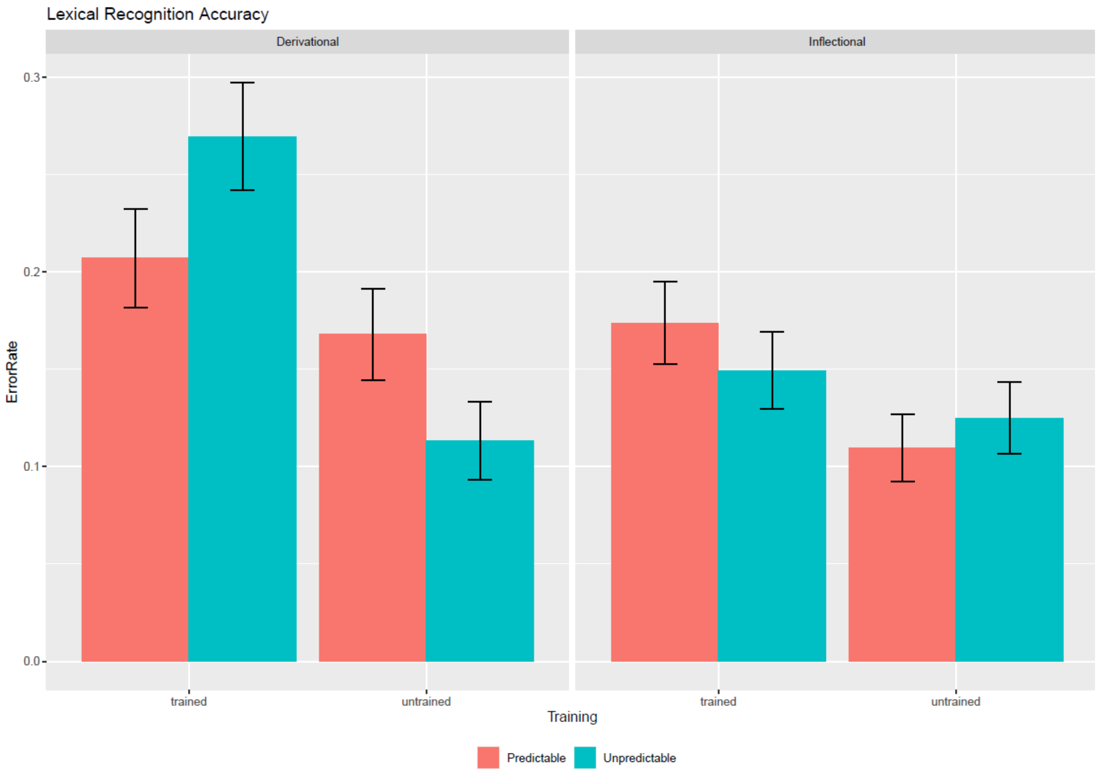

Figure 5. Means and standard errors of lexical recognition accuracy.

3.3. Discussion

In Experiment 2, we aimed to investigate whether orthographic skeletons are formed for the stems of morphologically complex words upon oral training of complex words. As in Experiment 1, adult readers participated in three days of oral vocabulary training in which they were exposed to novel morphologically complex words in either inflected (e.g., *jevving* and *jevved*) or derived (e.g., *jevvist* and *jevver*) forms. Following oral training, participants completed a lexical recognition task at test. Our key hypotheses related to participants' lexical recognition latencies to trained and untrained target words presented in isolation. Consistent with our predictions, significant effects of training, predictability and their interaction were observed. The key finding that the effect of spelling predictability was larger for orally trained than untrained novel words replicated results previously reported for morphologically simple (Jevtović et al., 2022; Wegener et al., 2018, 2020, under review) as well as morphologically complex inflected word forms (Beyersmann et al., 2021). We extended this prior work by additionally differentiating between oral training in either inflected or derivational word forms in the current experiment. Although responses in the derived condition were slower overall and less accurate than in the inflected condition, the magnitude of the two-way interaction between training and spelling predictability did not differ as a function of whether participants received oral training in inflectional or derivational complex word forms, suggesting that both types of training were equally effective.

We did not pre-register any predictions regarding lexical recognition accuracy. Interestingly, however, there was a significant three-way interaction between training, predictability and affix in the accuracy data. When this was unpacked, it showed that training and predictability interacted within the derivational condition whereas there was no such interaction in the inflectional condition. Further, the two-way interaction in the derived condition was driven by the difference between the trained and untrained items with unpredictable spellings. It is not entirely clear why this pattern was observed in the derivational but not inflectional condition. We speculate that that this pattern is another expression of the increased difficulty of the derivational condition experienced by participants.

4. General Discussion

In this study, we investigated whether adult readers formed orthographic skeletons for the novel stems upon receiving oral training for the morphologically complex forms of these stems by using two tasks: self-paced reading and lexical recognition. Through this investigation, we first aimed to test whether we could replicate the skeleton effect found by Beyersmann et al. (2021) for inflected novel words. Second, we wanted to see whether the same skeleton effect could be obtained for derived novel words as well.

The results of the self-paced reading task (Experiment 1) showed that there was no significant effect of training or predictability and no interaction between the two; namely, no skeleton effect. Moreover, no effect of affix or its interaction with any variable was found. The null result might have stemmed from two reasons. First, the static position of the novel stem within the sentences might have helped the readers to predict when the target word would appear and thus affected their processing pattern (e.g., pressing the button to move quickly to the end of the sentence). Secondly, the nature of the comprehension questions asking information about different parts of the sentences except the target word might have directed the readers' attention to other parts of the sentence to be able to answer the comprehension questions accurately.

The findings of the lexical recognition task (Experiment 2), on the other hand, revealed a main effect of training and predictability, showing that trained items were processed faster than the untrained ones, and predictable items faster than unpredictable ones. More importantly, the interaction between training and predictability was significant. There was a numerically larger predictability effect for the trained condition compared to untrained condition, which was the primary indication of the presence of a skeleton effect. In other words, in the trained condition, the readers benefited from predictable spellings more than unpredictable ones, as these spellings matched with the expectations they created during the oral training. In contrast, this predictability effect was reduced for untrained items as there was no orthographic skeleton formation taking place in this control condition.

These findings are consistent with the skeleton effect found for morphologically simple words (Jevtović et al., 2022; Johnston et al., 2004; McKague et al., 2008b; Wegener et al., 2018, 2020) morphologically complex inflected words (Beyersmann et al., 2021). The main effect of affix in the latency and accuracy analyses showed that derived items overall were processed more slowly and less accurately, which might be an indication that derived items are generally more challenging. However, there was no interaction of affix type with the predictability effect. These findings lend support to the argument that orthographic skeletons are formed independent of the affix type and are consistent with studies having yielded similar processing patterns between inflection and derivation (Ciaccio & Jacob, 2019; Feldman, 1994; Jacob et al., 2018; Kirkici & Clahsen, 2013; Raveh & Rueckl, 2000). For the current study, the linguistic differences between these two types of morphologically complex words (i.e., syntactic category and meaning change as well as frequency difference- inflectional affixes being more frequent) did not modulate the use of the skeleton formation as a cognitive mechanism connecting the oral vocabulary knowledge with written word reading. On the contrary, adult readers were found to refer to the same cognitive mechanism (i.e., forming orthographic skeletons) while reading two types of morphologically complex novel words.

The results of the current study replicated the orthographic skeleton effect found by recent studies on both morphologically simple and complex words. Adult readers formed orthographic skeletons for the embedded stems of the orally trained derived and inflected words independent of the affix type. These results reiterate that skilled readers appear to be sensitive towards morphemic parts of the morphologically complex words (James et al., 2021; Rastle, 2019; Ulicheva et al., 2020) and hence, have the capability of decomposing the trained complex novel words. This is consistent with a body of literature pointing to the important role of morphological processing in skilled readers (Beyersmann et al., 2016; Feldman et al., 2009; Heyer & Kornishova, 2018; Kazanina et al., 2008; Rastle et al., 2004). As suggested by Beyersmann et al. (2021), building skeletons for the novel stems (*vish*) of orally trained morphologically complex forms ("*visher*" or "*vished*") requires a process of decomposition into stems and affixes. We observed a similar process of decomposition, since readers were able to form skeletons for the embedded stems of both derived and inflected words.

Orthographic skeleton formation for morphologically complex words requires complex cognitive processes to be at play. For instance, when adult readers were trained on morphologically complex forms such as *vished* or *jayfer*, they must have used their existing knowledge of phoneme-to-grapheme mappings to come up with some expectations, (i.e., skeletons) about the written form of these spoken items. Since they did not see the written forms, oral vocabulary was their only source of information.

Parallel to this, they also needed to use their morphological knowledge to decompose these complex forms (*vished*) into their morphemic subunits (*vish* + *-ed*). In that regard, they had a cue, which is the real suffix (-ed), which helped them to decompose. When they were presented with the written embedded stems (e.g., *vish*) of the complex forms (e.g., *visher*, *vished*), their response latency was shorter for the predictable trained items (*vish*) compared to unpredictable items *(jayf*), and this predictability advantage was greater for the trained items (*vish*) than the untrained items (*nesh*). This was likely the case because for the predictable trained items like *vish*, there was a match between readers' expectations formed during oral training (v-I-ʃ-ə-r) and the written stem that they had seen during post-training (*vish*). For unpredictable items; however, this was not the case due to the less frequent phoneme-to-grapheme structure of these items (dʒ-aɪ-f-ə-r), which slowed down their reading. For the untrained condition, on the other hand, the predictability effect was at only baseline level since there was no opportunity for skeleton formation to take place.

These findings point to the use of skeleton formation as a cognitive mechanism applicable to different types of affixed words as well as the crucial role of morphological information embedded in oral vocabulary knowledge facilitating the formation of orthographic representations via skeletons. Our results once again show that how oral vocabulary knowledge can facilitate word reading, supporting the results of many previous studies (Beyersmann et al., 2021; Duff & Hulme, 2012; Hogaboam & Perfetti, 1978; Jevtović et al., 2022; McKague et al., 2001, 2008b; Wegener et al., 2018, 2020) . More importantly, these findings emphasise the integral role of morphological information interacting with oral vocabulary knowledge to facilitate written word reading. In that sense, current study expands our understanding of the complex processes readers undergo as they read new words.

5. Limitations and Suggestions for Further Research

In the present study, we obtained null results for the self-paced reading task. This was somewhat surprising, as it contrasted with the recent Spanish findings of Jevtović et al. (2022). One issue may have been that we could not manipulate the position of the target item in our study as our sentences were all 11-15 words long and of a similar structure. The comprehension questions may also have directed readers' attention away from the novel words. Future studies may seek to address these potential limitations.

The null results for the self-paced reading task were unfortunate, as this paradigm has the potential to provide important insights about the involvement of syntactic and semantic information in the formation of orthographic skeletons. However, with the lexical recognition task there was no sentence context to assist in determining the syntactic category and meaning of the embedded novel stems, and so we could not draw any conclusions about this issue. This limitation creates a room for further research using sentence reading tasks.

All in all, the results of the current study showed that adult readers can form orthographic skeletons for the embedded stems upon oral training of morphologically complex forms of these stems. Moreover, the skeleton formation does not seem to rely on whether the complex word is inflected or derived. All of these findings highlight that orthographic skeleton formation is a cognitive mechanism applicable to different types of complex words. Moreover, they indicate that skilled readers use morphological information integrated into morphologically complex spoken words in order to come up with an orthographic skeleton for the stems of the novel words that they have never seen in print. Thus, these two points are crucial as they help us to understand the complex cognitive processes during reading where readers need to integrate various information sources from phonology and orthography to morphology.

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7. Appendices

7.1. Oral Training Scripts for Exposure

Inflection/Set 1

1. ghakking/ghakked

Professor Parsnip has invented a machine that is used for making birds sing. If you want to get the birds to sing, switch the machine on and it will start **ghakking**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **ghakking** and makes the birds sing.

After the machine has **ghakked**, the birds will start to sing. When you are ready, press the button to start recording and say what the machine has done to make the birds sing. For example, say after the machine has **ghakked,** the birds start to sing.

2. thubbing/thubbed

Professor Parsnip has invented a machine that is used for cleaning out fish tanks. If you want to clean out fish tanks, switch the machine on and it will start **thubbing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **thubbing** and cleans out fish tanks.

After the machine has **thubbed**, the fish tank will be clean. When you are ready, press the button to start recording and say what the machine has done to clean out the fish tanks. For example, say after the machine has **thubbed,** the fish tank will be clean.

3. jevving/jevved

Professor Parsnip has invented a machine that is used for cleaning dirty socks. If you want to clean dirty socks, switch the machine on and it will start **jevving**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **jevving** and cleans dirty socks.

After the machine has **jevved** your socks, you can wear them again. When you are ready, press the button to start recording and say what the machine has done to clean dirty socks. For example, say after the machine has **jevved** your socks, you can wear them again.

4. veming/vemed

Professor Parsnip has invented a machine that is used for juicing oranges. If you want to juice oranges, switch the machine on and it will start **veming**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **veming** and juices oranges.

After the machine has **vemed**, you can drink the orange juice. When you are ready, press the button to start recording and say what the machine has done to juice oranges. For example, say after the machine has **vemed,** you can drink your orange juice.

5. neshing/neshed

Professor Parsnip has invented a machine that is used for shuffling cards. If you want to shuffle cards, switch the machine on and it will start **neshing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **neshing** and shuffles cards.

After the machine has **neshed** your cards, you can play with them. When you are ready, press the button to start recording and say what the machine has done to shuffle cards. For example, say after the machine has **neshed** your cards, you can play with them.

6. jeabbing/jeabbed

Professor Parsnip has invented a machine that is used for throwing balls to dogs. If you want to throw balls to dogs, switch the machine on and it will start **jeabbing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **jeabbing** and throws balls to dogs.

After the machine has **jeabbed**, you can put the balls back in. When you are ready, press the button to start recording and say what the machine has done to throw balls to dogs. For example, say after the machine has **jeabbed**, you can put the balls back in.

7. vibbing/vibbed

Professor Parsnip has invented a machine that is used for drying hats. If you want to dry hats, switch the machine on and it will start **vibbing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **vibbing** and dries hats.

After the machine has **vibbed** your hat, you can wear it again. When you are ready, press the button to start recording and say what the machine has done to dry hats. For example, say after the machine has **vibbed** your hat, you can wear it again.

8. yirping/yirped

Professor Parsnip has invented a machine that is used for sorting rubbish for recycling. If you want to sort rubbish for recycling, switch the machine on and it will start **yirping**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **yirping** and sorts rubbish for recycling.

After the machine has **yirped** your rubbish, it will be ready for collection. When you are ready, press the button to start recording and say what the machine has done to sort rubbish for recycling. For example, say after the machine has **yirped** your rubbish, it will be ready for collection.

9. phirfing/phirfed

Professor Parsnip has invented a machine that is used for warming up cold feet. If you want to warm up cold feet, switch the machine on and it will start **phirfing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **phirfing** and warms up cold feet.

After the machine has **phirfed** your feet, you can turn off the machine. When you are ready, press the button to start recording and say what the machine has done to warm up cold feet. For example, say after the machine has **phirfed** your feet, you can turn off the machine.

10. yagging/yagged

Professor Parsnip has invented a machine that is used for polishing flowers. If you want to polish flowers, switch the machine on and it will start **yagging**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **yagging** and polishes flowers.

After the machine has **yagged**, the flowers look shiny again. When you are ready, press the button to start recording and say what the machine has done to polish flowers. For example, say after the machine has **yagged**, the flowers look shiny again.

11. byping/byped

Professor Parsnip has invented a machine that is used for taking out the food you don’t like from a meal. If you want to take out the food you don’t like from a meal, switch the machine on and it will start **byping**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **byping** and takes out the food you don’t like from a meal.

After the machine has **byped**, you can eat your meal. When you are ready, press the button to start recording and say what the machine has done to take out the food you don’t like from a meal. For example, say after the machine has **byped**, you can eat your meal.

12. chobbing/chobbed

Professor Parsnip has invented a machine that is used for working out names of people you meet. If you want to work out names of people you meet, switch the machine on and it will start **chobbing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **chobbing** and works out names of people you meet.

After the machine has **chobbed** someone's name, you can use it. When you are ready, press the button to start recording and say what the machine has done to work out names of people you meet. For example, say after the machine has **chobbed** someone's name, you can use it.

13. tupping/tupped

Professor Parsnip has invented a machine that is used for fixing tummy aches. If you want to fix tummy aches, switch the machine on and it will start **tupping**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **tupping** and fixes tummy aches.

After the machine has **tupped** your tummy, you will feel better. When you are ready, press the button to start recording and say what the machine has done to fix tummy aches. For example, say after the machine has **tupped** your tummy, you will feel better.

14. koybing/koybed

Professor Parsnip has invented a machine that is used for crisping up soggy chips. If you want to crisp up soggy chips, switch the machine on and it will start **koybing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **koybing** and crisps up soggy chips.

After the machine has **koybed** soggy chips, they will be crispy. When you are ready, press the button to start recording and say what the machine has done to crisp up soggy chips. For example, say after the machine has **koybed** soggy chips, they will be crispy.

15. shugging/shugged

Professor Parsnip has invented a machine that is used for letting you walk up walls. If you want to walk up walls, switch the machine on and it will start **shugging**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **shugging** and lets you walk up walls.

After the machine has **shugged**, you can go back down again. When you are ready, press the button to start recording and say what the machine has done to let you walk up walls. For example, say after the machine has **shugged**, you can go back down again.

16. mirbing/mirbed

Professor Parsnip has invented a machine that is used for brushing the sand off your body. If you want to brush the sand off your body, switch the machine on and it will start **mirbing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **mirbing** and brushes the sand off your body.

After the machine has **mirbed** your body, no sand will be left on you. When you are ready, press the button to start recording and say what the machine has done to brush the sand off your body. For example, say after the machine has **mirbed** your body, no sand will be left on you.

Inflection/Set 2

1. phegging/phegged

Professor Parsnip has invented a machine that is used for making birds sing. If you want to get the birds to sing, switch the machine on and it will start **phegging**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **phegging** and makes the birds sing.

After the machine has **phegged**, the birds will start to sing. When you are ready, press the button to start recording and say what the machine has done to make the birds sing. For example, say after the machine has **phegged,** the birds start to sing.

2. chigging/chigged

Professor Parsnip has invented a machine that is used for cleaning out fish tanks. If you want to clean out fish tanks, switch the machine on and it will start **chigging**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **chigging** and cleans out fish tanks.

After the machine has **chigged**, the fish tank will be clean. When you are ready, press the button to start recording and say what the machine has done to clean out the fish tanks. For example, say after the machine has **chigged,** the fish tank will be clean.

3. temming/temmed

Professor Parsnip has invented a machine that is used for cleaning dirty socks. If you want to clean dirty socks, switch the machine on and it will start **temming**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **temming** and cleans dirty socks.

After the machine has **temmed** your socks, you can wear them again. When you are ready, press the button to start recording and say what the machine has done to clean dirty socks. For example, say after the machine has **temmed** your socks, you can wear them again.

4. yuning/yuned

Professor Parsnip has invented a machine that is used for juicing oranges. If you want to juice oranges, switch the machine on and it will start **yuning**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **yuning** and juices oranges.

After the machine has **yuned**, you can drink the orange juice. When you are ready, press the button to start recording and say what the machine has done to juice oranges. For example, say after the machine has **yuned,** you can drink your orange juice.

5. vishing/vished

Professor Parsnip has invented a machine that is used for shuffling cards. If you want to shuffle cards, switch the machine on and it will start **vishing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **vishing** and shuffles cards.

After the machine has **vished** your cards, you can play with them. When you are ready, press the button to start recording and say what the machine has done to shuffle cards. For example, say after the machine has **vished** your cards, you can play with them.

6. meaphing/meaphed

Professor Parsnip has invented a machine that is used for throwing balls to dogs. If you want to throw balls to dogs, switch the machine on and it will start **meaphing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **meaphing** and throws balls to dogs.

After the machine has **meaphed**, you can put the balls back in. When you are ready, press the button to start recording and say what the machine has done to throw balls to dogs. For example, say after the machine has **meaphed**, you can put the balls back in.

7. jitting/jitted

Professor Parsnip has invented a machine that is used for drying hats. If you want to dry hats, switch the machine on and it will start **jitting**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **jitting** and dries hats.

After the machine has **jitted** your hat, you can wear it again. When you are ready, press the button to start recording and say what the machine has done to dry hats. For example, say after the machine has **jitted** your hat, you can wear it again.

8. birving/birved

Professor Parsnip has invented a machine that is used for sorting rubbish for recycling. If you want to sort rubbish for recycling, switch the machine on and it will start **birving**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **birving** and sorts rubbish for recycling.

After the machine has **birved** your rubbish, it will be ready for collection. When you are ready, press the button to start recording and say what the machine has done to sort rubbish for recycling. For example, say after the machine has **birved** your rubbish, it will be ready for collection.

9. ghuzzing/ghuzzed

Professor Parsnip has invented a machine that is used for warming up cold feet. If you want to warm up cold feet, switch the machine on and it will start **ghuzzing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **ghuzzing** and warms up cold feet.

After the machine has **ghuzzed** your feet, you can turn off the machine. When you are ready, press the button to start recording and say what the machine has done to warm up cold feet. For example, say after the machine has **ghuzzed** your feet, you can turn off the machine.

10. nidding/nidded

Professor Parsnip has invented a machine that is used for polishing flowers. If you want to polish flowers, switch the machine on and it will start **nidding**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **nidding** and polishes flowers.

After the machine has **nidded**, the flowers look shiny again. When you are ready, press the button to start recording and say what the machine has done to polish flowers. For example, say after the machine has **nidded**, the flowers look shiny again.

11. kyving/kyved

Professor Parsnip has invented a machine that is used for taking out the food you don’t like from a meal. If you want to take out the food you don’t like from a meal, switch the machine on and it will start **kyving**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **kyving** and takes out the food you don’t like from a meal.

After the machine has **kyved**, you can eat your meal. When you are ready, press the button to start recording and say what the machine has done to take out the food you don't like from a meal. For example, say after the machine has **kyved**, you can eat your meal.

12. shepping/shepped

Professor Parsnip has invented a machine that is used for working out names of people you meet. If you want to work out names of people you meet, switch the machine on and it will start **shepping**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **shepping** and works out names of people you meet.

After the machine has **shepped** someone's name, you can use it. When you are ready, press the button to start recording and say what the machine has done to work out names of people you meet. For example, say after the machine has **shepped** someone's name, you can use it.

13. yabbing/yabbed

Professor Parsnip has invented a machine that is used for fixing tummy aches. If you want to fix tummy aches, switch the machine on and it will start **yabbing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **yabbing** and fixes tummy aches.

After the machine has **yabbed** your tummy, you will feel better. When you are ready, press the button to start recording and say what the machine has done to fix tummy aches. For example, say after the machine has **yabbed** your tummy, you will feel better.

14. jayfing/jayfed

Professor Parsnip has invented a machine that is used for crisping up soggy chips. If you want to crisp up soggy chips, switch the machine on and it will start **jayfing**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **jayfing** and crisps up soggy chips.

After the machine has **jayfed** soggy chips, they will be crispy. When you are ready, press the button to start recording and say what the machine has done to crisp up soggy chips. For example, say after the machine has **jayfed** soggy chips, they will be crispy.

15. thogging/thogged

Professor Parsnip has invented a machine that is used for letting you walk up walls. If you want to walk up walls, switch the machine on and it will start **thogging**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **thogging** and lets you walk up walls.

After the machine has **thogged**, you can go back down again. When you are ready, press the button to start recording and say what the machine has done to let you walk up walls. For example, say after the machine has **thogged**, you can go back down again.

16. vayping/vayped

Professor Parsnip has invented a machine that is used for brushing the sand off your body. If you want to brush the sand off your body, switch the machine on and it will start **vayping**. When you are ready, press the button to start recording and say what the machine does and what it is used for. For example, say the machine starts **vayping** and brushes the sand off your body.

After the machine has **vayped** your body, no sand will be left on you. When you are ready, press the button to start recording and say what the machine has done to brush the sand off your body. For example, say after the machine has **vayped** your body, no sand will be left on you.

Derivation/Set 1

1. ghakker/ghakkist

Professor Parsnip has invented a machine that is used for making birds sing. If you want to get the birds to sing, ask for help from a **ghakker**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **ghakker** is responsible for making the birds sing.

You can also say that the person responsible for making the birds sing is a **ghakkist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **ghakkist** is responsible for making the birds sing.

2. thubber/thubbist

Professor Parsnip has invented a machine that is used for cleaning out fish tanks. If you want to clean out fish tanks, ask for help from a **thubber**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **thubber** is responsible for cleaning out fish tanks.

You can also say that the person responsible for cleaning out fish tanks is a **thubbist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **thubbist** is responsible for cleaning out fish tanks.

3. jevver/jevvist

Professor Parsnip has invented a machine that is used for cleaning dirty socks. If you want to clean dirty socks, ask for help from a **jevver**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **jevver** is responsible for cleaning dirty socks.

You can also say that the person responsible for cleaning dirty socks is a **jevvist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **jevvist** is responsible for cleaning dirty socks.

4. vemer/vemist

Professor Parsnip has invented a machine that is used for juicing oranges. If you want to juice oranges, ask for help from a **vemer**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **vemer** is responsible for juicing oranges.

You can also say that the person responsible for juicing oranges is a **vemist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **vemist** is responsible for juicing oranges.

5. nesher/neshist

Professor Parsnip has invented a machine that is used for shuffling cards. If you want to shuffle cards, ask for help from a **nesher**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **nesher** is responsible for shuffling cards.

You can also say that the person responsible for shuffling cards is a **neshist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **neshist** is responsible for shuffling cards.

6. jeabber/jeabbist

Professor Parsnip has invented a machine that is used for throwing balls to dogs. If you want to throw balls to dogs, ask for help from a **jeabber**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **jeabber** is responsible for throwing balls to dogs.

You can also say that the person responsible for throwing balls to dogs is a **jeabbist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **jeabbist** is responsible for throwing balls to dogs.

7. vibber/vibbist

Professor Parsnip has invented a machine that is used for drying hats. If you want to dry hats, ask for help from a **vibber**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **vibber** is responsible for drying hats.

You can also say that the person responsible for drying hats is a **vibbist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **vibbist** is responsible for drying hats.

8. yirper/yirpist

Professor Parsnip has invented a machine that is used for sorting rubbish for recycling. If you want to sort rubbish for recycling, ask for help from a **yirper**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **yirper** is responsible for sorting rubbish for recycling.

You can also say that the person responsible for sorting rubbish for recycling is a **yirpist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **yirpist** is responsible for sorting rubbish for recycling.

9. phirfer/phirfist

Professor Parsnip has invented a machine that is used for warming up cold feet. If you want to warm up cold feet, ask for help from a **phirfer**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **phirfer** is responsible for warming up cold feet.

You can also say that the person responsible for warming up cold feet is a **phirfist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **phirfist** is responsible for warming up cold feet.

10. yagger/yaggist

Professor Parsnip has invented a machine that is used for polishing flowers. If you want to polish flowers, ask for help from a **yagger**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **yagger** is responsible for polishing flowers.

You can also say that the person responsible for polishing flowers is a **yaggist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **yaggist** is responsible for polishing flowers.

11. byper/bypist

Professor Parsnip has invented a machine that is used for taking out the food you don't like from a meal. If you want to take out the food you don't like from a meal, ask for help from a **byper**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **byper** is responsible for taking out the food you don't like from a meal.

You can also say that the person responsible for taking out the food you don't like from a meal is a **bypist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **bypist** is responsible for taking out the food you don't like from a meal.

12. chobber/chobbist

Professor Parsnip has invented a machine that is used for working out names of people you meet. If you want to work out names of people you meet, ask for help from a **chobber**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **chobber** is responsible for working out names of people you meet.

You can also say that the person responsible for working out names of people you meet is a **chobbist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **chobbist** is responsible for working out names of people you meet.

13. tupper/tuppist

Professor Parsnip has invented a machine that is used for fixing tummy aches. If you want to fix tummy aches, ask for help from a **tupper**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **tupper** is responsible for fixing tummy aches.

You can also say that the person responsible for fixing tummy aches is a **tuppist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **tuppist** is responsible for fixing tummy aches.

14. koyber/koybist

Professor Parsnip has invented a machine that is used for crisping up soggy chips. If you want to crisp up soggy chips, ask for help from a **koyber**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **koyber** is responsible for crisping up soggy chips.

You can also say that the person responsible for crisping up soggy chips is a **koybist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **koybist** is responsible for crisping up soggy chips.

15. shugger/shuggist

Professor Parsnip has invented a machine that is used for letting you walk up walls. If you want to walk up walls, ask for help from a **shugger**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **shugger** is responsible for letting you walk up walls.

You can also say that the person responsible for letting you walk up walls is a **shuggist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **shuggist** is responsible for letting you walk up walls.

16. mirber/mirbist

Professor Parsnip has invented a machine that is used for brushing the sand off your body. If you want to brush the sand off your body, ask for help from a **mirber**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **mirber** is responsible for brushing the sand off your body.

You can also say that the person responsible for brushing the sand off your body is a **mirbist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **mirbist** is responsible for brushing the sand off your body.

Derivation/Set 2

1. phegger/pheggist

Professor Parsnip has invented a machine that is used for making birds sing. If you want to get the birds to sing, ask for help from a **phegger**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **phegger** is responsible for making the birds sing.

You can also say that the person responsible for making the birds sing is a **pheggist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **pheggist** is responsible for making the birds sing.

2. chigger/chiggist

Professor Parsnip has invented a machine that is used for cleaning out fish tanks. If you want to clean out fish tanks, ask for help from a **chigger**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **chigger** is responsible for cleaning out fish tanks.

You can also say that the person responsible for cleaning out fish tanks is a **chiggist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **chiggist** is responsible for cleaning out fish tanks.

3. temmer/temmist

Professor Parsnip has invented a machine that is used for cleaning dirty socks. If you want to clean dirty socks, ask for help from a **temmer**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **temmer** is responsible for cleaning dirty socks.

You can also say that the person responsible for cleaning dirty socks is a **temmist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **temmist** is responsible for cleaning dirty socks.

4. yuner/yunist

Professor Parsnip has invented a machine that is used for juicing oranges. If you want to juice oranges, ask for help from a **yuner**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **yuner** is responsible for juicing oranges.

You can also say that the person responsible for juicing oranges is a **yunist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **yunist** is responsible for juicing oranges.

5. visher/vishist

Professor Parsnip has invented a machine that is used for shuffling cards. If you want to shuffle cards, ask for help from a **visher**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **visher** is responsible for shuffling cards.

You can also say that the person responsible for shuffling cards is a **vishist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **vishist** is responsible for shuffling cards.

6. meapher/meaphist

Professor Parsnip has invented a machine that is used for throwing balls to dogs. If you want to throw balls to dogs, ask for help from a **meapher**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **meapher** is responsible for throwing balls to dogs.

You can also say that the person responsible for throwing balls to dogs is a **meaphist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **meaphist** is responsible for throwing balls to dogs.

7. jitter/jittist

Professor Parsnip has invented a machine that is used for drying hats. If you want to dry hats, ask for help from a **jitter**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **jitter** is responsible for drying hats.

You can also say that the person responsible for drying hats is a **jittist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **jittist** is responsible for drying hats.

8. birver/birvist

Professor Parsnip has invented a machine that is used for sorting rubbish for recycling. If you want to sort rubbish for recycling, ask for help from a **birver**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **birver** is responsible for sorting rubbish for recycling.

You can also say that the person responsible for sorting rubbish for recycling is a **birvist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **birvist** is responsible for sorting rubbish for recycling.

9. ghuzzer/ghuzzist

Professor Parsnip has invented a machine that is used for warming up cold feet. If you want to warm up cold feet, ask for help from a **ghuzzer**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **ghuzzer** is responsible for warming up cold feet.

You can also say that the person responsible for warming up cold feet is a **ghuzzist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **ghuzzist** is responsible for warming up cold feet.

10. nidder/niddist

Professor Parsnip has invented a machine that is used for polishing flowers. If you want to polish flowers, ask for help from a **nidder**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **nidder** is responsible for polishing flowers.

You can also say that the person responsible for polishing flowers is a **niddist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **niddist** is responsible for polishing flowers.

11. kyver/kyvist

Professor Parsnip has invented a machine that is used for taking out the food you don’t like from a meal. If you want to take out the food you don’t like from a meal, ask for help from a **kyver**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **kyver** is responsible for taking out the food you don’t like from a meal.

You can also say that the person responsible for taking out the food you don’t like from a meal is a **kyvist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **kyvist** is responsible for taking out the food you don’t like from a meal.

12. shepper/sheppist

Professor Parsnip has invented a machine that is used for working out names of people you meet. If you want to working out names of people you meet, ask for help from a **shepper**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **shepper** is responsible for working out names of people you meet.

You can also say that the person responsible for working out names of people you meet is a **sheppist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **sheppist** is responsible for working out names of people you meet.

13. yabber/yabbist

Professor Parsnip has invented a machine that is used for fixing tummy aches. If you want to fix tummy aches, ask for help from a **yabber**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **yabber** is responsible for fixing tummy aches.

You can also say that the person responsible for fixing tummy aches is a **yabbist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **yabbist** is responsible for fixing tummy aches.

14. jayfer/jayfist

Professor Parsnip has invented a machine that is used for crisping up soggy chips. If you want to crisp up soggy chips, ask for help from a **jayfer**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **jayfer** is responsible for crisping up soggy chips.

You can also say that the person responsible for crisping up soggy chips is a **jayfist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **jayfist** is responsible for crisping up soggy chips.

15. thogger/thoggist

Professor Parsnip has invented a machine that is used for letting you walk up walls. If you want to walk up walls, ask for help from a **thogger**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **thogger** is responsible for letting you walk up walls.

You can also say that the person responsible for letting you walk up walls is a **thoggist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **thoggist** is responsible for letting you walk up walls.

16. vayper/vaypist

Professor Parsnip has invented a machine that is used for brushing the sand off your body. If you want to brush the sand off your body, ask for help from a **vayper**, who is responsible for operating the machine. When you are ready, press the button to start recording and say the name of the operator and what they do. For example, say the **vayper** is responsible for brushing the sand off your body.

You can also say that the person responsible for brushing the sand off your body is a **vaypist**. When you are ready, press the button to start recording and say the other name you can use for the operator and what they do. For example, say the **vaypist** is responsible for brushing the sand off your body.

7.2.Target Novel Stems

	Set 1	Set 2
Predictable	thub	chig
	jev	tem
	nesh	vish
	vib	jit
	yag	nid
	chob	shep
	tup	yab
	shug	thog
Unpredictable	ghakk	phegg
	veme	yune
	jeabb	meaph
	yirp	birv
	phirf	ghuzz
	bype	kyve
	koyb	jayf
	mirbe	vaype

7.3. Experimental Sentences in Self-paced Reading Task

Set 1	Set 2
Ben put the machine into the fish tank to thub the glass clean again.	Ben put the machine into the fish tank to chig the glass clean again.
Rick put his dirty socks into the machine to jev them clean.	Rick put his dirty socks into the machine to tem them clean.
Nick put the playing cards into the machine to nesh before starting the game.	Nick put the playing cards into the machine to vish before starting the game.
Sara put her soaking wet hat on the machine to vib it dry.	Sara put her soaking wet hat on the machine to jit it dry.
Pam put the dirty flowers under the machine to yag them shiny.	Pam put the dirty flowers under the machine to nid them shiny.
James put the picture of the girl into the machine to chob her name.	James put the picture of the girl into the machine to shep her name.
Lucas put his sore tummy beside the machine to tup it better again.	Lucas put his sore tummy beside the machine to yab it better again.
Matt put his feet into the machine to shug quickly up the wall.	Matt put his feet into the machine to thog quickly up the wall.
Sam saw a black bird and then made the machine ghakk to hear it sing.	Sam saw a black bird and then made the machine phegg to hear it sing.
Diana put the best orange on the machine to veme the juice.	Diana put the best orange on the machine to yune the juice.
Rex put the tennis ball into the machine to jeabb as he played fetch.	Rex put the tennis ball into the machine to meaph as he played fetch.
Lucy loaded all the rubbish into the machine to yirp it for recycling.	Lucy loaded all the rubbish into the machine to birv it for recycling.
Jane put her cold and sore feet into the machine to phirf them warm.	Jane put her cold and sore feet into the machine to ghuzz them warm.
Max put his food into the machine to bype the yucky peas.	Max put his food into the machine to kyve the yucky peas.
Jennifer put all her soggy chips under the machine to koyb them crispy.	Jennifer put all her soggy chips under the machine to jafy them crispy.
Pip waited for the brushes on the machine to mirbe the sand from his body.	Pip waited for the brushes on the machine to vaype the sand from his body.

7.4. Ethics Approval Letter

Human Sciences Subcommittee - 6499 - Castles- Ethics application - Amendment approved External Inbox ×

Jul 20, 2021, 4:38 AM

Dear Professor Castles,

Project ID: 6499
RE: 52021649930452 - Tracking children's word learning during independent reading

The above amendment for your application has been approved.

You may access the application by logging into the Human Research Ethics Management system at https://ethics-and-biosafety-form.mq.edu.au.

Kind regards,

Faculty Ethics Officer
Macquarie University | North Ryde
NSW 2109, Australia