EXPLORING THE NATURE AND TRANSFER OF ORTHOGRAPHIC LEARNING WITHIN THE SELF-TEACHING HYPOTHESIS

by

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ABSTRACT

The transition to being a skilled, fluent reader is an important focus of early education and, as such, of research on reading development. A prominent theory, the self-teaching hypothesis (Share, 2008), describes how this transition occurs. Share proposes that children learn the spelling patterns of new words during independent reading, helping to build a large store of known words that is essential for efficient word recognition and, in turn, reading comprehension. In this dissertation, we test several questions regarding the nature of self-teaching and how it supports reading development. Specifically, three studies test four core predictions of the self-teaching hypothesis: beginning readers are capable of self-teaching, accurate phonological decoding is required for self-teaching, self-teaching occurs on a word-specific basis, and self-teaching results in long-lasting high quality orthographic representations. Results from Study 1 show that beginning readers in Grades 1 and 2 engage in self-teaching, although it is less durable for those in Grade 1. Other findings from Study 1 suggest that self-teaching in beginning readers does not require accurate phonological decoding nor is it strictly word-specific, with children transferring learning of one word (e.g., *feap*) to facilitate processing of related novel words (e.g., *feaper*). Findings from Study 2 suggest that self-teaching is not a strictly word-specific process for more experienced readers in Grades 3 to 5 either. Here I show that learning one word (e.g., *feap*) facilitates better learning of related words (e.g., *refeap*) and, in turn, these accumulated learning experiences lead to even better processing of additional novel words (e.g., *misfeap*). Lastly, findings from Study 3 suggest that self-teaching leads to long-lasting quality orthographic representations in more experienced readers, with Grade 5 children able to access both orthographic and semantic information one year after learning. I place these findings in context of the original predictions of the self-teaching hypothesis (Share, 2008), and conclude by proposing an updated theoretical framework. This new framework provides three principles that may more accurately describe self-teaching and its role in reading development for beginner readers and more experienced readers alike.

Keywords: self-teaching, orthographic learning, elementary children, beginning readers, phonological decoding, learning transfer, lexical quality

LIST OF ABBREVIATIONS AND SYMBOLS USED

ANOVA	Analysis of variance
d	Cohen's *d* estimate of effect size
Gr.	Grade
M	Mean
MCAR	Missing completely at random
N	Number of participants in a sample
p	*p*-value indicating statistical probability
$\eta^2 p$	Partial-eta squared estimate of effect size
%	Percentage
RM-ANOVA	Repeated-measures analysis of variance
SD	Standard Deviation
t	Statistical value for comparing means using the *t*-distribution
F	Statistical value for comparing means using the *F*-distribution
TOWRE	Test of Word Reading Efficiency
W	Shapiro-Wilks test of normality

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Chapter 1. General Introduction

Skilled, fluent reading is an essential skill for full participation in society. Indeed, poor reading skills are related to negative outcomes across several areas of functioning ranging from education and employment (e.g., Public Health Agency of Canada, 2013; Statistics Canada, 2005) to mental and physical health (e.g., Boyes et al., 2020; Statistics Canada, 2005; Wilson et al, 2009). Given the importance of fluent reading skills to lifelong learning and success, acquiring efficient and accurate reading skill is an important goal for early education. Thus, a fundamental goal of research in reading development lies in understanding exactly how children move from being slow readers of individual words to fluent readers and comprehenders of complex texts. In considering this transition, it is worth reflecting on the fact that beginning reading often involves effortful decoding, or sounding out, of individual words, which can make it difficult for young readers to engage in reading comprehension. As word recognition becomes more efficient, more attention can be allocated to understanding the meaning of the text. Explaining this transition from effortful decoding to fluent reading, and thereby better reading comprehension, is a core challenge facing all models of reading development.

Most theories of reading development agree that fluent reading relies on having a store of orthographic representations that can be accessed efficiently when required (see Share, 2008; Perfetti & Hart, 2002; Ehri, 2005; 2014; Hoover & Gough; 1990; Gough & Tunmer, 1986). An orthographic representation is defined as the mental representation of the spelling pattern for a specific word (Apel, 2011; Share, 2008). Given this widespread agreement regarding the importance this store of orthographic representations in the transition to skilled reading, the next important question lies in understanding how children build this store of orthographic representations.

The process of acquiring these orthographic representations has been referred to as orthographic learning (Apel, 2011; Share, 2008). The self-teaching hypothesis (Share 1995; 2008) is the most prominent theory of reading development describing orthographic learning. The self-teaching hypothesis (Share 1995; 2008) proposes that children acquire orthographic representations through their independent reading experiences. When children read connected text, such as stories, they will often come across a word they have not seen before. The self-teaching hypothesis suggests that children learn the spelling pattern of new words (i.e., its orthographic representation) and store it in memory to access later when they see the word again. It is through this orthographic learning that, over time, children acquire a store of orthographic representations and word recognition becomes more efficient, enabling more attention to be devoted to understanding the text.

It is hard to underestimate the impact of the self-teaching hypothesis on the field. This theory has led to shifts in research focus, such as investigating the role of children's independent learning experiences in reading development (see Share, 1995; 2008 & Kilpatrick; 2015), and in educational practice, such as encouraging free reading as an avenue of vocabulary development (see McQuillan, 2019). Indeed, self-teaching is consistently and widely cited as the main mechanism by which orthographic learning happens, with repeated calls for understanding how this works. As noted by Nation and Castles, "Put simply, to understand more about reading development, we need to understand more about how [orthographic] learning happens." (2017, p. 27).

I respond to this call in this thesis by conducting three research studies which, together, address four key objectives related to the self-teaching hypothesis. In brief, these objectives are to investigate whether beginner readers are capable of self-teaching, whether phonological decoding is required for self-teaching to occur, whether self-teaching occurs solely on a word-specific basis or if learning transfers beyond specific items, and whether self-teaching leads to the development of long-lasting quality orthographic representations as required to play a role in reading development as proposed by the self-teaching hypothesis (Share, 2008). The goal of addressing these objectives is to clarify the role of the self-teaching process in the transition from beginning reading to skilled reading, to specify theories of reading development, and to identify avenues to support children's learning through independent reading.

1.1. Self-Teaching Hypothesis

My four research objectives are motivated by four core predictions of the self-teaching hypothesis. Below I review these ideas in detail and situate my own research question in brief within them.

1.1.1. Beginning readers can learn via self-teaching. A key prediction of the self-teaching hypothesis (Share, 2008) is that orthographic learning occurs during independent reading across all ages and reading levels, even in beginner readers who have limited decoding skills. Share describes this as the early onset hypothesis, noting that "…beginning reading is assumed to be beginning self-teaching" (2008, p. 41). Specifically, Share notes that even rudimentary decoding skills may be enough to lead to the acquisition of an orthographic representation, though it may be relatively primitive in nature. According to Share, beginning reading acts as beginning self-teaching as long as the child has three early skills: basic letter-sound knowledge, some level of awareness of initial and/or final sounds, and some ability to use contextual information to help with word pronunciation when they are not able to phonologically decode the word fully. Given this, the prediction is that very young children who are just learning to read should be able to form orthographic representations when they encounter a novel word during independent reading. In the face of this prediction, an open question lies in whether early readers can attend to the spelling patterns of whole words enough to form an orthographic representation that they can then later recall when needed given the extremely effortful decoding that is typically required at this stage. It is possible that rudimentary decoding skill is enough to form such orthographic representations; however, it may also be that early decoding involves too high of a cognitive load for early readers to form accurate orthographic representations that they are able to retain over time. Examining these possibilities is the first research objective of this dissertation.

1.1.2. Phonological recoding is required for self-teaching to occur. Another key prediction of the self-teaching hypothesis (Share, 2008) is that the primary mechanism for self-teaching is phonological recoding. Broadly, Share (2008) defines phonological recoding as the process of converting printed text to sound (i.e., decoding or pronouncing the word). To maintain consistency, throughout this dissertation I use the term phonological decoding—a term that is both commonly used in much of the literature and in line with Share's own definition—when referring to this prediction. In fact, Share (2004) stated that "…exhaustive letter-by-letter decoding (en route to a correct pronunciation) is assumed to be critical to the formation of well-specified orthographic representations" (p. 268). Self-teaching is proposed to occur via decoding because the process of decoding a word, or sounding it out, requires the reader to pay attention to each letter of the word in order. By attending to the letters one-by-one and in order, the reader is better able to encode the correct letters in the correct order and form an accurate orthographic representation. Practically, this means that if a child encounters the word *magic* and decodes it correctly, they are likely to form an orthographic representation of *magic.* In contrast, a child who encounters the word *magic* and decodes it incorrectly is unlikely to form an accurate orthographic representation for the word *magic*. Indeed, phonological decoding has been described as the 'sina qua non' of orthographic learning (Share, 1995), with the prediction that decoding must happen for learning to occur. Testing this strong prediction is the second objective in this dissertation, including exploring whether orthographic learning might occur in the absence of accurate decoding.

1.1.3. Self-teaching is word specific. A third key prediction is that orthographic learning via self-teaching occurs item-by-item. Share (1999) proposes that orthographic representations are learned item-by-item as readers encounter words they do not recognize in text. In this way, the learning is also said to be word-specific, with every encounter of a specific word providing the chance to acquire information about the spelling pattern of that specific word. Share suggested that acquiring orthographic representations that are able to support efficient word recognition "…depends primarily on the frequency to which a child has been exposed to a particular word (together with the nature and success of item identification)…" (1999, p. 121). Share (2008) notes that this process is in line with instance-based theories of reading that describe learning as relying on repeated exposures to the same stimuli. Practically, this would mean that children acquire orthographic representations through recurrent encounters with a specific word, such as *magic*, that allow them to encode the correct spelling pattern for *magic* that they can recall when they see that word again, helping them to recognize the word quickly and accurately. Exploring whether self-teaching occurs on this strictly item-specific basis or whether children can transfer this learning to other word forms that they encounter (e.g., *magical, magician*) is the third research objective of this dissertation.

As I explore this question, I acknowledge that Share (1995; 2008) himself raised the possibility of learning transferring beyond single items, discussing two possible methods through which prior learning may impact future learning of novel words. One comes from Share's suggestion that, with skill and reading experience, letter-by-letter decoding (a bottom-up process) can become more efficient through the use of more top-down knowledge and processes (e.g., applying knowledge of orthographic regularities, analogical mechanisms). This lexicalization process is a mechanism through which learning can extend beyond single items. The very term lexicalisation brings to mind the possibility that transfer might occur on the basis of morphology, given its status as an organisational feature of the lexicon (e.g., Frost, 2012; Rabin & Deacon, 2008). A second mechanism comes from his suggestion that orthographic knowledge, or a secondary orthographic component, may impact the self-teaching process (Share, 2008). This opens the possibility that children's knowledge of orthographic patterns acquired from other words might influence the likelihood that they will form orthographic representations for new words they encounter. In the face of a good deal of discussion and research on the item-by item nature of self-teaching, it certainly seems plausible that learning transfer occurs, which would in turn suggest that learning does not happen on a strictly item-by-item basis. If transfer does occur, it is open as to whether this occurs on the basis of morphological or orthographic similarities. I test these possibilities as part of the third research objective in this dissertation, exploring whether orthographic learning transfers to other items and the mechanism through which it might do so.

1.1.4. Self-teaching as a long-term learning process. Finally, inherent in the self-teaching hypothesis (Share, 2008) is the presumption that the orthographic learning that occurs through self-teaching is durable over long periods of time. Indeed, the self-teaching hypothesis describes self-teaching as key in the transition to skilled reading; self-teaching is thought to allow children to build a store of orthographic representations that can be quickly recalled when needed, allowing them to shift resources away from lower-level reading skills like decoding and towards higher-level reading skills like reading comprehension. For this to be true, children would need to be able to form long-lasting and high-quality orthographic representations through self-teaching, including with just few exposures to a particular word. This leads us to the question of the quality and durability of the orthographic representation that is established through self-teaching.

With regard to quality, it is useful to consider another theory of reading development, the lexical-quality hypothesis (Perfetti & Hart, 2002), in terms of the kind of orthographic representations required to support reading. Perfetti and Hart note that orthographic representations must be of high quality to support reading comprehension. High quality representations are defined as representations that integrate three forms of information: phonological (i.e., sound), semantic (i.e., meaning), and orthographic (i.e., spelling). Perfetti and Hart (2002) also suggest that children develop high-quality representations that are durable across time through repeated exposures to the same word. This idea is similar in some ways to the prediction that learning is item-specific within the self-teaching hypothesis (Share, 2008), according to which repeated exposures with accurate phonological decoding should lead to better representations.

One might also consider higher quality representations to be ones that are durable over time, which leads us to the question of whether self-teaching can lead to a durable orthographic representation after the few exposures typical in a self-teaching paradigm. And so, it seems important to test whether self-teaching results in the formation of the durable high-quality representations that may be necessary to support reading comprehension. This is an essential question in evaluating whether the self-teaching hypothesis (Share, 2008) as proposed can account for the transition to skilled reading, particularly in cases such as infrequent words that, by definition, children see far less often. I address these questions as part of the fourth research objective in this dissertation, investigating whether children are able to form durable high-quality representations that they can access when needed after a prolonged delay (i.e., one year), even with few initial exposures to a new word.

Taken together, given the significant impact of the self-teaching hypothesis on our understanding of reading development and on the development of educational practices, important questions still need to be answered in order to understand the nature of orthographic learning within the self-teaching context. In light of these questions, my four core objectives are to determine whether beginner readers are capable of self-teaching, whether phonological decoding is required for self-teaching to occur, whether self-teaching occurs solely on a word-specific basis or if learning transfers beyond specific items, and finally, whether self-teaching leads to the development of long-lasting quality orthographic representations.

1.2. Current Work

I conducted three separate research studies to address these four core research objectives that explore how children build a store of orthographic representations through self-teaching. The three studies conducted are described in more detail here, including the specific research questions in each one and how they achieve the identified research objectives.

1.2.1. Study 1. *Do beginning readers engage in self-teaching and, if so, what is the nature of this beginning self-teaching?*

In the first study, I examine the first prediction of the self-teaching hypothesis (Share, 2008), clarifying whether beginning reading really is beginning self-teaching. This work is an essential follow-up to previous research. The few available studies reveal conflicting findings as to whether young readers can engage in orthographic learning during independent reading (e.g., Deacon et al., 2019; Chen et al., 2018; Cunningham et al., 2002; Share; 2004; Cunningham, 2006).

Within the context of young readers, this study also addresses the second and third predictions of the self-teaching hypothesis, investigating the role of decoding in beginning self-teaching. To date, the role of decoding in beginning self-teaching also remains unclear, with few studies directly addressing this prediction in early readers (e.g., Deacon et al., 2019; Chen et al 2018) and some apparent differences in those results depending on how orthographic learning was measured (Chen et al., 2018). As noted earlier, this question is perhaps most hotly contested with young readers, for whom early reading is likely to be incredibly effortful, potentially negating any ability to engage in orthographic learning.

Finally, in this study, I test the third prediction of the self-teaching hypothesis that suggests beginning self-teaching occurs on an item-specific basis. Available evidence suggests that older children in Grades 3 and 5 transfer their learning to help them process related words when they are encountered (Tucker et al., 2016; Pacton et al., 2013; Pacton et al., 2018); however, it is currently not clear if this is also the case for young children. Again, given the effortful nature of decoding in early reading, the answer as to the question of the transfer of learning is not obvious in young readers. As such, this study fills in several gaps in available knowledge about self-teaching in early readers.

To recap, study one examines three specific research questions. To examine whether beginning reading is beginning self-teaching, I ask *Do beginner readers in Grades 1 and 2 learn the spelling patterns of novel words when encountered during independent reading?* To test the role of phonological decoding in self-teaching, I ask: *What role does phonological decoding play in orthographic learning for readers in Grades 1 and 2?* To evaluate the extent to which orthographic learning via self-teaching occurs on an item-specific basis in these early readers, I ask: *Do readers in Grades 1 and 2 transfer their learning of one word to help them recognize related novel words?* Together, answering these research questions build on the current literature to describe beginning self-teaching in beginning readers more fully.

1.2.2. Study 2. *Does self-teaching occur solely on an item-specific basis or does the learning transfer to future encounters with related words?*

The primary focus of the second study is to investigate the third prediction of the self-teaching hypothesis (Share, 2008), clarifying whether orthographic learning within the self-teaching context is strictly item specific. Previous research suggests that, within the self-teaching context, children in Grades 3 and 5 transfer their learning of one word (e.g., *lurb*) to help them process related words they have not previously seen (e.g., *lurber, lurble*; Tucker et al., 2016; see also Pacton et al., 2013; Pacton et al., 2018). To date, this type of learning transfer has been tested by assessing children's ability to recognize the unlearned items (e.g., *lurber*) on the basis of the idea that identifying the correct spellings at levels above chance would suggest that they transfer their knowledge of the originally learned item (e.g., *lurb*) to do so. This tells us about how prior learning of a simple word may impact subsequent processing of related items but does not test its impact on subsequent learning of related items. As such, I take this a step further and test whether learning of one word (e.g., *lurb*) will help them learn a related word (e.g., *relurb, pelurb*) when they encounter it in connected text, in effect testing whether prior learning can help children acquire a better orthographic representation for a related novel word. Testing these effects on later learning of related words likely more closely approximates children's learning and reading in naturalistic contexts, in which they will often encounter a novel word and later, in another text, a related form (e.g., Nagy & Anderson, 1984).

In testing this third prediction, I also explore the mechanism for learning transfer, specifically in terms of whether transfer occurs based on morphological or orthographic similarities. Doing so addresses the conflicting available evidence. Some results suggest it may occur via orthographic similarities (Tucker et al., 2016) and others via a morphologically based strategy (Pacton et al., 2013; Pacton et al., 2018).

Finally, in considering whether learning of one word enables subsequent learning of related words, I step into the territory of the impact of accumulated learning through independent reading. For example, I ask whether learning both *magic* and *magician* during independent reading then support better processing of a word like *magical* when it is encountered for the first time. It has been estimated that children in Grades 3 through 5 acquire more than 20 new words each day, with over a dozen of these likely to be new derived words (Anglin, 1993). As such, the possibility of a role for self-teaching in this kind of accumulated learning is an important avenue of investigation. Indeed, it may get at the heart of how children are able to engage in such fast-paced vocabulary development during elementary school years (e.g., Anglin, 1993; Nagy & Herman, 1987).

Taken together, study two tests three such specific research questions about transfer of learning with children in Grades 3, 4, and 5 through a novel modification of the self-teaching paradigm. To determine the initial question of whether learning of one word facilitates subsequent related words, I ask: *Do children transfer their learning of a simple word to their later learning of complex words?* To examine how such learning-to-learning transfer occurs (i.e., through a morphological or orthographic strategy), I ask: *What is the mechanism of any learning-to-learning transfer that occurs?* Finally, to investigate the impact of multiple self-teaching experiences on building stores of related words, I ask: *Do children generalize their accumulated learning experiences of both simple and complex to facilitate their processing of related words they have not* *previously learned?* Together, answering these research questions will shed light on the item-specificity of orthographic learning within the self-teaching paradigm, providing a better understanding of when and how learning transfer occurs during independent reading.

1.2.3. Study 3. *Does self-teaching result in long-lasting quality orthographic representations as would be required for it to play a role in reading development as proposed by the self-teaching hypothesis (Share, 2008)?* The goal of the third study is to investigate the fourth prediction of the self-teaching hypothesis, that of the durability and quality of orthographic representations acquired via self-teaching. To date, most self-teaching studies test retention up to 7 days after the initial reading experience (e.g., Bowey & Muller, 2005; Cunningham et al., 2002; Nation et al., 2007), with Share (2004) extending this to 30 days in one study with children in Grade 3. This leaves open the question of retention beyond one month. As such, it is unclear as to whether orthographic representations acquired through self-teaching will remain accessible to children in the long-term, as would be suggested by the self-teaching hypothesis (Share, 2008). In considering the durability of these representations, it is useful to consider the quality of the orthographic representations formed via self-teaching after longer periods of time and/or whether support may be required to access them.

As such, study three examines the durability and quality of the representations acquired via self-teaching. I do so by using a modified self-teaching design in which children in Grade 4 engage in independent reading, after which they complete outcome measures assessing learning of both orthographic information and semantic information. Children completed the same outcome measures again one year later.

Using this design, I answer two research questions. To investigate the durability of the orthographic representations formed during self-teaching, I ask: *Do children retain orthographic and semantic information one year after learning new pseudowords within the self-teaching context?* To investigate the quality of those orthographic representations retained after a longer period of time, I ask: *Do children still retain an integrated orthographic representation that contains both orthographic and semantic information, and do they require some form of memory cue to access it after one year?* Taken together, answering these questions gets at the heart of whether the self-teaching hypothesis can explain the transition to skilled reading as proposed, determining a key expectation if this were to be the case: whether orthographic representations learned via self-teaching remain available for children to access long-term.

In the papers that follow, I report on these three studies designed to elaborate the nature of orthographic learning within the self-teaching context by directly addressing the four core research objectives of the dissertation. By determining whether beginner readers are capable of self-teaching, whether accurate phonological decoding is required for self-teaching to occur, whether self-teaching occurs solely on an item-specific basis or if learning transfers beyond specific items, and whether self-teaching results in durable quality orthographic representations, I provide much-needed empirical evidence testing core predictions of the self-teaching hypothesis.

Chapter 2. Early self-teaching: Testing the nature of orthographic learning and learning transfer in beginning readers.

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2.1. Abstract

The current study aimed to clarify the nature of orthographic learning during independent reading (i.e., self-teaching) among beginning readers. The most prominent theory of early learning of word-specific orthographic forms, the self-teaching hypothesis, predicts that beginning reading is beginning orthographic learning. And yet, empirical evidence to date has focused on older children with more reading experience. Here we test the extent to which beginning readers learn new words during self-teaching experiences, as well as transfer that learning to their subsequent processing of related words, and the role of decoding in this learning and transfer. In this study, children in Grades 1 and 2 read simple nonwords (e.g., *lurb*) embedded in short stories adapted to be appropriate for young readers. Children then completed orthographic choice tasks to test both their learning of those words and the transfer of learning to novel words that are either morphologically or orthographically related (e.g., *lurber* and *lurble*, respectively). Results indicated that children in Grades 1 and 2 learned the spelling patterns of novel words. Further, they were able to transfer that learning to their processing of the novel related words. Notably, only children in Grade 2 were able to do retain, and transfer, their learning three days later. Finally, results indicated that accurate phonological decoding is not required for learning to occur, although there is some evidence that it may facilitate better learning for children in Grade 2. Taken together, these findings help us to better understand the nature of self-teaching in beginning readers, informing future research and educational practices.

Keywords: reading; self-teaching; orthographic learning; beginning readers; phonological decoding; learning transfer

2.2. Introduction

The Self-Teaching Hypothesis (Share, 2008) proposes that readers learn the spelling patterns of novel words during independent reading, specifically through phonological decoding, or sounding out, of each individual word. There is abundant support for this prediction for readers in Grade 3 through to adulthood, with consistent evidence that older children and adults can learn spelling patterns through their independent reading (e.g., Nation et al., 2007; Share, 1999; Tucker et al., 2016; Wang et al., 2011). And indeed, this learning generalises; older readers transfer their learning of new words to processing of related words (e.g., learning *feap* transferring to *feaper* and *feaple*; Tucker et al., 2016). It is not yet clear if these processes apply for young readers with less reading experience; despite the original suggestion that "beginning reading is assumed to be beginning self-teaching" (Share, 2008, p. 41), there is mixed evidence in the few studies to date on this question in Grade 1 readers (Cunningham, 2006; Deacon et al., 2019; Share, 2004). As such, the question of the extent to which young readers can engage in self-teaching is relatively open, as is the question of whether this learning transfers to processing of related words. Further still, the role of decoding, considered the 'sina qua non' of self-teaching (Share, 1995), in early learning is unclear. We report here on a study with young readers assessing the extent of early orthographic learning alongside two other core tenets of the self-teaching hypothesis: the possibility of transfer of this learning and the role of decoding. Fleshing out the nature of early self-teaching will delineate the degree to which young readers can capitalize on independent reading opportunities, while also determining the generalizability of the Self-teaching hypothesis to early reading development.

2.2.1. Is early reading early self-teaching?

We frame the value of answering these questions by revisiting the original conceptualisation of the Self-Teaching Hypothesis (Share 1995; 2008), a theory that has shifted the field's attention to the child's capacity for independent learning (Kilpatrick, 2018). A first key tenet of the Self-Teaching Hypothesis is that "beginning reading is beginning self-teaching" (Share, 1999, p. 97; see also Share, 2008). The idea here is that children can establish orthographic representations of words they encounter in their early reading as soon as they have basic knowledge of letter-sound correspondences and some phonological sensitivity. And yet, these strong theoretical predictions might not fully acknowledge the cognitive consequences of incredibly labour-intensive early decoding. Novice readers expend far more effort on letter-by-letter decoding than do more experienced readers (Share, 2004) and indeed becoming more automatic in decoding is key to word reading development (e.g., Bresnitz, 2006; Samuels, 1994; Samuels & Flor, 1997; Stanovich, 2000). The effort of early decoding might come at a cost to the ability to form full orthographic representations from these experiences. The effort of beginning decoding, particularly of novel words, might interfere with beginning readers' ability to focus on, and encode, whole spelling patterns to the extent that they do not retain much from these early decoding experiences.

Available evidence does not resolve these conflicting predictions. The clearest evidence comes from Deacon et al.'s (2019) study in which English-speaking children in Grades 1 and 2 read short stories containing novel words. Results indicated that the children were above chance in their recognition of the spellings of the novel words both immediately after reading the stories and again a few days later. A more mixed picture emerges in Cunningham's (2006) study with Grade 1 English-speaking students who read short stories embedded with real words or homophonic alternatives (e.g., *prince-prinse*). In an orthographic choice task administered a few days later, children chose the correct spelling for the target word 49% of the time, numerically more than the chance level of 25%. No statistical tests against chance were reported. In the same study, children spelled 36% of the targets correctly, a level of accuracy not that much higher than the degree to which they wrote incorrect homophonic spellings (21%). And in two other studies, these with Hebrew-speaking children in Grade 1, Share (2004) found no evidence of orthographic learning in either orthographic choice and spelling tasks; children were at chance in most cases in both orthographic choice and spelling tasks. The results of this set of studies tempers enthusiasm that early reading is early self-teaching and points to the need for further empirical scrutiny of this question.

The inconsistency in results at Grade 1 across studies is even more striking, and motivating of further empirical inquiry, when contrasted with the remarkable consistency in findings that orthographic learning occurs during independent reading by Grade 2. Several studies with Grade 2 children have found that orthographic learning occurs via self-teaching regardless of the type of outcome test used, including orthographic choice, spelling, and naming latency tasks (e.g., Share, 1999; 2004, de Jong et al., 2009; Cunningham et al., 2002; Deacon et al., 2019). Taken together, the literature to date suggests that very early readers may not be able to learn spellings from their independent reading to the extent that they are able to make use of that learning across tasks, especially more complex tasks (i.e., spelling). However, it also suggests that there may be a significant developmental shift in a reader's ability to reliably learn the spelling patterns of new words via self-teaching as they transition from Grade 1 to Grade 2. A first question that we test in this study then is the extent to which English-speaking children in Grades 1 and 2 can engage in self-teaching during independent reading.

2.2.2. Can young readers transfer their orthographic learning?

If young readers can engage in self-teaching, we then need to flesh out the nature of this early orthographic learning, specifically in terms of whether beginning readers can transfer their learning to the processing of new words. Although the Self-Teaching Hypothesis (Share, 2008) posited that orthographic learning occurs on an item-by-item basis, three studies to date suggest that children in Grades 3 and 5 transfer learning during independent reading to facilitate processing of related words (Pacton et al., 2013; Pacton et al., 2018; Pacton & Peereman, 2023; Tucker et al. 2016). These findings align with other suggestions from Share (1995; 2008) that the process of phonological decoding itself is lexicalized over time. Morpheme units and regular spelling patterns are both predicted to be a part of this lexicalisation process. These ideas also align with Ehri's (2005; 2014) view of sight word reading in consolidated alphabetic reading as reflecting consolidation through larger units that are both morphemes and letter-patterns. Evidence and some theorising suggest that self-teaching transfers from one word to related words, either on the basis of morphological relations in particular or shared orthographic patterns in general.

Interestingly, findings from the few available reports conflict on the nature of this transfer, with some suggesting transfer specifically to morphologically related words and others suggesting transfer on an orthographic basis. Specifically, Pacton et al (2018) showed that French-speaking Grades 3 and 5 were better able to learn target nonwords when they were presented along with novel morphologically related nonwords than with orthographically related nonwords (see also Pacton et al., 2013). These results have been interpreted as suggesting that transfer during self-teaching occurs on the basis of morphological relations. In contrast, in three separate studies, Tucker et al. (2016) showed that Grades 3 and 5 English-speaking children's learning of a nonword (e.g., *feap*) helped them choose the correct spelling of novel nonwords, both when these were morphologically related (e.g., *feaper*) and only orthographically related (e.g., *feaple*). These studies are remarkably consistent in demonstrating Grade 3 and 5 children transfer their learning, showing that self-teaching extended beyond individual words (Share, 2008), although there is some debate as to the proposed mechanism of transfer.

Turning to younger children, it is an open question as to the extent to which less experienced readers can transfer their learning from independent reading and the basis on which this transfer might occur. Given the inconsistency in the extent to which orthographic learning is detected in beginning readers (e.g., Cunningham, 2006), this learning may not be strong enough to enable transfer to the processing of other words. If transfer does emerge for beginning readers, it seems possible that young readers might be more likely to transfer their learning when there is additional supporting information, as offered by the semantic information in morphemes (e.g., Schreuder & Baayen, 1995; see also Merkx, Rastle & Davis, 2011). Alternatively, evidence from other paradigms suggests that young readers rely on orthographic analogies in their reading of real words (e.g., Goswami, 1988), we might see similar effects in their learning of novel words. We explore these possibilities here, testing the extent to which beginning readers can transfer their learning of spelling patterns of novel words to their processing of related words.

2.2.3. What is the role of decoding in early self-teaching?

As we consider the extent to which beginning readers can engage in orthographic learning through self-teaching and the possibility of transfer of this learning, we return to a core tenet of the self-teaching hypothesis. Phonological decoding is considered to be a necessary component, or the 'sina qua non' (Share, 1999), of self-teaching, with decoding drawing attention to the individual letters in words in the correct order and cementing that pattern into long-term memory (Share, 2008). The literal interpretation of this tenet is that phonological decoding is required for orthographic learning to occur, with a softer interpretation that phonological decoding supports orthographic learning. The evidence to date supports this latter view, at least for more experienced readers. Children in Grades 3 and 5 showed orthographic learning and even transfer for targets that they had decoded correctly and those that they had not, although both learning and transfer was stronger with accurate decoding (Tucker et al., 2016). Together these findings suggest that, for more experienced readers, decoding supports but is not required for orthographic learning, and transfer of that learning, to occur.

Thinking this through for less experienced readers leaves it unclear as to whether decoding is required for orthographic learning in beginning readers. On the one hand, decoding, and the close processing of individual letters in order associated with it, might be essential for early word learning. In short, decoding might be the 'magic ingredient' that young readers need to retain new words in mind. On the other hand, decoding might not be required for orthographic learning to occur in early self-teaching; Share himself (1999) wrote that "some rudimentary self-teaching skills, perhaps sufficient to establish primitive orthographic representations of the kind discussed by Perfetti (1992), may exist at the very earliest stages of learning to read even before a child possesses any decoding skill in the conventional sense" (p. 97). In this case, orthographic learning might occur in the absence of fully accurate decoding. To date, one study has tested this question in young readers. Deacon et al. (2019) re-analysed their data in terms of decoding accuracy and showed evidence of significant orthographic learning when the child had and had not accurately decoded a target nonword for children in Grades 1 and 2. With a single study to date with beginning readers, this question seems far from resolved, particularly given the strength of the theoretical predictions that phonological decoding is required for self-teaching to occur.

Turning to the softer interpretation of the role of decoding, we also need to explore whether accurate decoding supports better orthographic learning for beginning readers. One might think that the answer is obvious; decoding draws attention to each letter and its associated sound and encourages letter by letter processing, all of which should support better retention of the word form. And yet, decoding is far more effortful for beginning readers than for more experienced readers with increasing automaticity in decoding key to strong word reading development (see Bresnitz, 2006; Samuels, 1994; Samuels & Flor, 1997; Stanovich, 2000). The effort that young readers expend on letter-by-letter decoding might come at a cost to the ability to form and retain detailed orthographic representations from these experiences. In short, the effortful nature of beginning decoding, particularly with novel words, might reduce beginning readers' ability to focus on, and encode, whole spelling patterns to the extent that there is no added benefit of accurate decoding experiences. In this case, we may not see improved learning following on successful decoding experiences.

The evidence to date is remarkably mixed in the few available studies with beginning readers, complicating disambiguating these possibilities. In their study of children in Grades 1 and 2, Deacon et al. (2019) reported that scores for both the orthographic learning measure were higher with successful decoding than without it. In a re-analysis of data for children in Grade 1 from Cunningham (2006), Chen et al. (2018) found that higher levels of target decoding accuracy were related to more accurate spelling of the target words, but not to greater accuracy in the orthographic choice task. Given that evidence of orthographic learning in the original study (Cunningham, 2006) only clearly emerged on the orthographic choice task, these findings are challenging to interpret.

Naturally, these questions as to whether decoding is required for and/or supports orthographic learning are relevant to questions about the transfer of orthographic learning in these young readers. Specifically, if the effortful phonological decoding impedes children's ability to form, and store, accurate orthographic representations then it would be expected that transfer of learning is even less likely to occur in this context. On the other hand, accurate decoding supports orthographic learning in beginning readers, we would expect effects of decoding on transfer of that learning. Whether decoding will shift the nature of transfer, as either morphological or orthographic, is also an open question. As we noted earlier, decoding supported but was not required for learning and transfer of that learning for children in Grades 3 and 5 (Tucker et al., 2016). Whether this is the case for beginning readers remains to be seen.

2.2.4. The present study

Here we report on a study testing the implications of the Self-Teaching Hypothesis (Share, 2008) for young readers. We ask three key questions in beginning readers through three research questions. First, we ask whether "beginning reading is beginning self-teaching" (Share, 1999, p. 97) by testing whether children in Grades 1 and 2 learn the spelling patterns of novel words when encountered during independent reading. This question responds directly to conflicting available evidence in this age group (e.g., Cunningham, 2006; Deacon et al., 2019; Share, 2004) Second, we examine whether beginning readers transfer their learning of one word to help them recognize related novel words, as has been uncovered for more experienced readers (e.g., Tucker et al., 2016), as well as the basis for that transfer. Finally, we examine the role of phonological decoding in orthographic learning, and transfer of that learning, in beginning readers. This latter question takes seriously the cognitive demands of early decoding.

We tested these research questions with children in Grades 1 and 2. We modified the classic orthographic learning paradigm (e.g., Tucker et al., 2016; Wang et al., 2011; Share, 2004) for use with younger children. We used simplified stories and nonwords that were appropriate for beginning readers. Children read six short stories, each with a different nonword (e.g., *feap*) embedded four times. The children's decoding accuracy was tracked during story-reading. Children were not given feedback on their reading to mimic independent reading experiences as much as possible. After children read the stories, orthographic learning was measured using an orthographic choice task, which is a common task used in self-teaching studies (e.g., Deacon et al., 2019; Nation et al., 2007; Share, 1999; Tucker et al., 2016; Wang et al., 2011). To test transfer, children were tested on morphologically complex (e.g., *feaper*) and orthographically complex (e.g., *feaple*) forms of the nonwords.

Using this design, we can answer our first research question by testing children's learning of the six target nonwords that they read in the stories. If learning of the target nonwords occurred, the children should choose the correct answer to items more often than what we would expect based on chance alone. Based on previous research (e.g., Cunningham et al., 2002; de Jong, Bitter, van Setten & Marinus, 2009; Deacon et al., 2019; Share, 1999), we expect that children in Grade 2 will show evidence of learning on the orthographic choice task. Predictions are less clear for children in Grade 1, for which we have conflicting available evidence. That said, it seems likely that, as Share (1999) expected, early reading is early self-teaching.

We test the extent and nature of transfer of learning, by exploring performance on an orthographic choice task for non-words that are related in terms of either morphology and orthography (e.g., *feaper*) or just orthography (e.g., *feaple*) to the non-words that they had encountered in the stories (e.g., *feap*). We are interested in whether they choose the same spelling as they encountered in the story (e.g., choosing *feaper* if they had read *feap*). We compare their processing of both the morphologically and orthographically complex nonwords for insight into underlying mechanism of that transfer. For example, if learning transfer primarily occurs due to orthographic similarity, we should see similar levels of performance for morphologically (e.g., *feaper*) and orthographically complex nonwords (e.g., *feaple*). In contrast, if learning transfer occurs due to (or is impacted by) morphological relationships, we should see a advantage of the additional morphological information such that scores are higher for morphologically than orthographically related complex nonwords. Based on prior research with more experienced readers (e.g., Tucker et al., 2016), we would expect transfer of learning that occurs in beginning readers to do so based on orthographic similarity.

To answer our third research question, we will evaluate the role of phonological decoding in orthographic learning and learning transfer for beginning readers. To examine whether decoding is required for orthographic learning and transfer to occur, we evaluate whether learning and transfer occurred when children were able to successfully decode the target (e.g., *feap*) during story reading at least once and when they were not (based on Tucker et al., 2016). This learning and transfer would be reflected in above chance performance on orthographic choice tasks. We are also interested in whether decoding orthographic learning supports learning of the targets and transfer of this learning; here we compare scores on orthographic choice tasks between when children were able to successfully decode the target (e.g., *feap*) during story reading at least once and when they were not (based on Tucker et al., 2016). Admittedly, defining the decoding experience in this way, grouping responses from children who decoded the target inaccurately on all chances together and grouping children who decode the target accurately at least once (but who may still be pronouncing it incorrectly one, two, or three times) creates a false dichotomy. We are losing significant nuance in their reading experience, especially within the decoded accurately group. However, given the decoding skill of children in these grades and the expected variability of decoding success, we would not have the power to group children more precisely. Despite this, we believe this approach can still provide valuable information about the role of accurate decoding experiences in orthographic learning. Based on results in more experienced readers

(Tucker et al., 2016) and limited available data with beginner readers (Chen et al., 2018; Deacon et al., 2019), we would expect that successful decoding experiences will facilitate, but not be required for, the occurrence of orthographic learning and transfer.

2.3. Methods

2.3.1. Participants

We recruited 121 children across grades one and two. There were 60 children in Grade 1 (M_{age} = 6 years, 6 months; 29 female) and 61 children in Grade 2 (M_{age} = 7 years, 5 months; 31 female). Mean scores on the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999) for children in both grades were near the standardization means and standard deviations, suggesting that our sample represents typical readers at these grade levels (see Table 2.1). All participating children were recruited in public schools within Nova Scotia, Canada. The curriculum guide for reading education in Nova Scotia reflects a mix of phonics and whole language strategies, beginning at the kindergarten level; however, based solely on the available curriculum guide, it is difficult to know exactly how much explicit teaching of reading strategies would have occurred before Grade 1. Given the information we do have about the kindergarten curriculum, and the reading accuracy across grades (see Table 2.1), we believe these Grade 1 children are reflective of relative beginners, or very new readers. Importantly, Grade 1 is likely the earliest grade in which children could reliably complete the full study as described without shifting to a different reading task (e.g., shared book reading, recently used to study orthographic learning in four- to six-year-olds; see Heintzman & Deacon, In Press).

Table 2.0.

TOWRE Subtest Standard Scores and Reading Accuracy for Each Grade

	Sight Word Efficiency	Phonological Decoding Efficiency	Number of reading errors, excluding targets (mean out of 179)	Nonword target decoding accuracy (mean out of 24)
	Mean (SD)	Mean (SD)	Mean (SD); %	Mean (SD); %
Grade 1	104.10 (12.82)	100.85 (13.99)	16.58 (19.44); 9%	8.58 (7.96); 36%
Grade 2	104.28 (15.31)	101.46 (16.09)	5.35 (7.54); 3%	14.52 (8.08); 61%

Note. TOWRE = Test of Word Reading Efficiency; Number of reading errors includes real words read incorrectly, real words skipped or added, and real words that testers helped with.

2.3.2. Materials

2.3.2.1. Nonword items during exposure phase

The nonwords were six pairs of homophonic nonwords (e.g., *cloot*—*clewt*) chosen from the larger set within Tucker et al. (2016), with half the children exposed to one item from a homophonic pair (e.g., *cloot*) and the other half of the children exposed to the other homophone of that pair (e.g., *clewt*). All selected nonwords were monosyllabic and contained four or five letters. All spellings followed regular letter-sound correspondence in English (Rastle & Coltheart, 1999). The expected pronunciations of the vowel sounds were also regular, as checked against the Children's Printed Word Database (Masterson, Stuart, Dixon, & Lovejoy, 2003) and the MRC Psycholinguistic Database (Wilson, 1988).

2.3.2.2. Stories and pictures

The six stories were adapted from previous work (Wang et al., 2011; Mimeau et al., 2018), with the goal of simplifying the stories for our young readers as much as possible. The passages were shortened, with reductions in the number of words per story and sentence length. The language was simplified as much as possible (e.g., using only present tense, using grade appropriate words). Each story contained four exposures to one target nonword (e.g., *cloot*). To control any potential preferences for representing a specific sound with a specific spelling pattern, two story sets were created.

Nonword items in the orthographic choice and naming tasks.

We used the nonwords from the orthographic choice task used by Tucker et al. (2016). The items consisted of 18 homophonic pairs of nonwords: 6 tested the target nonwords (e.g., *cloot*, *clewt*), 6 tested a morphologically complex form (e.g., *clooter*, *clewter*), and 6 tested an orthographically complex form (e.g., *clootle*, *clewtle*). The morphological and orthographic forms of the nonwords were created by adding one of two endings (-*er* or -*le*) to each base word as the -*er* ending can be a suffix, while the -*le* ending has no independent meaning. We chose these endings because they have similar token frequency at the end of English words, $t(6) = 0.986$, $p = .362$. We also ensured that the morphological and orthographically complex words were orthographically legal, such that the final three letters (e.g., -*ter* and -*tle*) occurred at the ends of real words in English.

For the orthographic choice task, each question consisted of a quadruplet set of nonwords: two nonwords were the homophonic pair (e.g., *cloot-clewt*) testing learning of the target and two nonwords that acted as visual distractors. As such, the visual distractors were created to contain the same homophonic vowel sounds and spellings as in the targets, with one change to a consonant (e.g., *cloob-clewb*). Across the items, the consonants that were changed varied randomly across items, including in the location of this change. For example, a set testing their learning of the base target *cloot* would be *cloot-clewt-cloob-clewb,* while the sets testing the morphologically and orthographically complex versions had distractors with different consonants (e.g., *clooter-clewter-clewper-clooper* and *clootle-clewtle-plootle-plewtle*, respectively). We did this to reduce the possibility that repeated exposure to the same distractor and/or order would influence performance. To this same end, we also randomized the order of the items within each set.

For the naming task, no distractors were used, with the task containing 36 nonwords in total: 12 target nonwords (e.g., *cloot*, *clewt*), 12 morphologically complex forms (e.g., *clooter*, *clewter*), and 12 orthographically complex forms (e.g., *clootle*, *clewtle*).

2.3.2.3. Presentation of items in the orthographic choice task

The 18 items on the orthographic choice task were distributed across three pages, with each page containing only one item that tested a nonword (e.g., *cloot* would be the first page, *clooter* on the second, and *clootle* on the third). Furthermore, the items testing the base, morphologically complex, and orthographically complex nonwords were distributed across the three pages so there would be no order effects that prioritized one word-type over another. Once the items were assigned to a page, their order of presentation on the page was randomized. The process of creating the orthographic choice task was completed two times, creating a different task for each of the two time points (immediate and delayed).

2.3.2.4. Presentation of items in the naming task

The 36 items on the naming task were split into three lists of 12, ensuring that no list had both items of a homophone pair (e.g., if a set included *cloot*, it could not also include *clewt*) and no set had more than two forms of a nonword (e.g., it may contain *cloot* and *clooter* but could not then also contain *clootle*). Within each list, the order of the nonwords were randomized, with some adjustments made to each set to ensure no two related nonwords (e.g., *cloot* and *clooter*) and no two nonwords of the form (i.e., target, morphologically complex, orthographically complex) would appear in a row. Finally, the naming task was programmed to randomly assign the order of the three lists for each child to try to prevent potential order effects due to children always seeing the same spelling of a nonword first.

2.3.3. Procedure

All testing was conducted one on one in a quiet area of the children's school over two sessions.

2.3.3.1. Exposure phase

At the first time point, children were introduced to Professor Parsnip, an inventor, and shown his picture. Children were then told they were going to read stories about six of his latest inventions, which were named with words they had not seen or heard before. They were asked to pay attention to the invention names as they would be asked about their spelling later. The children were then shown a picture of the first invention and given information about its features and function; they were not told its name. After removing the picture of the invention from view, children were then asked to read a story about that invention aloud. Children were not corrected on mispronunciations of the real words or nonwords in the stories. This sequence was repeated for each of the six stories. The stories were presented to children in a duo tang folder, printed on 8.5 x 11-inch white paper with a 22-point font size. The images of Professor Parsnip and the inventions were taken from Wang et al. (2011; see also Mimeau et al., 2018 and Tucker et al., 2016). The images were presented to children in a duo tang folder, printed in colour ink on 8.5 x 11-inch white paper. See Appendix A for an example of the images, stories, and information provided to children about the inventions.

2.3.3.2. Orthographic test phase

The orthographic choice task was administered two times: once immediately after reading the stories (Time 1; "Immediate") and again 2 – 3 days later (Time 2; "Delayed"). At each administration, the children were told to look carefully at each word and choose the best spelling based on what they knew from reading the stories. If they were unsure of an answer, they were encouraged to take their best guess.

The naming task was administered one time after the orthographic choice task at Time 2 ("Delayed"). This task was only administered once as the final task to avoid introducing further discrepancies in the number of exposures to the correct spelling and corresponding pronunciation attempts. The children provided a headset with microphone, which was calibrated to their volume of voice to minimize inaccurately recorded reaction times. The children were asked to read each word out loud as soon as they appeared on the screen, as well as told that they would need to speak clearly as the word would disappear once the microphone recorded their voice and the next word would appear. Each child completed a short practice with three words to ensure they understood the task and that the microphone was working. Using DirectRT software (Jarvis, 2008), the nonwords were then presented to children one at a time, written in black text (48-point font size) placed in the middle of a white screen. The nonwords remained on the screen until the software detected the children's voice, at which time the nonword disappeared. If the child did not attempt to read the nonword, and thus no sounds were detected, within five seconds the nonword disappeared and children were asked if they had a guess about what that word was. After each list of 12 nonwords, a break screen appeared on screen and the experimented provided the children a short break before continuing with the next list. [1]

2.4. Results

We inspected the data for missing values. On the Immediate orthographic choice task, there was just one missing data point, representing less than 0.1% of data. On the Delayed orthographic choice task, there were 15 missing data points across 7 participants, representing less than 0.1% of the data. A non-significant Little's MCAR test, $c^2(94) = 86.35$, $p = .70$, revealed that the data for the Delayed testing were missing completely at random. Given the very small portion of data was missing across the two orthographic choice tasks, and that it was missing completely at random, we used the expectation maximization algorithm to generate a single imputation as it gives unbiased parameter estimates and improves the statistical power of analyses (Enders, 2001; Scheffer, 2002). Missing data were imputed for each testing point (Immediate and Delayed) separately

[1] In the initial cleaning of the reaction time data, we excluded reaction times for incorrect responses, inaccurate reaction times (e.g., children self-corrected after the reaction time was recorded, a noise triggered the reaction time before the child read the word), and reaction times that were too high (i.e., more than 3.29 SDs above the mean) or too low (325ms or less). Due to the low accuracy rate (30% for children in Grade 1, 57% for children in Grade 2), and the rate of self-correction on correctly pronounced words, there was not sufficient reaction time data to use in analyses as planned.

using Missing Values Analysis within SPSS 26. After the Missing Values Analysis, one Grade 2 participant was removed due to a univariate outlier in their data.

In all analyses presented below, we considered an orthographic choice response to be correct if it had the same spelling as the nonword they read in the short stories (e.g., if children were exposed to *feap*, then spelling choices of *feap*, *feaper* and *feaple* were considered correct and *feep*, *feeper* and *feeple* incorrect).

2.4.1. Decoding accuracy during exposure phase.

Average decoding accuracy for the targets are reported in Table 2.1. Inspection of these means shows that children in Grade 1 were less accurate than those in Grade 2. This pattern was confirmed with a univariate ANOVA with between-subjects factor of grade (Grades 1 and 2), $F(1, 119) = 15.95$, $p < .001$, $\eta^2p = .12$. The children's accuracy reading real words was also evaluated, with more errors for children in Grade 1 ($M = 16.58$, SD = 19.44) than in Grade 2 ($M = 5.35$, SD = 7.54) emerging; $F(1, 118) = 17.42$, $p < .001$, $\eta^2p = .13$.

2.4.2. Research Question 1: Do beginning readers in Grades 1 & 2 learn the spelling patterns of novel words when encountered during independent reading?

To answer this first research question, we evaluated whether children in Grades 1 and 2 showed evidence of orthographic learning by comparing their mean number of correct choices on Target items to chance levels using one-sample *t*-tests, with Bonferroni corrections (see Lockhart, 1998). Given that the children had four options to choose from on each orthographic choice item chance level was 25%. At each time point the children answered a total of 6 items assessing their knowledge of the Target item, resulting in a chance level of 1.5 correct items out of 6. For children in Grade 1, their accuracy on items testing the Target word was significantly above chance during Immediate testing, $t(59) = 5.66$, $p < .001$, $d = 0.73$ but accuracy did not meet statistical significance level during Delayed testing after Bonferonni corrections were applied, $t(60) = 2.19$, $p = .03$, $d = 0.28$. For children in Grade 2, accuracy on Target items was significantly above chance during both Immediate, $t(60) = 6.88$, $p < .001$, $d = 0.88$, and Delayed testing, $t(60) = 6.67$, $p < .001$, $d = 0.85$.

2.4.3. Research Question 2: Do beginning readers transfer their learning of spelling patterns to processing of related novel words?

To answer this second research question, we analysed performance on the orthographic choice task across the nonword types using a repeated measures ANOVA with a between-subjects variable of Grade (Grade 1 and Grade 2) and within-subject variables of Word-Type (target, morphological transfer, and orthographic transfer) and Time (Immediate and Delayed). There was a significant main effect of Word-Type, $F(2, 238) = 8.28$, $p < .01$, $\eta^2 p = .07$. There was a significant interaction of Time by Grade, $F(2,119) = 11.73$, $p < .01$, $\eta^2 p = .09$. There were no other significant effects or interactions, all Fs < 1.46, all ps $> .23$. Means for children's accuracy in the orthographic choice task are presented in Table 2.2.

Following up on the main effect of Word-Type, we completed a series of comparisons, using paired-sample two-tailed t-tests implementing Bonferroni corrections. We contrasted each word type combining data for Immediate and Delayed testing and across Grades, given the absence of significant interactions of either Time or Grade with Word-Type. The important comparison for determining the mechanism of transfer was in the comparison between the transfer conditions as this provides insight to whether

Table 2.1.

Mean Number of Correct Choices on Orthographic Choice Task(s)

	Time One			Time Two			Time One & Two		
	Grade 1	Grade 2	Grades 1 and 2	Grade 1	Grade 2	Grades 1 and 2	Grade 1	Grade 2	Grades 1 and 2
Nonword Type Testing for:	*M* *(SD)*	*M* *(SD)*	*M* *(SD)*	*M* *(SD)*	*M* *(SD)*	*M* *(SD)*	*M* *(SD)*	*M* *(SD)*	*M* *(SD)*
Target (e.g., *cloot*)	2.48 (1.35)	2.46 (1.09)	2.47 (1.22)	1.93 (1.52)	2.55 (1.23)	2.24 (1.41)	4.41 (2.38)	5.01 (1.99)	4.71 (2.21)
Morphological Transfer (e.g., *clooter*)	2.10 (1.07)	1.74 (1.08)	1.92 (1.08)	1.84 (1.38)	2.14 (1.32)	1.99 (1.35)	3.94 (1.95)	3.88 (1.84)	3.91 (1.89)
Orthographic Transfer (e.g., *clootle*)	2.22 (1.39)	2.15 (1.45)	2.18 (1.41)	2.03 (1.33)	2.26 (1.34)	2.15 (1.33)	4.25 (2.26)	4.41 (2.28)	4.33 (2.26)

children benefit from morphological information or if they are able to do so solely based on orthographic similarities. Critically, although there is a slight numerical trend towards higher scores in the orthographic versus morphological transfer conditions, this was not statistically reliable. There was no difference in performance between these two transfer conditions after Bonferroni corrections, $t(120) = -2.19$, $p = .03$, $d = -0.20$. As expected, children were more accurate in orthographic choice tasks testing the target than in the transfer conditions, with this difference emerging as significant in comparison to the morphological transfer condition, after Bonferroni corrections, $t(120) = 4.27$, $p < .001$, $d = 0.39$, though not for the orthographic transfer condition, $t(120) = 1.85$, $p = .07$, $d = 0.17$.

Confirmation that learning transfer occurred comes from findings that, when combining across both grades and testing times due to the lack of interactions of either Time or Grade with Word-Type, accuracy for the two transfer conditions was significantly above what would be expected by chance, all *t*s > 5.28, all *p*s < .001, and all *d*s > 0.48. This suggests that, while their performance was stronger for nonwords that they had read in the stories, children transferred this learning to their processing of novel words.

We completed analyses to follow up on the significant interactions of Time by Grade. We conducted paired-sample two-tailed *t*-tests contrasting performance within each grade for Immediate and Delayed testing points combined across nonword types. For children in Grade 1, there was a significant decline in performance between Immediate and Delayed testing, $t(59) = 3.30$, $p = .002$, $d = 0.43$. In contrast, children in Grade 2 performed equally well at both Immediate and Delayed testing, $t(60) = -1.70$, *p*

= .10, d = -0.22. Again, we confirmed there was evidence of learning and learning transfer at both time points using one-sample t-tests comparing accuracy for all nonwords types at Time 1 and Time 2 for both Grade 1 and Grade 2. For children in Grade 1, their accuracy for all nonword types combined was significantly above what would be expected by chance at both Time 1, $t(59) = 6.57$, $p < .001$, $d = .85$, and Time 2, $t(59) = 3.25$, $p < .001$, $d = .42$. For children in Grade 2, their accuracy for all nonword types combined was significantly above what would be expected by chance at both Time 1, $t(60) = 5.42$, $p < .001$, $d = .69$, and Time 2, $t(60) = 6.30$, $p < .001$, $d = .81$. Taken together, these results confirm that orthographic learning, and its transfer to related words, is evident for both grades across time but it is likely more stable for older, more experienced readers.

2.4.4. Research Question 3: What is the role of phonological decoding in orthographic learning and transfer for beginning readers?

To answer this third research question, we evaluated the role of decoding accuracy in orthographic learning with the same analytic approach reported in Tucker et al. (2016). We created two new totals: Decoded Correctly and Decoded Incorrectly. Both new totals are calculated for the orthographic choice task sets testing learning and transfer of learning. Decoded Correctly is for responses for target nonwords that children had decoded correctly at least once during the exposure phase; Decoded Incorrectly refers to responses for target nonwords that children were unable to decode correctly at any point during the exposure phase. Given the low decoding accuracy during the exposure phase, these analyses have substantially reduced power, although we report them here to begin to explore this question.

Table 2.2.

Mean Number of Responses Contributed to Decoded Correctly and Decoded Incorrectly Totals With Corresponding Chance Levels

		Decoded Correctly		Decoded Incorrectly	
		Immediate	Delayed	Immediate	Delayed
Grade 1	Responses Contributed	4.34	4.03	4.26	3.65
	Chance Level	1.09	1.01	1.06	0.91
Grade 2	Responses Contributed	4.49	5.30	3.28	3.34
	Chance Level	1.12	1.32	0.82	0.84

With these new totals in hand, we first examined whether decoding is required for orthographic learning and transfer to occur. We did so by evaluating whether children in Grades 1 and 2 showed evidence of orthographic learning and transfer to related items when they had decoded a target word correctly and when they had not. We compared the mean number of correct choices for each nonword type to chance levels with one-sample *t*-tests. As in Tucker et al. (2016), we calculated new chance levels for the two totals—Decoded Correctly and Decoded Incorrectly—by dividing the mean number of choices each child contributed to each total by 4 (the number of options in the orthographic choice task). These new chance levels represent 25% of the mean number of responses each child is contributing to the new analyses. Due to variations in decoding accuracy, the number of children contributing responses to the new totals for each nonword type at each testing time varied substantially. The new chance levels calculated separately for each testing time and each grade are shown in Table 2.3. Results are similar for children in Grades 1 and 2. For children in both grades, orthographic choice accuracy was above chance both when they had and had not decoded a single target correctly (i.e., both Decoded Correctly and Decoded Incorrectly) for all nonword types at both the Immediate and Delayed test points, all *t*s > 3.56, *p*s < .01, *d*s > 0.63. To summarise, children in Grades 1 and 2 demonstrated learning and transfer of that learning for targets they had decoded accurately and for those that they had not decoded accurately even a single time.

Turning to the question of whether decoding supports better orthographic learning, we can turn to a visual inspection of Figures 1 and 2. Overall, there is little apparent difference in mean accuracy for Decoded Correctly and Decoded Incorrectly totals for children in both Grades 1 and 2, suggesting that accurate decoding does not facilitate better orthographic learning for these beginning readers in general.

We completed a series of comparisons to directly contrast the extent of orthographic learning based whether the children had decoded the targets accurately or not. Notably, this analysis has substantially reduced power. We provide it with an eye to transparency. To do this analysis, we calculated difference scores between chance and mean levels of performance; these reflect the level of learning achieved (see Tucker et al., 2016). We calculated these difference scores within each grade separately and for each word type at both Immediate and Delayed testing for when nonwords were decoded accurately at least once and when they were not decoded accurately. We then conducted a series of paired *t*-tests contrasting the differences scores for decoded accurately and decoded inaccurately. After Bonferroni corrections were applied, only one comparison remained significant: Grade 2 children performed better on orthographic transfer items at Delayed testing when they decoded the associated target nonword correctly at least once,

$t(40) = -3.15$, $p = .002$, $d = -0.49$ (for all other ts < 2.15, all ps > .02). We note however, that these analyses were likely somewhat underpowered, in that they divide responses for accurate and inaccurate decoding. That said, these results support the suggestion that, for beginning readers, accurate decoding does not generally facilitate better orthographic learning, at least not when measured on an orthographic choice task.

Figure 2.1. Mean number of choices for all nonword types for children in Grade 1 when target words were Decoded Correctly at least once and words that were Decoded Incorrectly at each exposure. Error bars indicate 95% Confidence Intervals. Black lines indicate chance level for that nonword type.

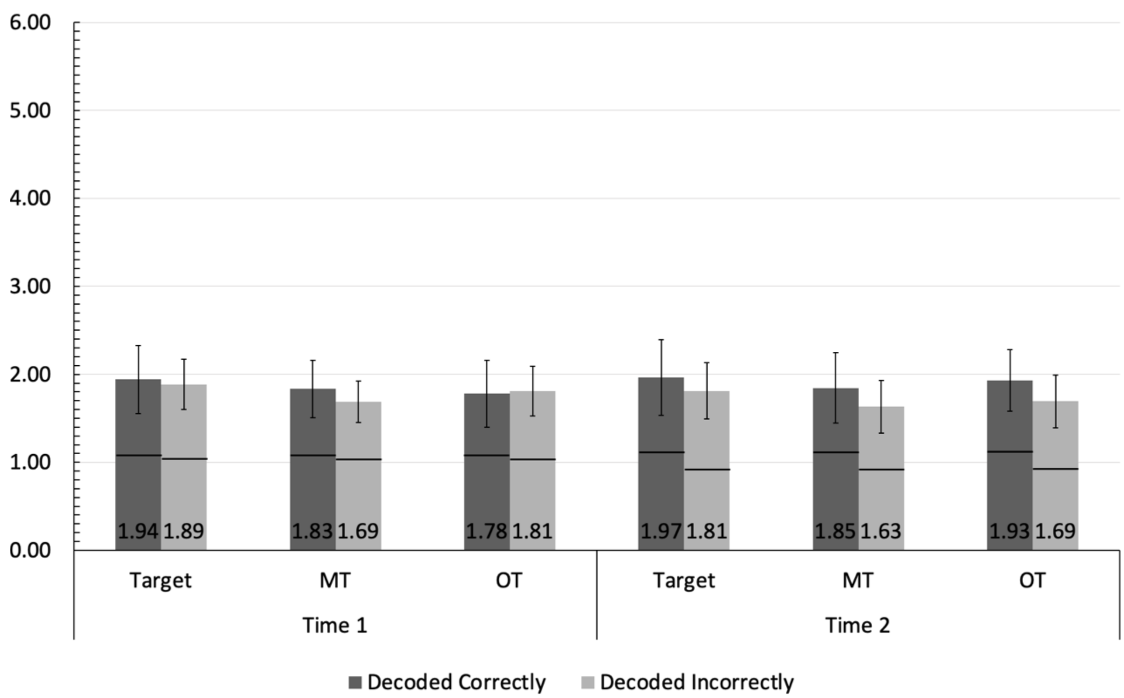
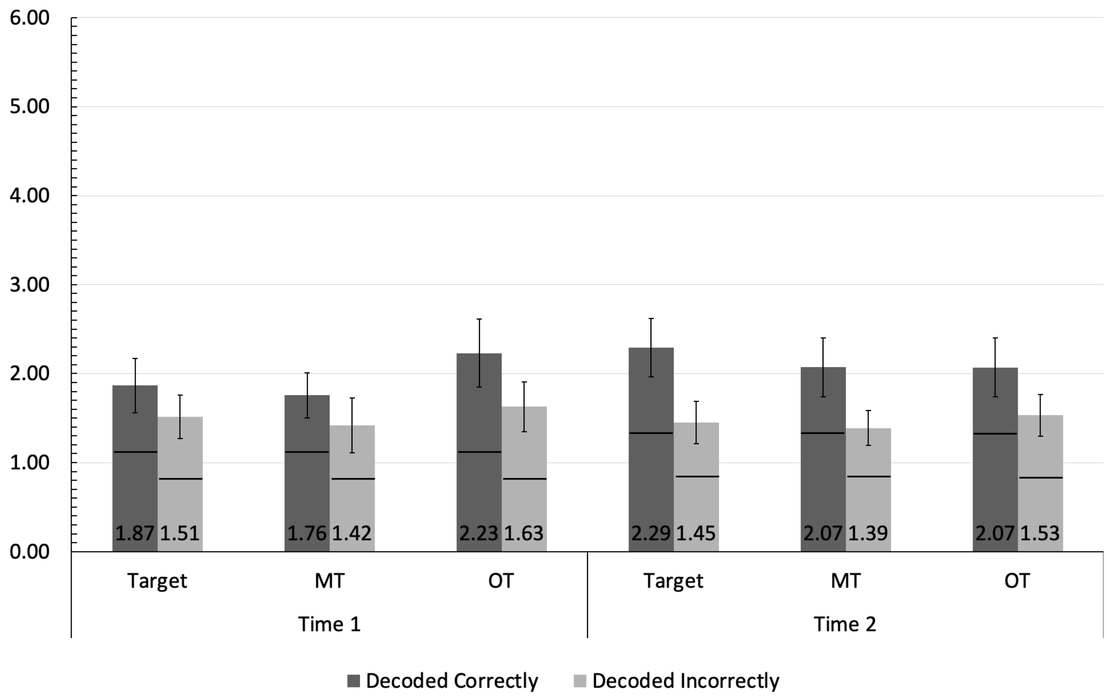


Figure 2.2. Mean number of choices for all nonword types for children in Grade 2 when target words were Decoded Correctly at least once and words that were Decoded Incorrectly at each exposure. Error bars indicate 95% Confidence Intervals. Black lines indicate chance level for that nonword type.



2.5. Discussion

In the current study we evaluated the occurrence and transfer of orthographic learning in beginning readers using a self-teaching paradigm (as in Tucker et al., 2016) modified for younger children. Using simplified stories and nonwords, we asked children in Grades 1 and 2 to read aloud short stories with embedded target nonwords (e.g., *feap*) without receiving feedback on their pronunciation of any words (target or not). After reading the stories, the children completed an orthographic choice task measuring their learning of the targets (e.g., *feap*), as well as novel nonwords that were either morphologically (e.g., *feaper*) or orthographically related (e.g., *feaple*). These tasks were completed both immediately after the story book reading and a few days later (i.e., Immediate and Delayed, respectively). Using this design, we tested three key questions: whether beginning readers learn novel words through self-teaching, whether they transfer this learning to their processing of related complex words, and the role of phonological decoding in both of these processes.

Addressing the first research question, our results suggest that beginning readers are able to learn the spelling patterns of novel words they encounter during independent reading to varying degrees. Children in both Grades 1 and 2 demonstrated evidence of orthographic learning when this was assessed in the short-term; children chose the correct spelling of target words at levels above chance in an orthographic choice task completed immediately after reading the short stories. Interestingly, on the orthographic choice task completed a few days after delayed, children in Grade 2, but not Grade 1, were above chance in choosing the correct spellings. These findings suggest that Grade 1 children learn detailed orthographic representations from independent reading experiences, but that this learning is not yet retained over time. This longer-term retention, at least as assessed a few days after independent reading, is in evidence at Grade 2. In some ways these results are challenging to calibrate with prior studies. Children in Grade 1 demonstrated orthographic learning on orthographic choice tasks at the delayed post-test in Deacon et al. (2019), although performance was certainly better at immediate than at delayed testing point. This was also the case in Cunningham's study (2006), in which orthographic choice was only tested at the delayed test point, with at least numerically higher performance than chance at this point. As we noted earlier, Share (2004) reported no evidence of orthographic learning in his study of Grade 1 Hebrew speaking children. Taking these studies together, the bulk of the evidence to date supports Share's (2008) suggestion that beginning reading is beginning self-teaching. And yet, these findings, taken together, also suggest that orthographic learning might be somewhat less consistent in Grade 1 than in older children, with evidence of orthographic learning emerging in most, although not all studies (e.g., Share, 2004) and at most, although not all testing points (e.g., not at delayed in this study). We later discuss the relevance of decoding in understanding the factors influencing early self-teaching learning.

Turning to our second research question, we found that beginning readers transfer their learning of a novel word to facilitate their immediate processing of related complex words in the self-teaching context. Immediately after reading the short stories, both Grade 1 and Grade 2 children chose the correct spelling of the complex nonwords (e.g., *feaper* and *feaple*) related to the novel words they had read (e.g., *feap*) at levels above chance. Findings of similar levels of performance with the morphological (e.g., *feaper*) and orthographic transfer items (e.g., *feaple*) suggest that this transfer occurs on the basis of orthographic rather than morphological processes. These findings are consistent with those of Tucker et al. (2016) with Grade 3 and 5 children using the same study design. In contrast, in a study with French children, Pacton et al. (2013; 2018) found that reading two morphologically related word forms (i.e., a base and a related morphologically complex word) in a single story strengthens recognition of the base as compared to when children read two forms that were not morphologically related. Importantly, these results support the presence of morphological facilitation when the two words are presented simultaneously within a story rather than looking at the transfer of learning across time to unlearned words as we do here. Overall, our findings align with the conclusion that young readers transfer their learning of a novel word to the processing of new words and suggest that this occurs on the basis of orthographic similarities (see also Goswami, 1988).

In an interesting nuance in relation to this second research question, the durability of transfer differed for less experienced versus more experienced readers. On the delayed orthographic choice test, Grade 2 but not Grade 1 children demonstrated transfer of learning. Just as children in Grade 1 did not retain spellings of the simple words that they learned on the delayed orthographic choice task, they also did not demonstrate evidence of transfer at this delayed test point. It seems then that at Grade 1, children learn the spelling of a novel word encountered in independent reading to the extent that they choose its correct spelling when tested immediately after this learning; they do not retain this to 2 to 3 days, either for the original form nor for related forms. These findings suggest that orthographic learning is in evidence at Grade 1, with key development between Grades 1 and 2 in the durability of this learning and its transfer. These findings go a long way to fleshing out how self-teaching differs in less versus more experienced readers.

In answer to our third research question, our results suggest that orthographic learning and transfer occurs in the absence of accurate phonological decoding, with little additional support from decoding to the extent of orthographic learning. Across both Grades 1 and 2, children chose the correct spelling for the target words and for novel, though related, complex words at levels above chance even when they had not decoded the target word accurately a single time during the learning phase. These findings suggest that phonological decoding is not required for orthographic learning or transfer of that learning to occur in young readers. These findings are consistent with prior work showing that orthographic learning of simple novel words occurs in the absence of accurate decoding for children in Grades 1 and 2 (Deacon et al., 2019). Critically, they extend prior work by showing transfer of learning occurs in the absence of decoding with beginning readers, consistent with findings from the single prior study with more experienced readers (Tucker et al., 2016). Quite clearly, and in contrast to earlier suggestions of decoding as required for orthographic learning to occur (Share, 2008), children can acquire novel orthographic forms even when they have not accurately decoded these new words during their reading experience.

Turning to whether there is a benefit to learning from decoding, there is little evidence of improved learning or transfer for targets decoded correctly versus incorrectly in our study of children in Grades 1 and 2. These findings are surprising given the enthusiasm of earlier predictions of decoding as required for orthographic learning to occur (Share, 1995); surely, then, decoding should lead to better orthographic learning. And yet, as we raised in the introduction, it is possible that effortful nature of beginning decoding, as would be the case in Grade 1 children, might interfere with the ability to focus on and encode spelling patterns. This detriment might occur to the extent that there is no (or little) added benefit of accurate decoding experiences for beginning readers. This interpretation is consistent with the relatively mixed set of findings to date; evidence of decoding facilitating learning emerged in Deacon et al.'s (2019) study with a larger sample of children in Grades 1 and 2 and yet no evidence of stronger performance on orthographic choice tasks with successful decoding emerged in Chen et al.'s (2018) analyses of orthographic choice data with Grade 1 children (Cunningham, 2006). Evidence of benefits of decoding are far clearer in Tucker et al.'s (2016) study of children in Grades 3 and 5. Consistent with the idea that the effort of early decoding might interfere with learning, in our study, the one glimmer of evidence of successful decoding improving orthographic learning emerged at Grade 2; a statistical difference emerged, after careful Bonferroni corrections, on the Orthographic Transfer items at delayed testing (2 – 3 days after learning). Taking these findings together, the 'benefits' of decoding on learning and transfer of learning are far clearer for more experienced readers than for beginning readers. It would be useful to explore these speculations by tracking the nature of orthographic learning as the decoding process becomes more efficient, both on the level of individual words and of reader skill.

One key implication of the results of the current study for the Self-Teaching Hypothesis (Share 2008), lies in fleshing out whether and the extent to which beginning reading is beginning orthographic learning. To begin, we provide much-needed confirmation of early self-teaching. Indeed, our study shows that readers as young as Grade 1 reliably learn novel words during independent reading. Our study takes this one step further, demonstrating that they can do so to the extent that their learning facilitates their processing of related unlearned words up to three days later. This suggests that the lexicalisation of orthographic learning begins much earlier than previously suspected. Building on this, we offer developmental nuance to the Self-teaching hypothesis. Our findings suggest a potential shift in the quality and mechanisms of orthographic learning between Grades 1 and 2 (or roughly 6 and 7 years). In our study, children in Grade 1 showed less consistent and durable learning and transfer than those in Grade 2, for whom patterns of learning are similar to older children (i.e., Grade 3 and 5; Tucker et al., 2016).

Early reading is early self-teaching, though there is clearly room to improve in the durability and transfer of this learning.

Another contribution to theory lies in understanding the role of decoding in self-teaching. This is far less clear than predicted in the original self-teaching hypothesis. To begin, decoding is not required for orthographic learning to occur. Children appear to be processing the novel words that they encounter in their reading to a degree that enables their retention and transfer, even when they have not decoded them correct. Further, there appears to be a shift in the role of decoding across the two grades. Children in Grade 1 showed no significant improvement in learning from the phonological decoding experience, with glimmers of this emerging at Grade 2, which other research has shown to be consistent by Grades 3 (Tucker et al., 2016). This shifting role of phonological decoding in the formation of orthographic representations may be explained through the lens of the Lexical Quality Hypothesis (Perfetti & Hart, 2002). Perfetti & Hart suggest that more skilled readers are better able to learn from novel encounters with words and improve on the-quality of their orthographic representations. They also suggest that readers will experience difficulty when a phonological tag activates a lower-quality orthographic representation, which may be especially true when required to choose between two homophonic spellings. Using this framework, there could be two potential reasons that phonological decoding had more of an effect on orthographic learning for children in Grade 2 than it did for children in Grade 1.

First, it may be that children with more reading experience (i.e., those in Grade 2) have better phonological decoding skills and a larger bank of known words and, as such are more able to focus their resources on accurately decoding and creating a higher-quality orthographic representation for new words they do encounter. These higher-quality representations are more likely to have an accurate phonological tag in combination with the correct spelling pattern, resulting in older readers being better able to efficiently access the representation later and transfer it to processing new words. An alternative possible explanation is that older children, or more experienced readers, do not benefit more from accurate phonological decoding (and the resulting phonological tags) but rather they are more negatively impacted by any inaccurate phonological attempts. It may be that, as readers become better and more efficient phonological decoders, any inaccurate attempts are more likely to be strongly encoded as part of a new orthographic representation and the resulting inaccurate phonological tag that makes it harder to form the quality of orthographic representation necessary to call upon when required at a later point in time. And, of course, these explanations are not mutually exclusive. It may be that these findings are due to a combination of both suggested explanations, which could contribute to why the difference was even more apparent at delayed testing. Moving forward, it will be important to investigate this developmental shift and why the role of phonological decoding in orthographic learning is so different for children just one grade-level apart.

Practically, the current study has educational implications as it suggests ways to support children in getting the most learning they can from independent reading experiences. Firstly, consistent with prior research showing that orthographically similar clue words influence both the accuracy of word reading (Goswami, 1986; 1990) and spelling (Deacon & Bryant, 2006), our results suggest that transfer of learning primarily occurs via orthographic analogies. As such, with these young readers, it may be helpful to highlight orthographic similarities between words and help them learn how to notice, and capitalize on, those similarities during independent reading (see Goswami,1999). Secondly, our results suggest that self-teaching of orthographic representations is more consistent and durable by Grade 2, at which time it is similar in nature to that seen in older children (e.g., Tucker et al., 2016). As such, it may be less effective to rely significantly on independent reading experiences in very early readers (i.e., Grade 1 and below) for the purpose of long-term retention of orthographic representations for the novel words they encounter. As we consider how these findings might play out for even younger children, we need to remain mindful of findings that when they are being read to, young pre-reading children spend more time looking at pictures than text (Evans & Saint-Aubin, 2005), with this gradually shifting to looking at text as they learn more letters (Evans, Saint-Aubin, & Landry, 2009). Testing the extent of orthographic learning in shared book reading (e.g., Shakory et al., 2021) as compared to independent reading will be important in fleshing out when independent reading can result in durable orthographic representations that transfer to the processing of new words. These findings will help to determine these potential educational impacts.

As we consider the implications of this study, it is important to keep the limitations in mind. One is the generalizability of the task to silent independent reading. We asked children to read out loud so that we could track their decoding accuracy; however, requiring children to read the stories aloud might have increased their likelihood to sound out novel words and focus on letter-by-letter decoding. Certainly, there is evidence of orthographic learning in children's silent reading (e.g., Bowey & Muller, 2005; de Jong & Share, 2007; de Jong et al., 2009), but it is difficult to know how reading aloud may change the nature of self-teaching in comparison to more natural reading contexts. It would also be useful to test these effects across additional outcome measures. We originally included both orthographic choice and naming tasks; however, the naming task included in this study was likely not a good measure for such young children given the overall low decoding accuracy (even during story reading) in combination with the naming task containing many words in a row while being time dependent. Due to the difficulty of the task, the accuracy was too low to include data for the naming task and analyses of a single task limits our ability to make broader claims as to whether effects extend beyond recognition-based tasks. It will be important to create tasks that are appropriate for young readers to fully understand the quality of orthographic learning in beginning readers and the mechanisms through which it occurs.

A third important limitation comes from relatively low accuracy levels for both decoding and orthographic choice tasks. Lower decoding accuracy levels during story reading also impacted our ability to analyse effects of decoding on orthographic learning and transfer due to the number of students that contributed to the decoded inaccurately and decoded accurately totals. Relatedly, this significantly impacts the ability to take a more nuanced look at the role of decoding by examining varied levels of decoding success rather than creating the accurate versus inaccurate dichotomy. For example, it may be that the role of decoding looks different when children decode a target accurately one time and inaccurately three times as compared to when children decode it accurately three times and inaccurately once. Further, the timing of the accurate and inaccurate decoding experiences may also matter. For example, the accuracy of the final decoding experience may be more important than the first. These potential differences in the children's decoding experiences are not captured using the current method and we did not have the statistical power to do so in this study. As such, it is likely important for future studies to complete a study with the same paradigm but a larger sample size to allow for better conclusions regarding the phonological decoding in beginning orthographic learning.

In summary, the current study has helped to clarify both the nature and mechanisms of beginning orthographic learning, including suggesting the presence of a potential developmental shift in orthographic learning between Grade 1 and Grade 2. First, we have shown that children in both Grades 1 and 2 are able to learn the spelling patterns of novel words. Second, we demonstrate that children in Grades 1 and 2 and transfer that learning to the processing of unlearned related words, for a short period of time. In both of these cases, only children in Grade 2 were able to retain this learning three days later. This suggests a fundamental shift in the durability and utility of early self-teaching between Grades 1 and 2. Finally, accurate phonological decoding does not appear to be required for children in both Grades 1 and 2 to engage in orthographic learning, with a glimmer of evidence that it supports learning in Grade 2. Together these findings flesh out early self-teaching, with significant theoretical implications that can inform both research and educational practices moving forward.

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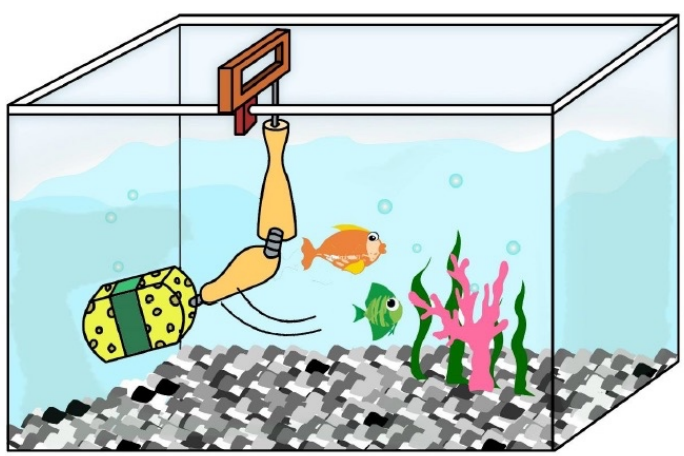
2.7. Appendix A: Examples of Research Materials – Images and Instructions

A.1 Introduction to Professor Parsnip and image used to show who he is:

> "I am going to tell you a story about someone called Professor Parsnip [**show picture of Prof.**]. He likes to invent new things and he has an invention factory. He named each and every one of the inventions with words you have never heard or seen before. We are going to read about 6 of his latest inventions. For each one, I will **first**, show you a picture of one of Professor Parsnip's inventions, and tell you a little bit about it. **Then**, you will read a short story about that invention. He likes people to remember how the names of his inventions are spelled because after we learn about the Professor's neat inventions, you will do some activities that involve these words. So, when you read the word for the invention, try and remember what the word looks like because I will ask you about its spelling later. But now, let's take a look at his first invention!"

A.2 Example of image and information and provided about the invention prior to reading the story:



“Professor Parsnip has invented this [point to image]. It is used for cleaning out fish tanks. It has **a sponge** and is **shaped like an arm**. Do you have a fish tank at home? [based on child’s response, say “yeah, me too” or “yeah, me neither.”] Fish make the tank dirty sometimes, so you can put this gadget inside the fish tank, and it will move around and clean up the fish tank for you. So, you don’t need to put your hand in the tank to clean it.”

A.3 Example of first story and instructions provided to children before reading the stories out loud:

“You can now turn to page 1 in this short story book. This story is about the invention that I just talked about. You will now see how the word for this invention is written down. I will use this recorder [show recorder to child] because Professor Parsnip likes to listen to these stories, so please read the story out loud, and as clearly and carefully as you can. When you read the word for the invention, **try and remember what it looks like because** later I will ask you to do an activity that involves the spelling of this word.”

Ben’s fish tank is dirty. Ben picks up the clewt. The clewt is used to clean fish tanks. Ben puts the clewt in the fish tank. The clewt cleans Ben’s fish tank.

Chapter 3. Does learning *lurg* help you learn *relurg*? Effects of orthographic learning on later learning and of accumulated learning on processing of related words

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Submitted for publication (format adapted for dissertation)

3.1. Abstract

The current study investigates whether orthographic learning that occurs during independent reading (i.e., self-teaching) facilitates later learning of related words and the influence of this accumulated learning on processing. Recent evidence testing the prominent self-teaching hypothesis demonstrates that learning through independent reading transfers to the processing of related words. We build on this evidence to test the nature of this learning transfer, including whether it supports later learning of related words and effects of accumulated learning on processing of related words. Children in Grades 3 through 5 engaged in two phases of story reading: first reading simple nonwords (e.g., *lurg*) embedded in short stories and then later reading complex nonwords (e.g., *relurg, rejope*) in other short stories. Children then completed orthographic choice tasks testing their learning of the nonwords in the stories (e.g., *lurg*, *relurg/pelurg*, *rejope/pejope*) and additional nonwords not seen before (e.g., *mislurg/fislurg*, *misjope/fisjope*). Scores on learning of complex words were higher when children first learned the related simple nonword than when they had not, and processing of new complex words was better after reading both the simple and complex forms than just the complex forms. Effects were similar for words that were morphologically and orthographically related. These results suggest that children transfer their learning of one word within the self-teaching context to support later learning and that accumulated learning improves processing of novel words with similar spelling patterns. Together these findings clarify the nature of self-teaching and its effects on accumulated learning.

Keywords: reading; self-teaching; orthographic learning; learning transfer; accumulated word learning; vocabulary

3.2. Introduction

It is now well established that independent reading is an active forum for the learning of new words (e.g., Sternberg & Powell, 1983; McKeown, 1985; Nagy, Anderson & Herman, 1987; Nagy & Scott, 1990). Children are far more likely to encounter new words in the texts they read than in the language they hear (Gardner, 2004; Nagy & Anderson, 1984), making independent reading a particularly rich place for word learning. The prominent self-teaching hypothesis (Share, 2008) offers a powerful explanation for just how this learning occurs. According to this theory, decoding of a new word during independent reading enables children to learn the spelling patterns of that new word, that is, its orthographic representation (see also Nation & Castles, 2017). Over time, then, orthographic learning creates a store of these orthographic representations that enable more fluid word reading and, in turn, better reading comprehension (Share, 2008). The self-teaching hypothesis has been impactful, shifting research attention to the power of children's active learning in determining their own reading development (Share, 2004; 2008; Kilpatrick, 2015). It has also moved educational practice to encourage free reading as a real source of vocabulary growth (e.g., McQuillan, 2019). Given the impact of the self-teaching hypothesis (Share, 2008), it is important to better understand the extent to which orthographic learning supports children's acquisition of words and, critically, to do so with an eye to understanding its effects beyond one specific word at a time.

Certainly, evidence to date firmly establishes that children in elementary school are able to learn new individual words via self-teaching during independent reading (e.g., Nation et al., 2007; Share, 1999; Tucker et al., 2016; Wang et al., 2011); and yet, the question of whether initial orthographic learning helps with learning of other words, however, is largely unexplored. Does learning *feap* during independent reading then enable children to better learn *feaper* if they later encounter it within text? We are interested in this question because it gets to the heart of assumptions about just how independent reading accounts for the rapid pace of children's vocabulary acquisition. By some estimates, children learn several thousand words a year (e.g., Anglin, 1993; Nagy & Herman, 1987). Taking this to a daily level, children are estimated to acquire more than 20 new words each day in Grades 3 through 5, with over a dozen of these estimated to be new derived words (Anglin, 1993). Resonating with these ideas, corpus analyses show that most of the words that children encounter in texts are related to another word, with this proportion even greater for less frequent words (Nagy & Anderson, 1984). As an implication of these text analyses, Nagy and Anderson (1984) write that "for every word a child learns, we estimate that there are one to three additional related words that should also be understandable to the child" (p. 311). So, the idea is that encountering one word in text will help children learn that word, but also help them to learn other novel words (Nagy & Anderson, 1984). This now common assumption is the basis for widespread advocacy both to teach children explicitly about morphology (e.g., Elleman, Oslund, Griffin, & Myers, 2019; Wright & Cervetti, 2017) and to increase time for independent reading (McQuillan, 2019).

In the face of these assumptions of this wide value of independent reading in supporting children's word learning, there is little empirical evidence directly showing that children's orthographic learning during independent reading facilitates their later learning of related complex words. We review in the sections below the little evidence that there is to date on this question. And, given the importance and impact of this assumption on both reading theories and instructional practice, we report on a study testing the assumption that children's learning of a simple word (e.g., *feap*) during independent reading helps them in turn to learn other novel complex words (e.g., *refeap*, *pefeap*), as well as the basis of that transfer and of accumulated learning on processing over time.

3.2.1. What do we know about whether learning of simple words enables learning of related complex words?

As we noted earlier, there is a large body of research supporting the assertion that elementary school children can learn new words during independent reading time (e.g., Nation et al., 2007; Share, 1999; Tucker et al., 2016; Wang et al., 2011). To date, much of this evidence has emerged from studies testing the Self-Teaching Hypothesis (Share, 2008). According to this theory, readers learn the spelling patterns of words, that is, their orthographic representations, during independent reading experiences. This orthographic learning process creates a store of orthographic representations that enable more efficient word reading, freeing resources for better reading comprehension. Studies testing this theory typically use the traditional self-teaching paradigm in which children read nonwords (e.g., *feep*) embedded four times within short stories. Children then complete outcome measures, often testing their subsequent recognition of single items by having them choose the correct spelling for the target word (e.g., *feap*) from a set of distractors (e.g., *feep*-*feap*-*veep*-*veap*) on a recognition task. Studies using this paradigm have consistently shown that children as young as seven years of age successfully learn new words they have encountered during independent reading, as demonstrated by their ability to accurately recognise or spell the new words (see Chen, Irey, & Cunningham, 2018; Deacon, Mimeau, Chung & Chen, 2019; Share, 1999). This evidence is consistent with original suggestions that children's orthographic learning occurs on an item-by-item basis (Share, 2008).

A few more recent studies take this one step further, showing that children transfer their learning of new words during independent reading to the processing of related complex words. In one such study, English-speaking children in Grades 3 and 5 read a set of short stories, each with a nonword embedded within it four times (e.g., *feep*; Tucker et al., 2016). Following this reading experience, children chose the correct spellings of the words they read from a set of distractors (e.g., *feep* within *feep-feap-veep-veap*) at levels above chance. Critically, children were also above chance in choosing correct spellings for related complex items that they had not encountered in the stories (e.g., *feeper*, *feeple*). This study demonstrates that children transfer learning of a simple word to the processing of related complex words (i.e., choosing the correct spelling), although it does not test effects on subsequent learning of those related complex words per se. Other studies with French-speaking children show that independent reading of both a simple word and a morphologically related word (e.g., *couriard* and *couriardage*) in texts leads to greater accuracy in recognizing the spelling of the simple words (e.g., *couriard*; Pacton et al., 2018; 2013) than does experience of two unrelated words. As such, Pacton et al. (2018; 2013) showed that reading two different word forms, a base and a related morphologically complex word, in a single story strengthens recognition of the base. This study did not, however, test learning of complex words, a key aspect of the prediction that experience learning one word will enable later learning of complex words (Nagy & Anderson, 1984).

To this point, we have reviewed evidence that children can learn words in independent reading and transfer this knowledge of simple words to process related complex words (e.g., Tucker et al., 2016; Pacton et al., 2013). Put another way, independent reading of *feep* appears to result in better recognition of both *feap* and *feaper* in an orthographic choice task. We build on these findings to test the possibility that prior learning of a simple word will facilitate later learning of related complex words: here we ask whether independent reading of *feap* will result in, not only better processing, but also better learning of *refeap* during subsequent independent reading?

To test whether prior learning of a simple word will facilitate later learning of a related word, we implement a novel adaptation of a self-teaching paradigm. In the classic self-teaching paradigm, children read a new simple word (e.g., *lurg*) four times within a short story. In our adaptation of the paradigm, children go on to later read another set of new stories. Half of the stories contain a related complex word (e.g., *relurg*) while the other half contain a complex word with no relation to previously learned simple one (e.g., *remerl*). Children are then tested on their learning of both the "familiar" complex words (i.e., those related to the simple ones initially read) and "unfamiliar" complex words (i.e., those not related to the initial simple words). The key question we answer with this design is whether prior learning of a simple word (e.g., *lurg*) will support stronger learning of complex words when these are related to this previously learned word (e.g., *relurg*) than when they are not (e.g., *remerl*). Importantly, in this design children encounter a base in their reading and later a complex form; this likely parallels a realistic timeline of first learning a simple word and then encountering a complex word during a later reading experience (e.g., Nagy & Anderson, 1984). We predict that children's learning of a simple word will support their later learning of a complex form; effectively, we expect higher levels of recognition of complex words when children have had prior experience learning their base than when they have not.

3.2.2. Does learning enable learning based on shared meaning or orthography?

As we explore the question of the effects of learning on learning, we also test the basis of this transfer: whether this is a result of shared meaning and/or orthography. One possibility is that learning transfers to learning based on morphological relationships. Certainly, this was Nagy and Anderson's (1984) conceptualisation of transfer. For instance, taking an example from their analyses, children's learning of *visual* is expected to enable them to better learn the word *visualise* when they encounter it in text. A second possibility is that learning is transferred via an orthography-based mechanism (e.g., orthographic analogies), with children relying on similarities in spelling between related words to better learn new complex words. Nagy and Anderson identified such word pairs in their analyses as words that have similar spellings but "no discernable semantic connection" (p. 311; e.g., *cleric-clerical*). To date there is evidence in support of transfer based on morphological relationships and also on orthographic analogies; although, as we noted earlier, studies to date have not tested transfer of learning to learning.

The possibility of transfer to learning of morphologically related words is supported by Pacton et al.'s (2013; 2018) findings. In their 2018 study, one group of children read both a simple word and a morphologically related word (e.g., *couriard* and *couriardage*) within a text. The other group of children read two unrelated words (e.g., *couriard* and *couriardume*, where *ume* is not a suffix). The children who had read two related words were more accurate in recognising the simple words (e.g., *couriard*) than those who had read two unrelated words. These findings suggest that learning two morphologically related forms at the same time strengthens learning of the base. And certainly, Pacton et al interpreted their results as showing that morphological relationships facilitate orthographic learning within the self-teaching context. This interpretation aligns with a large body of evidence showing that children are sensitive to the morphological structure of words in their reading and spelling of known words (e.g., Carlisle, 2000; Deacon & Bryant, 2005). For instance, children are more accurate in reading derived words like *shady* than morphologically simple words like *lady* (e.g., Carlisle & Stone, 2005). The question of whether morphology will be the basis of transfer from learning of simple words to learning of complex words remains open, as studies to date tested effects on processing.

Alternatively, learning could transfer to learning via an orthography-based mechanism (e.g., orthographic analogies), with similarities in spelling between related words supporting transfer to learning of correct spelling patterns. To date, this is the pattern found in studies on transfer of learning to processing. Tucker et al. (2016) found that children transferred learning of a base form (e.g., *feep*) to processing of complex words that were morphologically related (e.g., *feeper*) and to those that were only orthographically related (e.g., *feeple*). This transfer occurred to a similar extent to morphologically and orthographically related items. Tucker et al. concluded that analogy based on shared orthography is likely a key mechanism by which learning transfers to the processing of related words. Similar effects have emerged in other paradigms. Most relevant to our research, presenting a clue word (e.g., *turn*) to 7- to 9-year-old children had similar effects on their ability to spell orthographically similar (e.g., *turnip*) and morphologically related (e.g., *turning*) words (Deacon & Bryant, 2006). Taken together, this evidence suggests that children use orthographic analogies to facilitate their reading of known words, with one study extending this to transfer to the processing of new words. The possibility that orthographic analogies will be the basis of transfer of learning of a base word to the learning of a complex related words is an open one.

We test this research question by including two types of related complex words in the second set of stories. In the first set of stories, children read simple words (e.g., *lurg*). The second set of stories contain complex words that are either morphologically related (e.g., *relurg*) or only orthographically similar (e.g., *pelurg*) to the simple words in the first set of stories. Here we are looking for a main effect or interaction with Story type. Predictions as to the basis of transfer of learning to learning are not entirely clear; given the mixed set of results to date on transfer to processing (Tucker et al., 2016; Pacton et al., 2013; Pacton et al., 2018), it seems reasonable to suspect that transfer could occur based on shared morphology and/or orthography.

3.2.3. What are the effects of accumulated learning experiences?

Our final question is whether these cumulative learning experiences impact subsequent word processing. Nagy and Anderson's (1984) corpus analyses (and those of others) show us that children experience a number of related words during independent reading. This leads us to wonder whether accumulated learning of related simple and complex words have downstream impacts on processing of additional related words. For instance, if children have learned both *visual* and *visualise* in their reading of text, will they be better able to recognise the correct spelling for *visualisation*? And in terms of the paradigm that we have described thus far, we test whether learning of both a simple (i.e., *lurg*) and complex nonword (i.e., *relurg* or *pelurg*) leads to better processing of novel related complex words (e.g., *mislurg, fislurg*) in comparison to learning of just the complex word at Phase 2. This kind of accumulated learning reflects the reality of children's reading experience in which they come across a good deal of related words in their reading over time. For instance, Nagy and Anderson (1984) use the example of a simple word like *add* being related to several more complex words (e.g., *adds*, *adding*, *addition*, *additions*, *additional*, *additive*, etc.). We expect that children's accumulated experience with multiple related words will improve processing of newly encountered words. And again, our design includes items that have the appearance of a morphological relationship or simply share orthography, so that we can test the mechanism of any transfer that occurs.

3.2.4. The present study

In this study we test whether children's prior learning of new words supports their learning of novel complex words during independent reading of texts, as well as the basis of that transfer and of accumulated learning on processing over time. We investigate our research questions within a modification of the classic self-teaching paradigm (building on Share, 1999) with children in Grades 3 through 5. This is an age range in which children experience a great deal of morphologically related words in texts (Nagy & Anderson, 1984) and an age at which prior studies have successfully implemented self-teaching paradigms on transfer of learning to processing (e.g., Tucker et al., 2016).

Our first research question investigates whether children transfer their learning of a simple word to their later learning of complex words. To do so, we included two exposure phases in the current study. In Phase 1, children read simple base words (e.g., *lurg*) embedded in short stories, as in prior self-teaching studies (e.g., Tucker et al., 2016). In a novel manipulation, two to four days later, children read a second set of stories. These Phase 2 stories contained complex words, half of which were related to the base words in exposure phase one (e.g., *relurg*), while the other half were not (e.g., *remerl*). With this within-subjects manipulation called prior learning, we can test whether children's previous learning of a base word leads to better decoding and/or learning of complex words when these are related to a base word that they have previously read than when they are not. Given widespread, though largely untested, predictions that learning will support subsequent reading and learning (e.g., Share, 2008; Nagy & Anderson, 1984), we expect that children will be better able to both read and learn new words when these are related to bases they have learned earlier than when they have not. If children do use their learning of bases to support subsequent reading and learning of complex words, it would be reflected in an effect of prior learning on orthographic choice performance and also on decoding of the novel complex words within the stories themselves.

Our second research question evaluates the mechanism for any transfer of learning to learning (as well as of accumulated learning our third research question), determining whether this is a morphologically or orthographically based mechanism. To test this in relation to transfer of learning to learning we include two different word types within the story conditions in Phase 2. In the morphologically complex story condition, children read morphologically complex words embedded in short stories (e.g., *relurg, remerl*), and in the orthographically complex story condition children read orthographically complex words (e.g., *pelurg, pemerl*). We refer to this manipulation as story condition because the stories containing the morphologically complex words highlighted the meaning of the affix (e.g., to *rejope* means to make frozen again), while those for the orthographically complex words referred to the meaning of the whole word (e.g., to *pejope* means to flavour). In our view, it is an open question as to whether transfer of learning to learning occurs based on morphological relations (as in Pacton et al., 2013) or orthographic analogies (Tucker et al., 2016).

Our third research question investigates whether children generalize their accumulated learning experiences of both simple (e.g., *lurg*) and complex words (e.g., *relurg*) to facilitate their processing of novel related words (e.g., *mislurg*). We test this question by contrasting performance with novel related forms that children had read at both Phase 1 and 2 (e.g., *lurg* and *relurg*) to those for which they had read a single related form at Phase 2 (e.g., *relurg*). We label this as an effect of Accumulated Learning. And as with our question of transfer of learning to learning, we are interested in whether any detected effects occur on the basis of morphology or orthography. To answer this question, there were two types of novel nonwords on which we tested recognition at Phases 2 and 3: either morphologically related (e.g., *mislurg*) or simply orthographically similar (e.g., *fislurg*) to the items learned during Phase 2 (e.g., *relurg*). With these manipulations, we can test whether accumulated learning experiences transfer to the processing of novel words when they are later encountered and, if they do so, what the mechanism underlying that process may be. We expect children's accumulated experience with multiple related words to improve their processing of newly encountered words, and we will examine the basis of this transfer here by examining an interaction with word type (morphologically or orthographically related). See Table 3.1 for a summary of the nonword forms that contributed to each of these manipulations.

Table 3.1.

Example of Nonword Forms Contributing to Each Word Type Included in Analyses Based Stories Seen at Phase 1 and Phase 2

Phase 1 Story Set: Group 1 (e.g., *lurg*)						
Phase 2 Story Condition	Transfer-to-Learning		Morphological Transfer-to-Processing		Orthographic Transfer-to-Processing	
	Familiar	Unfamiliar	More Experience	Less Experience	More Experience	Less experience
Morphologically Complex (e.g., *relurg*, *remerl*)	*relurg*	*remerl*	*mislurg*	*mismerl*	*fislurg*	*fismerl*
Orthographically Complex (e.g., *pelurg*, *pemerl*)	*pelurg*	*pemerl*	*mislurg***	*mismerl***	*fislurg*	*fismerl*
Phase 1 Story Set: Group 2 (e.g., *merl*)						
Phase 2 Story Condition	Transfer-to-Learning		Morphological Transfer-to-Processing		Orthographic Transfer-to-Processing	
	Familiar	Unfamiliar	More Experience	Less Experience	More Experience	Less experience
Morphologically Complex (e.g., *relurg*, *remerl*)	*remerl*	*relurg*	*mismerl*	*mislurg*	*fismerl*	*fislurg*
Orthographically Complex (e.g., *pelurg*, *pemerl*)	*pemerl*	*pelurg*	*mismerl***	*mislurg***	*fismerl*	*fislurg*

** For analytic purposes, we label the new morphologically complex nonwords as "morphological transfer" for those in the Phase 2 Orthographically Complex Story Condition. In reality, given the orthographically complex nature of target items in the Orthographically Complex Story Condition, none of the test words are morphologically related to the target in this exposure condition.

3.3. Methods

3.3.1. Participants

We recruited 169 children in Grades 3 through 5. Data from 14 children were excluded from the study; nine due to incomplete data (e.g., three did not complete all timepoints and the others were missing full tasks) and five due to experimenter error As such, we retained the data from 155 children: 61 in Grade 3 (M_{age} = 8 years, 5 months, SD_{age} = 5 months; 32 female), 53 in Grade 4 (M_{age} = 9 years, 5 months, SD_{age} = 5 months; 28 female), and 41 children in Grade 5 (M_{age} = 10 years, 5 months, SD_{age} = 6 months; 31 female). Mean scores on the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999) for children in all three grades were near the standardization means and standard deviations, suggesting that the children's reading level was as expected for their age (see Table 3.2).

Table 3.2.

TOWRE Subtest Standard Scores for Each Grade

	Sight Word Efficiency	Phonemic Decoding Efficiency
	Mean (SD)	Mean (SD)
Grade 3	103.00 (12.31)	97.09 (15.29)
Grade 4	102.21 (14.39)	100.59 (17.32)
Grade 5	97.63 (12.40)	96.16 (17.27)

Note. TOWRE = Test of Word Reading Efficiency

3.3.2. Materials

3.3.2.1. Phase 1: Learning of Base Nonwords

At Phase 1, children read stories containing simple nonwords, followed by an orthographic choice task testing their learning of these simple nonwords.

3.3.2.1.1. Nonwords in Phase 1 stories. The nonwords in the stories at Time 1 were 12 pairs of homophonic nonwords (e.g., *lurg—lerg; merl—murl*) taken from prior studies (Tucker et al., 2016; Mimeau et al., 2018). Spellings for these homophonic nonwords were regular, following regular letter-sound correspondences in English (Rastle & Coltheart, 1999), confirmed against the Children's Printed Word Database (Masterson, Stuart, Dixon, & Lovejoy, 2003) and the MRC Psycholinguistic Database (Wilson, 1988).

3.3.2.1.2. Phase 1 Stories. The 12 stories at Phase 1 were adapted from those in previous studies (e.g., Deacon et al., 2019; Wang et al., 2011), so that all 12 had the same story structure and a similar number of words. Each story contained four exposures to a target nonword (e.g., *lurg*), with the nonwords being randomly assigned to each story. We then split the 12 stories into two groups: Story Group 1 and 2. After the stories were randomly assigned to the two groups, they were reviewed to ensure that the nonwords embedded in the stories for each group had similar characteristics (e.g., vowel combinations, such as *-ee* and *-ai*, were spread evenly across the Groups and that any given vowel combination occurred a single time in a group of stories). Within each story group, half the children read a story containing one item from a homophonic pair (e.g., *lurg*) and the other half of the children read the other homophone of that pair (e.g., *lerg*).

3.3.2.1.2. Nonword items in the orthographic choice task. To assess learning from reading at Phase 1, we created two orthographic choice tasks based on prior research (e.g., Tucker et al., 2016). One tested the six target nonwords read by Group 1 (e.g., *lurg*) and the other tested those read by Group 2 (e.g., *merl*). Children only completed the orthographic choice task for the target nonwords they had read. Each item in the orthographic choice task contained four nonwords: two were the homophonic pair (e.g., *lurg*-*lerg* or *merl*-*murl*) and two were visual distractors that included a change to the consonant in the homophonic pair (e.g., *lurb*-*lerb* or *mert*-*murt*).

3.3.2.2. *Phase 2: Learning of Complex Nonwords*

At Phase 2, children read stories containing complex nonwords, followed by an orthographic choice task testing the nonwords from Phase 1 and Phase 2, as well as a new set of nonwords.

3.3.2.2.1. Nonwords in Phase 2 stories. The nonwords in the Phase 2 stories were 24 pairs of homophonic nonwords, 12 were morphologically (e.g., *relurg*-*relerg*) and 12 were orthographically (e.g., *pelurg*-*pelerg*) complex forms of the Phase 1 base nonwords. The morphologically and orthographically complex forms of the nonwords were created by adding one of two beginnings (*re*- or *pe*-) to each base word from Phase 1. Importantly, *re*- is as a prefix with an independent meaning (e.g., to do something again) that, when added to a root word, changes its meaning. In contrast, the *pe*- beginning has no independent meaning. As we will see, this difference was also highlighted in the stories. We chose these word beginnings because they have similar token frequency at the beginning of English words that contain at least four letters, $t(11) = 0.052$, $p = .959$, with *re*- at 2607 and *pe*- at 3253 as per the Children's Printed Word Database (Masterson, Stuart, Dixon, Lovejoy, & Lovejoy, 2003). As with the Phase 1 nonwords, all spellings were regular and followed regular letter-sound correspondence in English (Rastle & Coltheart, 1999; Masterson et al., 2003; Wilson, 1988). We also ensured that the morphological and orthographically complex words were orthographically legal, such that the first three letters (e.g., *rel*- and *pel*-) occurred at the beginnings of real words in English.

3.3.2.2.2. Stories and pictures. We created twenty-four stories for Phase 2, most of which were adapted from previous research (e.g., Deacon et al., 2019; Wang et al., 2011).

Each story contained four exposures to a complex nonword and all 24 stories had the same story structure and a similar number of words. Twelve of these contained morphologically complex nonwords (e.g., *relurg*) and 12 contained orthographically complex nonwords (e.g., *pelurg*). Importantly, the stories for morphologically complex condition highlighted the similarity in meaning (i.e., the morphological relationship) between the target morphologically complex nonword at Phase 2 (e.g., *relurg*) and the related base word (e.g., *lurg*) from Phase 1. For example, the story for *relurg* in Phase 2 indicated that socks had been separated so that the character needs to *relurg* them, specifically noting that “to relurg means to match again”, similar to the story for *lurg* in Phase 1 which described a *lurg* as an invention used to match the socks into pairs. The stories created for the orthographically complex condition did not highlight any relation in meaning between the complex and base nonwords. For example, the story for *pelurg* indicated that “to pelurg means to iron”, which is not similar to the meaning of *lurg* from the story in Phase 1 (i.e., an invention used to sort/match socks). As in Phase 1, two story sets were created for each group; half the children in each condition (i.e., morphologically complex and orthographically complex) read stories containing one item from a homophonic pair (e.g., *relurg* or *pelurg*) and the other half read its homophone (e.g., *relerg* or *pelerg*).

3.3.2.2.3. Nonword items in the orthographic choice task. The orthographic choice task at Phase 2 evaluated the 12 base forms from the Phase 1 stories (e.g., *lurg*) and the 12 morphologically and the 12 orthographically complex forms from the Phase 2 stories (e.g., *relurg* and *pelurg*, respectively). Half of these base forms were in Group 1 and the other in Group 2. Including all forms enabled us to test the retention of learning that occurred during Phase 1, as well as testing the effects of prior learning on learning of complex forms seen in-text during Phase 2.

The orthographic choice task at Phase 2 also included 12 morphologically and 12 orthographically complex words that were not read in prior materials (e.g., *mislurg* and *fislurg*, respectively). These were included to test the effects of prior learning on processing of related complex words they had not learned in text. These additional morphological and orthographic forms of the nonwords were created by adding either *mis*- or *fis*- to each base word. We chose these beginnings because they have similar token frequency at the beginning of English words that contain at least four letters, $t(11) = 0.57$, $p = .58$, with *mis*- at 826 and *fis*- at 1025 as per the Children's Printed Word Database (Masterson, Stuart, Dixon, Lovejoy, & Lovejoy, 2003). Importantly, the *mis*- beginning is a prefix with independent meaning (e.g., to do something badly or incorrectly) that typically changes the meaning of a base word when it is added. In contrast, the *fis*- beginning has no independent meaning and, as such, does not similarly change the meaning of a base word when added.

Each item in the orthographic choice task included four nonwords: two were the homophonic pair (e.g., *relurg-relerg*) and two were visual distractors with one change to the consonant in the homophonic pair (e.g., *relurb-relerb*).

3.3.2.2.4. Orthographic choice task structure. The 60 items on the orthographic choice task were distributed across five pages. Each page contained only one item for any given base form (e.g., *lurg* would be the first page, *relurg* on the second, *pelurg* on the third, and so on), with items for each set (e.g., base, complex forms and novel complex forms of each nonword) distributed across the five pages to remove order effects across conditions. Once the items were assigned to a page, their order of presentation on the page was randomized. Within each item, we randomized the presentation order of the nonword types.

3.3.2.3. *Phase 3: Retention of Learning*

3.3.2.3.1. Orthographic choice task. The same items were included in the orthographic choice task at Phase 3 as in Phase 2. To reduce any potential bias or practice effects, items were re-pseudo-randomised across the five pages based on the same criteria.

3.3.3. Procedure

All testing was conducted one on one in a quiet area of the children's school over three sessions, each occurring two to four days apart. All stories were presented to children in a duo tang folder, printed on 8.5 x 11-inch white paper with a 36-point font size.

3.3.3.1. Phase 1: Learning of Base Nonwords

In Phase 1, children were introduced to Professor Parsnip, an inventor, and shown his picture printed in colour ink, taken from prior studies (e.g., Wang et al., 2011; Tucker et al., 2016). Children were told they were going to read stories about six of his latest inventions, which were named with words they had not seen or heard before. They were instructed to pay attention to what the invention names looked like as they would be asked about their spelling later. The children were then provided the duotang containing the six stories and asked to read each one aloud. In all phases of testing, children were not told the name of the inventions, nor were they given any feedback on their pronunciations of the nonwords during any of their reading.

After reading all six stories, children completed the Phase 1 orthographic choice task. Prior to this orthographic choice task and all others, they were told to look carefully at each set of four words before choosing the best spelling based on what they know from reading about Professor Parsnip's inventions. For this orthographic choice task, and all others, they were also instructed to take their best guess on any items they were not sure about.

3.3.3.2. Phase 2: Learning of Complex Nonwords

In Phase 2, children were reminded about their prior introduction to Professor Parsnip and they were shown his picture again. They were told they were going to read 12 more stories about how other children use some of Professor Parsnip's inventions. They were again instructed to pay attention to what the new words looked like as they would be asked about their spelling later. The children were then provided with the duotang containing the 12 stories and asked to read each one aloud. After reading all 12 stories, the children were asked to complete the Phase 2 orthographic choice task.

3.3.3.3. Time 3: Test of Learning Retention

At Phase 3 the children were once again reminded of their prior meetings with the experimenters and they completed the Phase 3 orthographic choice task.

3.4. Results

3.4.1. Data Cleaning

We inspected the data for missing values. We had less than 1% of data missing and this was found to be missing at random (Little, 1988). Given there was a very small portion of data missing completely at random, we used the expectation maximization algorithm to generate a single imputation as it gives unbiased parameter estimates and improves the statistical power of analyses (Enders, 2001; Scheffer, 2002). Missing data were imputed for each testing point separately using Missing Values Analysis within SPSS 26. After the Missing Values Analysis, three participants were removed, one from each grade, due to data outliers.

3.4.2. Preliminary analyses

We performed an initial set of analyses confirmed that learning occurred in Phase 1, as we would expect given prior studies; without this learning at Phase 1, we could not then test the effects of learning on learning, from Phase 1 to 2. We assessed whether learning occurred by comparing the mean number of correct choices to chance levels using a one-sample *t*-test. In this analysis and in all analyses presented here, we considered an orthographic choice response to be correct if it had the same spelling as the target item (e.g., if children were exposed to *lurg*, then spelling choices of *lurg*, *relurg*, *mislurg,* and *fislurg* were considered correct and *lerg*, *relerg*, *mislerg,* and *fislerg* incorrect).

Given that the children had four options to choose from on each orthographic choice item, chance level was 25%. At Time 1 the children answered a total of 6 items assessing their knowledge of the Target item, resulting in a chance level of 1.5 correct items out of 6. Children chose the correct spellings at levels significantly higher than chance for the simple nonwords learned during Phase 1, $t(152) = 19.76$, $p < .001$, $d = 1.60$. For reference, across grade and story group the children's performance on the Phase 1 orthographic choice task was $M = 4.04$, SD = 1.59, far higher than the chance level of 1.5. Further analyses of Phase 1 data confirm that there are no differences in difficulty with the two word sets. A univariate ANOVA with between-subjects factors of grade

(Grade 3, Grade 4, Grade 5) and Phase 1 word set (Group 1 and Group 2) revealed no significant effects or interactions, all *F*s < 2.03 and all *p*s $> .14$. The absence of main effects or interactions with Group show no differences in extent of learning of word sets (e.g., Set A versus Set B), confirming that these are similar. The absence of main effect of Grade shows similar extent of learning of simple words in a traditional self-teaching paradigm across the upper elementary school years (see also Tucker et al., 2016).

We also inspected children's accuracy in decoding to determine whether there were group differences in decoding accuracy during Phase 1 story reading. We did so with a univariate ANOVA with between-subjects factor of grade (Grade 3, 4, and 5) and Group (Group 1 and 2). There was no effect of Group, $F(1, 145) = 0.213$, $p = .645$, nor was there an interaction between Grade and Group, $F(2, 145) = 1.72$, $p = .183$. There was a significant main effect of Grade, $F(2, 145) = 3.12$, $p = .047$, although there were no significant differences between grades after applying Bonferroni corrections (all *t*s $<$ 2.25; all *p*s $> .27$). Mean Phase 1 decoding averages are reported in Table 3.

Analyses of the orthographic choice data confirm that learning occurred in Phase 1 as expected, and the absence of differences based on word sets (Group 1 and Group 2) in either orthographic choice or decoding confirm that our matching was effective. Means for the Phase 1 orthographic choice task are included in Table 3.3. Both of these results enable us to move forward in testing our research questions.

Table 3.3.

Phase 1 Decoding Average for Targets During Story reading and Mean Number of Correct Choices on Orthographic Choice Task

	Decoding Average			Orthographic Choice Task		
	Group 1	Group 2	Combined Groups	Group 1	Group 2	Combined Groups
	Mean (SD) %	Mean (SD) %	Mean (SD) %	Mean (SD)	Mean (SD)	Mean (SD)
Grade 3	12.79 (6.89) 53%	13.83 (7.46) 58%	13.32 (7.14) 56%	3.47 (1.66)	4.06 (1.56)	3.76 (1.62)
Grade 4	17.73 (4.69) 74%	14.23 (8.99) 59%	15.98 (7.32) 67%	4.50 (1.42)	3.88 (1.75)	4.19 (1.61)
Grade 5	16.10 (6.46) 67%	16.95 (6.79) 71%	16.5 (6.55) 69%	4.23 (1.23)	4.32 (1.80)	4.27 (1.50)
All Grades	15.39 (6.39) 64%	14.76 (7.88) 62%	15.08 (7.15) 63%	4.03 (1.52)	4.06 (1.67)	4.04 (1.59)

3.4.3. Research Questions 1 and 2: Effects of Prior Learning to Learning and the Basis of this Transfer

To answer our first two research questions, we evaluated whether learning a simple nonword (e.g., *lurg*) in Phase 1 would lead to better learning of complex nonwords (e.g., *relurg*, *pelurg*) in Phase 2 and retention to Phase 3 than when there was no such prior learning. We examined effects of learning on learning by inspecting for effects of the variable of prior learning, either in a main effect or interaction, with stronger performance with complex nonwords that were related to the simple nonwords read in the Phase 1 stories (i.e., familiar nonwords; *relurg* related to *lurg*) in comparison to those that were not related to any nonwords read in Phase 1 stories (i.e., unfamiliar nonwords; e.g., *remurl* not related to *lurg*). We examined the mechanism of transfer by inspecting for effects of story condition (i.e., whether the complex words were morphologically or orthographically related to the base words in Phase 1). We examined these effects across Time (Phase 2 and 3) and Grade (3, 4 and 5).

To answer these questions, we analysed data for the orthographic choice task performance with a repeated measures ANOVA with between-subjects factors of grade (Grade 3, Grade 4, Grade 5) and story condition (Morphologically Complex, Orthographically Complex) and the within-subject variables of prior learning (Familiar, Unfamiliar) and testing time (Phase 2, Phase 3). There were significant main effects of time, $F(1, 146) = 14.25$, $p < .001$, $\eta^2p = .09$, of grade, $F(2, 146) = 7.27$, $p = .001$, $\eta^2p = .09$, and of prior learning, $F(1, 146) = 69.86$, $p <.001$, $\eta^2p = .32$. The time effect shows better performance at Phase 2 than Phase 3, which is expected given decrements in memory over time. In terms of the Grade effect, means for Grade 3 were lower than in Grade 4, $t(110) = -2.83$, $p = .005$, or Grade 5, $t(98) = -3.54$, $p = .001$, with no difference between Grades 4 and 5, $t(90) = -0.95$, $p = .34$. Means for children's accuracy for all familiar and unfamiliar items on the orthographic choice tasks are presented in Table 3.4 and Table 3.5, respectively. There were no other significant main effects or interactions, all Fs < 1.81 and all ps > .18.

The main effect of prior learning is the key result that answers our first research question. The children performed significantly better on complex nonwords that were related to words read at Phase 1 (i.e., familiar) than those that were not (i.e., unfamiliar). This effect suggests that learning a simple word first does facilitate subsequent learning of related complex words. The lack of a significant interaction with story condition shows that the benefits of familiarity were similar for morphologically and orthographically related words. As such, transfer of learning to learning is likely occurring via a more general orthographic strategy, answering our second research question.

Our next analyses on research question 1 examined whether prior learning improves decoding of a related word at Phase 2; this examines effects beyond recognition and on decoding. To examine this, we analysed Decoding accuracy at Phase 2 with a univariate ANOVA with the between-subjects factor of Grade (Grade 3, 4, and 5) and Story Type (Morphologically Complex, Orthographically Complex) and within-subjects factor of Prior Learning (Familiar, Unfamiliar). There were significant main effects of Prior Learning, $F(1, 139) = 5.35$, $p = .02$, $\eta 2p = .04$, and of Grade, $F(2, 139) = 7.75$, $p = .001$, $\eta 2p = .10$, as well as a significant interaction between the two, $F(2, 139) = 3.28$, $p = .04$, $\eta 2p = .05$. All other effects and interactions were not significant, all Fs < 3.54 and all ps > .06. We investigated the Prior Learning by Grade interaction with a series of paired-samples *t*-tests with Bonferroni corrections. Children in Grade 3 were significantly more accurate at decoding familiar words (i.e., those for which they had learned the base version in Phase 1) than unfamiliar words, $t(54) = 3.76$, $p < .001$. In contrast, there was no difference in decoding accuracy based on novelty for children in Grades 4, $t(49) = 0.45$, $p = .66$ and 5, $t(49) = 0.08$, $p = .93$. These results suggest that, at least for children in Grade 3, having learned a simple word (e.g., *lurg*) facilitates better decoding of complex words (e.g., *relurg, pelurg*) when later encountered. Mean Phase 2 decoding averages are reported in Table 3.6.

Our final analyses on research question two examined the extent to which prior learning helps learning. In these analyses we compared their mean number of correct choices for familiar and unfamiliar words at each phase to chance levels. We did so with a series of planned comparisons using one-sample *t*-tests, with Bonferroni corrections (see Lockheart, 1998). Given that the children had four options to choose from on each orthographic choice item, chance level was 25% (i.e., six items, so chance level is 1.5). We report on these for each grade given the clear interactions in effects on decoding by grade. Despite the fact that there were no significant interactions with grade in the ANOVA, comparisons against chance show some intriguing suggestions of changes in effects across grades. Children in Grade 3 chose the correct spellings at levels significantly higher than chance for familiar nonwords at both Phase 2, $t(59) = 5.72$, $p < .001$, $d = 0.74$, and Phase 3, $t(59) = 5.47$, $p < .001$, $d = 0.71$. However, means were at chance for unfamiliar complex nonwords at Phase 2, $t(59) = 1.40$, $p = .17$, and Phase 3, $t(59) = 0.75$, $p = .40$. Children in Grade 3, then, demonstrated significant evidence of learning at Phase 2 and 3 for the complex nonwords related to those read at Phase 1, but not for the no evidence of learning (or retention of learning) when these were not related to those read at Phase 1.

In contrast, children in Grades 4 and 5 chose the correct spellings at levels significantly higher than chance for familiar nonwords at Phase 2 (Gr 4: $t(51) = 8.64$, $p < .001$, $d = 1.20$, Gr 5: $t(39) = 8.64$, $p < .001$, $d = 1.37$) and Phase 3 (Gr 4: $t(51) = 5.92$, $p < .001$, $d = 0.82$, Gr 5: , $t(39) = 6.97$, $p < .001$, $d = 1.10$), as well as for unfamiliar complex nonwords at Phase 2 (Gr 4: $t(51) = 3.10$, $p = .003$, $d = 0.43$, Gr 5 $t(39) = 4.37$, $p < .001$, $d = 0.69$). For both Grades scores were above chance for the unfamiliar nonwords at Phase 3, although this difference did not quite reach statistical significance at Grade 5 (Gr 4: $t(51) = 3.03$, $p = .004$, $d = 0.42$; Gr 5: $t(39) = 1.74$, $p = .09$). For children in Grade

4 and 5, then, there was significant evidence of learning of complex non words at Phase 2 and 3 when these were related to those read at Phase 1, as well as of learning of complex nonwords read a single time at Phase 2. There is also some evidence of retention of learning of the complex nonwords read at Phase 2 to Phase 3, although this is not always statistically significant.

Taking these results together, all children showed effects of prior learning, with better learning at Phase 2 and retention to Phase 3 for novel words related to those read at Phase 1 in comparison to those not related to those read at Phase 1. The influence of prior learning was far more impactful at Grade 3 than at Grade 4 and 5. Children in Grade 3 demonstrated significant learning of the complex nonwords read at Phase 2 and 3 only when these were related to those read at Phase 1; in contrast, children in Grades 4 and 5 showed evidence of learning (or retention of learning) of complex nonwords both when these were related to those read at Phase 1 and when they were not.

Table 3.4.

Mean Number of Correct Choices for Familiar Target Items on Orthographic Choice Tasks During Phases 2 and 3

	Phase 2				Phase 3				Combined Phases			
	Grade 3	Grade 4	Grade 5	All Grades	Grade 3	Grade 4	Grade 5	All Grades	Grade 3	Grade 4	Grade 5	All Grade s
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Morphologically Complex Story Condition	2.62 (1.71)	3.57 (1.64)	3.57 (1.44)	3.20 (1.67)	2.61 (1.50)	3.21 (1.69)	3.14 (1.43)	2.96 (1.55)	5.23 (2.86)	6.79 (2.94)	6.71 (2.59)	6.15 (2.88)
Orthographically Complex Story Condition	2.74 (1.46)	3.46 (1.77)	3.82 (1.81)	3.26 (1.70)	2.50 (1.52)	2.67 (1.88)	3.53 (1.91)	2.82 (1.78)	5.24 (2.70)	6.13 (3.34)	7.35 (3.57)	6.08 (3.22)
Combined Story Conditions	2.67 (1.59)	3.52 (1.69)	3.68 (1.59)	3.23 (1.68)	2.56 (1.50)	2.96 (1.78)	3.31 (1.64)	2.89 (1.65)	5.23 (2.77)	6.48 (3.12)	6.98 (3.02)	6.12 (3.03)

Table 3.5.

Mean Number of Correct Choices for Unfamiliar Target Items on Orthographic Choice Tasks During Phases 2 and 3

	Phase 2				Phase 3				Combined Phases			
	Grade 3	Grade 4	Grade 5	All Grades	Grade 3	Grade 4	Grade 5	All Grades	Grade 3	Grade 4	Grade 5	All Grades
Story condition	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Morphologically Complex	1.83 (1.31)	2.11 (1.34)	2.61 (1.23)	2.14 (1.32)	1.67 (1.22)	1.86 (1.11)	1.78 (0.99)	1.76 (1.11)	3.50 (1.99)	3.96 (2.15)	4.39 (1.43)	3.90 (1.93)
Orthographically Complex	1.59 (1.15)	2.04 (1.37)	2.18 (1.47)	1.90 (1.32)	1.56 (1.22)	2.00 (0.88)	1.83 (1.28)	1.78 (1.13)	3.15 (1.66)	4.04 (1.92)	4.01 (2.49)	3.68 (2.00)
Combined	1.72 (1.24)	2.08 (1.34)	2.43 (1.34)	2.03 (1.32)	1.62 (1.21)	1.92 (1.01)	1.80 (1.11)	1.77 (1.12)	3.34 (1.84)	4.00 (2.03)	4.23 (1.93	3.80 (1.96)

Table 3.6.

Decoding Averages on Target Words During Phase 2 Story Reading

	Grade 3		Grade 4		Grade 5		All Grades	
	Familiar	Unfamiliar	Familiar	Unfamiliar	Familiar	Unfamiliar	Familiar	Unfamiliar
	Mean (SD) %	Mean (SD) %	Mean (SD) %	Mean (SD) %	Mean (SD) %	Mean (SD) %	Mean (SD) %	Mean (SD) %
Morphologically Complex Story Condition	12.87 (7.51) 54%	10.45 (7.77) 44%	16.74 (6.68) 70%	15.74 (7.87) 66%	13.48 (7.71) 56%	14.39 (7.12) 60%	14.33 (7.42) 60%	13.33 (7.89) 56%
Orthographically Complex Story Condition	9.08 (7.45) 38%	6.54 (6.42) 27%	13.00 (7.61) 54%	13.52 (8.00) 56%	14.82 (7.70) 62%	13.41 (6.73) 56%	12.02 (7.83) 50%	10.88 (7.77) 45%
Combined Story Conditions	11.22 (7.66) 47%	8.75 (7.41) 36%	15.02 (7.30) 63%	14.72 (7.93) 61%	14.05 (7.64) 59%	13.98 (6.89) 58%	13.31 (7.66) 56%	12.25 (7.90) 51%

Similarly, prior learning improved decoding accuracy at Phase 2 for children in Grade 3 but not for those in Grades 4 and 5. All effects were consistent across morphologically- and orthographically-related words, suggesting that the basis of transfer lies in an orthographic analogy.

3.4.4. Research Questions 2 and 3: Transfer of Accumulated Learning to Processing and the Basis of that Transfer

Our third research question was whether children generalize their accumulated learning experiences of simple and complex nonwords in Phase 1 and 2, respectively, (i.e., *lurg* and *relurg*) to facilitate their processing of related words they have not previously learned tested at Phase 3 (e.g., *mislurg*). The core effect that we were interested in was one of accumulated learning, with performance contrasted for nonwords that were related to those experienced at Phases 1 and 2 versus to those only experienced at Phase 2 (i.e., more versus less experience). And, in line with our interest in the basis of transfer (i.e., research question 2), we examined whether there were main effects or interactions with two variables: story condition, which contrasted whether the complex words were morphologically or orthographically related to the base words seen in Phase 1, and of word type (Morphological Transfer, Orthographic Transfer). The former variable tells us about the mechanism of learning-to-learning transfer that occurred during the accumulated learning experiences while the latter variable tells us about the mechanism of learning-to-processing transfer that occurs based on those earlier accumulated learning experiences.

To answer these questions, we examined accuracy in the orthographic choice task using a repeated measures ANOVA with between-subjects factors of grade (Grade 3, Grade 4, Grade 5) and Phase 2 story condition (Morphologically Complex, Orthographically Complex) and the within-subject variables of Accumulated learning (more versus less experience), word type (Morphological Transfer, Orthographic Transfer), and testing time (Phase 2, Phase 3). There were significant main effects of time, $F(1, 146) = 12.45$, $p = .001$, $\eta^2 p = .08$, with higher performance at Phase 2 than at Phase 3, and of grade, $F(2, 146) = 6.78$, $p = .002$, $\eta^2 p = .09$. Regarding the main effect of grade, means for Grade 3 were lower than for Grade 4, $t(110) = -2.74$, $p = .007$, $d = -.52$, and Grade 5, $t(98) = -3.67$, $p < .001$, $d = -.75$, with no difference between Grades 4 and 5, $t(90) = -0.71$, $p = .24$. Means for children's accuracy for all transfer items on the orthographic choice tasks after more and less experience are presented in Table 3.7 and Table 3.8, respectively. Critically, there was a main effect of accumulated learning, $F(1, 146) = 138.65$, $p < .001$, $\eta^2 p = .49$, with higher performance on the items related to those read at both Phase 1 and 2 than to those only read at Phase 2. There were no other main effects or interactions, all Fs < 3.12 and all ps ≥ 05. This main effect of accumulated learning suggests that, relevant to our third research question, accumulated learning experiences do lead to more accurate processing of related complex words when required to identify their spelling.

The basis of these accumulated learning effects appears to be one of orthographic similarity. Indeed, the lack of interaction of accumulated learning with story condition suggests that transfer to processing occurs to a similar extent when children have previously learned non-words that are related morphologically (such as *mislurg*) as for non-words that simply share orthographic form (such as *fislurg*). Further, the lack of interaction of accumulated learning with word type suggests that this transfer then occurs regardless of the appearance of morphological complexity in the new form encountered.

Building on these ANOVA results showing that accumulated learning transfers to the processing of novel complex words, we then examined the extent to which accumulated learning supports the processing new words. We did so by conducting analyses of performance against chance in each condition, with a series of planned one-sample *t*-tests within each grade in each condition, with Bonferroni corrections applied. Given that the children had four options to choose from on each orthographic choice item, chance level was 25%. At each phase children completed 12 familiar and 12 unfamiliar transfer items, leading to a chance level of 3 for each type of item. As with the analyses of the learning-to-learning effects, we find differences in patterns between children in each Grade.

Results are consistent across grades for the familiar transfer nonwords at Phase 2 and 3. Children in Grades 3, 4 and 5 chose the correct spellings at levels significantly higher than chance for familiar transfer nonwords at both Phase 2 and Phase 3, all ts $\geq$ 5.44, ps $\leq .001$, ds ≥ 0.70. These results suggests that children in Grades 3 to 5 were able to capitalize on their accumulated learning of two related nonwords in two different stories (e.g., *lurg* in Phase 1 and *relurg* in Phase 2) to support their processing of novel related nonwords (e.g., *mislurg, fislurg*).

Results differed for each Grade for the less familiar nonwords. At Grade 3, performance was at chance at Phase 2, $t(59) = 1.86$, $p = .07$, and Phase 3, $t(59) = 0.27$, $p = .39$. At Grade 4, scores were higher than chance at Phase 2, $t(51) = 3.36$, $p = .001$, $d = 0.47$, but not at Phase 3, $t(51) = 0.79$, $p = .47$.

Table 3.7.
Mean Number of Correct Choices for Transfer Items on Orthographic Choice Tasks Phases 2 and 3 After More Experience (i.e., learning of base during Phase 1)

	Phase 2				Phase 3				Combined Phases			
	Grade 3	Grade 4	Grade 5	All Grades	Grade 3	Grade 4	Grade 5	All Grades	Grade 3	Grade 4	Grade 5	All Grades
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Morphological Transfer Items												
Morphologically Complex Story Condition	2.89 (1.46)	3.46 (1.53)	3.43 (1.20)	3.23 (1.43)	2.45 (1.55)	3.54 (1.64)	3.01 (1.60)	2.97 (1.64)	5.34 (2.71)	7.00 (2.92)	6.44 (2.43)	6.20 (2.77)
Orthographically Complex Story Condition	2.41 (1.72)	2.96 (1.76)	3.65 (1.69)	2.91 (1.77)	2.48 (1.37)	2.75 (1.85)	3.59 (2.09)	2.85 (1.77)	4.89 (2.47)	5.71 (3.28)	7.24 (3.51)	5.76 (3.14)
Combined Story Conditions	2.67 (1.58)	3.23 (1.64)	3.53 (1.41)	3.09 (1.59)	2.46 (1.46)	3.17 (1.77)	3.26 (1.83)	2.92 (1.70)	5.14 (2.59)	6.40 (3.13)	6.78 (2.92)	6.00 (2.94)
Orthographic Transfer Items												
Morphologically Complex Story Condition	3.04 (1.58)	3.39 (1.40)	2.91 (1.35)	3.12 (1.46)	2.28 (1.35)	3.36 (1.34)	3.31 (1.33)	2.92 (1.42)	5.31 (2.53)	6.75 (2.43)	6.22 (2.37)	6.04 (2.50)
Orthographically Complex Story Condition	2.44 (1.58)	3.33 (1.76)	3.65 (1.41)	3.06 (1.67)	2.26 (1.35)	2.63 (1.79)	3.53 (1.81)	2.71 (1.68)	4.70 (2.64)	5.96 (3.24)	7.18 (2.88)	5.76 (3.04)
Combined Story Conditions	2.77 (1.59)	3.37 (1.56)	3.23 (1.40)	3.09 (1.55)	2.27 (1.34)	3.02 (1.59)	3.40 (1.53)	2.82 (1.54)	5.04 (2.58)	6.38 (2.83)	6.63 (2.61)	5.92 (2.75)
Combined Transfer Items												
Morphologically Complex Story Condition	5.93 (2.72)	6.86 (2.51)	6.35 (2.21)	6.35 (2.52)	4.73 (2.62)	6.89 (2.81)	6.32 (2.66)	5.89 (2.83)	10.66 (4.83)	13.75 (5.02)	12.66 (4.51)	12.24 (4.94)
Orthographically Complex Story Condition	4.85 (2.82)	6.29 (3.17)	7.29 (2.93)	5.97 (3.10)	4.74 (2.33)	5.38 (3.42)	7.12 (3.53)	5.56 (3.16)	9.59 (4.62)	11.67 (6.18)	14.41 (6.01)	11.53 (5.80)
Combined Story Conditions	5.44 (2.80)	6.60 (2.82)	6.75 (2.55)	6.18 (2.79)	4.73 (2.47)	6.19 (3.17)	6.66 (3.05)	5.74 (2.98)	10.18 (4.73)	12.79 (5.63)	13.41 (5.20)	11.92 (5.34)

Table 3.8.

Mean Number of Correct Choices for Transfer Items on Orthographic Choice Tasks Phases 2 and 3 After Less Experience (i.e., no learning of base during Phase 1)

	Phase 2				Phase 3				Combined Phases			
	Grade 3	Grade 4	Grade 5	All Grades	Grade 3	Grade 4	Grade 5	All Grades	Grade 3	Grade 4	Grade 5	All Grades
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Morphological Transfer Items												
Morphologically Complex Story Condition	1.58 (0.97)	2.00 (1.28)	2.13 (1.06)	1.87 (1.12)	1.48 (1.03)	1.46 (0.79)	1.87 (1.10)	1.58 (0.98)	3.06 (1.35)	3.46 (1.62)	4.00 (1.88)	3.45 (1.62)
Orthographically Complex Story Condition	1.70 (1.07)	2.29 (1.20)	1.65 (0.79)	1.90 (1.08)	1.45 (0.93)	1.42 (1.10)	1.60 (0.86)	1.48 (0.97)	3.16 (1.36)	3.71 (1.90)	3.25 (1.29)	3.37 (1.56)
Combined Story Conditions	1.63 (1.01)	2.13 (1.24)	1.93 (0.97)	1.88 (1.10)	1.47 (0.98)	1.44 (0.94)	1.76 (1.00)	1.54 (0.97)	3.10 (1.34)	3.58 (1.74)	3.68 (1.68)	3.42 (1.59)
Orthographic Transfer Items												
Morphologically Complex Story Condition	1.76 (1.20)	1.73 (1.20)	1.96 (1.40)	1.80 (1.25)	1.73 (1.01)	1.86 (1.18)	1.95 (1.27)	1.83 (1.13)	3.48 (1.66)	3.58 (1.82)	3.91 (1.99)	3.63 (1.79)
Orthographically Complex Story Condition	1.74 (1.20)	1.96 (1.20)	1.76 (0.83)	1.82 (1.11)	1.41 (1.01)	1.58 (0.93)	2.06 (1.03)	1.63 (1.01)	3.15 (1.48)	3.54 (1.67)	3.82 (1.38)	3.46 (1.53)
Combined Story Conditions	1.75 (1.19)	1.83 (1.19)	1.88 (1.18)	1.81 (1.18)	1.58 (1.01)	1.73 (1.07)	2.00 (1.16)	1.74 (1.08)	3.33 (1.58)	3.56 (1.73)	3.87 (1.73)	3.55 (1.68)
Combined Transfer Items												
Morphologically Complex Story Condition	3.33 (1.69)	3.73 (2.18)	4.09 (2.09)	3.67 (1.97)	3.21 (1.60)	3.32 (1.66)	3.82 (1.91)	3.42 (1.70)	6.55 (2.43)	7.05 (2.90)	7.91 (3.34)	7.09 (2.88)
Orthographically Complex Story Condition	3.44 (1.50)	4.25 (1.96)	3.41 (1.23)	3.72 (1.65)	2.86 (1.51)	3.00 (1.84)	3.66 (1.48)	3.11 (1.64)	6.31 (2.01)	7.25 (3.25)	7.07 (2.17)	6.83 (2.55)
Combined Story Conditions	3.38 (1.60)	3.97 (2.08)	3.80 (1.79)	3.69 (1.83)	3.05 (1.56)	3.17 (1.73)	3.75 (1.72)	3.28 (1.68)	6.44 (2.24)	7.14 (3.04)	7.55 (2.90)	6.97 (2.73)

At Grade 5, scores were above chance at both Phase 2, $t(39) = 2.83$, $p = .004$, $d = 0.45$, and Phase 3, $t(39) = 2.77$, $p = .004$, $d = 0.44$. To summarise, learning a single complex form at Phase 2 resulted in accuracy in processing related forms at Phase 2 only for children in Grades 4 and 5, with retention of this learning for children in Grade 5.

Taking these results together, all children showed effects of accumulated learning, with better processing at Phases 2 and 3 for novel words related to those read at Phases 1 and 2 in comparison to those not related to those read at Phase 2. The effects of accumulated learning were far more substantive at Grade 3 than at Grade 4 and 5. At Grade 3, accurate processing of novel related forms at Phases 2 and 3 emerged only when these were related to forms read at both Phases 1 and 2. At Grade 4, accurate processing of novel related forms at Phase 2 emerged both when these were related to forms read only at Phase 2 and when these were related to forms read at both Phases 1 and 2. At Grade 5, we see effects on accurate processing at both Phase 2 and 3 in all of these cases.

3.5. Discussion

We conducted a study with English-speaking children in Grades 3 to 5 to test the assumption (Nagy & Anderson, 1984) that children's learning of a simple word (e.g., *lurg*) during independent reading helps them in turn to learn other novel complex words. At the same time, we explored the basis of that transfer (e.g., *relurg*, *pelurg*), investigating whether it occurs on the basis of morphological or orthographic analogies, and of accumulated learning over time. We modified a classic self-teaching paradigm to answer these questions (building on Share, 1999) with children in Grades 3, 4, and 5. As in standard self-teaching tasks, we asked children to read a set of short stories with simple nonwords (e.g., *lurg*) embedded in them four times. In a novel design addition, we asked the children to read another set of stories that contained complex nonwords embedded in them four times and then asked them to complete an orthographic choice task to assess their learning and any learning transfer. To answer our first research question about the effects of prior learning on learning of novel complex forms, half of the Phase 2 stories included "familiar" complex words (i.e., nonwords related to the simple words they learned previously, e.g., *relurg*) while half of the stories had "unfamiliar" complex words (i.e., nonwords not related to the simple words they learned previously, e.g., *remerl*). To answer our second research question regarding the mechanism of transfer, the second set of stories contained either morphologically (e.g., *relurg*, *remerl*) or orthographically complex nonwords (e.g., *pelurg, pemerl*). Finally, to answer our third research question regarding the effects of accumulated learning on processing, we tested effects of learning of both a simple (i.e., *lurg*) and complex word (i.e., *relurg* or *pelurg*) on additional complex words that the children had not seen within stories; again, these included both morphological (e.g., *mislurg, mismerl*) and orthographically complex items (e.g., *fismerl and fislurg*).

In terms of our first research question, our results indicate that children's learning of a simple word (e.g., *lurg*) does facilitate their subsequent learning of related complex words (e.g., *relurg*) later encountered in connected texts. Specifically, children performed significantly better on the orthographic choice items testing complex nonwords for which they had learned the related simple nonword at Phase 1 than for those for which they had not. This was a large main effect that was consistent across grade and testing times. This effect suggests that learning a simple word first does facilitate subsequent learning of related complex words. These findings are consistent with prior studies showing transfer of learning to the processing of related complex words (e.g., Tucker et al., 2016); here we extend this to the transfer of learning to subsequent learning, Certainly, it is clear that orthographic learning within the Self-Teaching Hypothesis (Share, 2008) does not occur on a strictly word-specific basis, and that prior learning does indeed lead to better learning of related complex words during subsequent independent reading experiences (Nagy & Anderson, 1984).

Intriguingly, follow up analyses exploring the extent to which prior learning enables learning showed some differences across our three grades, with a far stronger impact of prior learning at Grade 3 than at Grades 4 and 5. Children in Grade 3 demonstrated significant learning of the complex nonwords read at Phase 2 and 3 only when these were related to those read at Phase 1 (and not when they were not related to those read at Phase 1); in contrast, for children in Grades 4 and 5 there was evidence of learning (and retention of learning) of complex nonwords both when these were related to those read at Phase 1 and when they were not. In a similar manner, prior learning improved decoding accuracy at Phase 2 for children in Grade 3 but not for those in Grades 4 and 5. This latter effect is in contrast to similar performance across grades in decoding the simple nonwords. These effects were consistent across morphologically- and orthographically related words, a point to which we return in discussing our second research question. These grade level differences might be related to the amount of experience, or lack thereof, that young readers have complex words in comparison to children in Grades 4 and 5. Anglin (1993) reported that the number of derived words children know rises sharply between Grades 3 and 5, estimating that children in Grade 3 know 5,577 derived words while children in Grade 5 likely know 16,088 derived words. Given this, it may be that children with less experience reading complex words may benefit from their learning of a simple word to learn and/or decode a novel complex word to a far greater extent when those with more experience. We also note that these grade-level differences emerged in this study specifically testing transfer of learning to learning, while there is little evidence of differences in patterns of results for the same grade levels in studies of transfer of learning to processing (e.g., Tucker et al., 2016). Transfer of learning to learning might be more taxing with a greater influence of prior reading; that said, this is speculative and the similarities and differences between processing and learning are worthy of further investigation.

In terms of our second research question, our findings suggest that children transfer learning of a simple word (e.g., *lurg*) to the same extent to words that are morphologically related (e.g., *relurg*) as those that are only orthographically similar (e.g., *pelurg*). The lack of any effects or interactions involving story condition indicates that children transferred their learning of a simple nonword to their subsequent learning of morphologically- and orthographically- related complex nonwords to a similar extent. It is noteworthy that these effects occurred despite the fact that the short stories emphasised the morphological relationship between the simple and morphologically complex nonwords (in contrast to Tucker et al., 2016). Our findings suggest that effects of prior learning on learning occur via an orthographic rather than morphological mechanism. This finding is consistent with prior research showing that children transfer their learning of a simple nonword (e.g., *lurb*) to their processing of both morphologically (e.g., *lurber*) and orthographically (e.g., *lurble*) complex nonwords (Tucker et al., 2016). This finding also fits with prior research by showing that children use a cue word (e.g., *turn*) to facilitate their spelling of both morphologically related (e.g., *turning*) and orthographically related (e.g., *turnip*) words (Deacon & Bryant, 2006). These findings do not however align with results from other paradigms pointing to transfer based on morphology. Specifically, there is clear evidence of stronger reading and spelling of morphologically complex words than of morphologically simple words, when these are known, established words (e.g., Carlisle, 2000; Deacon & Bryant, 2005). Taking these findings together, we think that the use of a provided clue, whether this is a real word or a newly read word, generally transfers on the basis of orthographic analogy, and that morphological effects emerge in processing more established words. We note as well that the way in which new words are provided might be another variable to consider; Pacton et al (2018; 2013) found that French children learned a base word better when they read both the base word and a morphologically complex word within the same short story (e.g., Pacton et al., 2018; 2013). We wonder if this experience of reading two related words within the same story might have increased the likelihood of considering these to be morphologically related. That said, we think that the primary difference in whether effects are orthographic or morphological might be in accumulated experience with words and their meaning, with morphological effects emerging far more consistently for known real words. That said, these ideas are speculative, and it would be worthwhile to systematically explore when and how morphology specific effects emerge. Overall, our findings support the suggestion that elementary-school aged children transfer their learning of a new simple word to their later learning of related complex words, and they appear to do so on the basis of shared spelling patterns.

In terms of our third research question, our results indicate that learning of both a simple (i.e., *lurg*) and complex word (i.e., *relurg* or *pelurg*) have downstream impacts on processing of novel related complex words (e.g., *mislurg, fislurg*). We saw a large main effect, with better processing at Phases 2 and 3 for novel words related to those read at Phases 1 and 2 compared to those related only to those read at Phase 1. This suggests that children across Grades 3 to 5 showed effects of accumulated learning on later processing. As we noted earlier, Nagy and Anderson's (1984) corpus analyses (and those of others) describe the vast number of related words that children experience during their independent reading (e.g., *add*, *adds*, *adding*, *addition*, *additional*, *additive*). Despite the fact that this experience is common for children, the question of these effects of accumulated learning on later processing has not been tested, to our knowledge. Here we find that indeed, as suggested by Nagy and Anderson (1984) and others, experience with related forms does improve processing of other related forms.

Further, in exploring the extent of the impact of these effects, as with our findings for the effects of learning on learning, again we see grade-level differences. The effects of accumulated learning were far more substantive at Grade 3 than at Grade 4 and 5. At Grade 3, accurate processing of novel related forms at Phases 2 and 3 emerged only when these were related to both the base and complex forms that they had learned in Phases 1 and 2 (and not when they learned only the complex form it at Phase 2). At Grades 4 and 5, accurate processing of novel related forms emerged far more broadly: in cases when these were related to forms learned only at Phase 2 and when these were related to forms learned at both Phases 1 and 2. These effects on accurate processing emerged at Phase 2 for children in Grade 4 and at both Phases 2 and 3 for Grade 5, suggesting that they are longer lasting for older children. As with our discussion of results from research question one, we think that these age-related differences are worth exploring as they do not appear to emerge, at least in the available studies with older elementary school aged children, in paradigms testing transfer of learning to processing of novel words. They emerged, however, in our paradigm exploring transfer of learning to learning and the effects of that accumulated learning experiences on processing. We think that Grades 3 to 5 is indeed a rich period of learning about derived forms (e.g., Anglin, 1993) and that there might be associated shifts during this time of the nature of processing and learning that children are capable of.

In terms of theory, the current study has implications for the Self-Teaching Hypothesis (Share, 2008), as well as for our broader understanding of how children build their vocabulary through independent reading experiences. First, our study supports Share's (1999; 2008) suggestion that children can engage in orthographic learning of both simple and complex words during independent reading; critically, though, our results expand our understanding of how this process can impact future reading experiences. We show that children transfer their learning of one word to support their processing of another (as in Tucker et al., 2016), and, in a novel extension, that they also learn new complex words more effectively when they have first learned a base word. Extending even further, we have shown that, within the self-teaching paradigm, children capitalize on these accumulated learning experiences to support their processing of additional complex words they have not learned. These results speak directly to how self-teaching processes can lead to orthographic learning over time, going beyond children having to decode and learn each specific word one-by-one. Relatedly, our results connect self-teaching processes (e.g., Share, 2008) to the rapid vocabulary development during the elementary school period (e.g., Anglin, 1993; Nagy & Anderson, 1984). Indeed, our study provides evidence of just how children can understand one to three additional words for every word they learn (Nagy & Anderson, 1984) when that learning occurs within the self-teaching context. We suggest that children's learning of simple word (e.g., *lurg*) during an early independent reading experience can help them to read and learn a related complex word (e.g., *relurg*) when they encounter it in text, which, in turn, helps them process other complex words (e.g., *mislurg, fislurg*). That this can all occur through independent reading experiences demonstrates the power of children's own reading and learning.

A second contribution lies in demonstrating that, at least in this context in which children are learning novel words in text, these transfer effects occur on the basis of the orthographic similarities between the novel words. Testing when, and in what contexts, transfer effects may become morphology specific will be essential as it could enable us to bring theoretical speculations from related fields to bear. For instance, according to the form hypothesis, children detect statistical regularities between letters and sounds that then lead them to develop morphological regularities (e.g., Rastle & Davis, 2008; see also Deacon, Conrad & Pacton, 2008); critically though, these regularities are first extracted on the basis of orthographic probabilities. Another suggestion is that children rely on both form and meaning to develop morphological representations (e.g., Schreuder & Baayen, 1995; Merkx, Rastle & Davis, 2011; see also Quémart, Wolter, Chen & Deacon, 2022). Our findings align with the first of these ideas and provide novel support for them by testing the initial stages of the development of orthographic representations. Building on these findings, we think that testing the nature of the learning experience (e.g., Nation, 2017) will be important, as will be testing effects on semantic representations in establishing when and in what contexts orthographic versus morphological effects emerge.

Beyond theory, the current study has educational implications. Theoretical assumptions related to the self-teaching process and how children make use of shared word features (e.g., similar spellings, shared meaning) to support their reading have already had a significant impact on educational practices. For example, there are already relatively widespread suggestions to increase independent reading time as a method of vocabulary growth (e.g., McQuillan, 2019) and to explicitly teach children about morphology (e.g., Elleman, Oslund, Griffin, & Myers, 2019; Wright & Cervetti, 2016). Given this, the current study further supports increasing independent reading time as a way for children to build word representations. Critically, our differences in results across ages give some guidance as to the likely degree of learning at different ability levels. For example, children in Grade 3 appeared to benefit more from learning the base word first; this appeared to be needed to transfer that learning to decoding related words, learning complex words during story reading, and to processing additional complex words. In contrast, while children in Grade 5 still benefitted from learning the base word first, they still learned complex words in stories and transferred that learning to processing additional complex words when they did not. These results suggest that reading experiences could be tailored to give children experience with base forms first; this would be particularly important for children in Grade 3, with some benefits predicted even for older readers. And building on our findings of the basis of transfer effects, at least for these novel words experienced for the first time in text, it seems that highlighting orthographic similarities between words may be helpful for supporting children's word recognition and decoding. There being a potential benefit to highlighting orthographic similarities is in line with suggestions regarding the teaching of orthographic analogy-based strategies to support reading (see Goswami, 1999 for a review). Certainly, studies directly testing these educational implications are required to make any firm conclusions, but we think that the current study has some insights for how to best support reading development in elementary-aged children.

While considering the implications of the current study, it is important to also keep its limitations in mind. One is the lower performance for both decoding during story reading and orthographic choice tasks in comparison to other self-teaching studies. Across grades, we saw lower mean decoding accuracy levels and lower mean correct choices on the orthographic choice tasks than is typical in self-teaching studies (e.g., Wang et al., 2011). We believe this is, in part, due to the difficulty of our tasks with modifications made to the standard self-teaching paradigm; these include multiple reading phases with more target items across stories, and a relatively large number of items in the orthographic choice tasks. That said, mean accuracy levels across tasks are closer to those in Tucker et al. (2016) with a more similar research design than other self-teaching studies. We also consider the fact that the children in our study had standardised reading levels closer to what is considered typical development than in some prior studies (e.g., Nation et al., 2007; Wang et al., 2011). A second related limitation is that we only had one measure of orthographic learning for which we could analyse data: the orthographic choice task. Although the children completed a naming task, accuracy levels on the task were too low to be included in analyses. We stand by the decision to use an orthographic choice task, as it assesses the acquisition of detailed orthographic representations and allows our results to be aligned with those of other studies with similar paradigms (e.g., Tucker et al., 2016). Further still, we were intrigued that there were similar patterns of results for our other measure, that of decoding during story reading, as for orthographic choice where these could be compared. This gives us some confidence in the results. Nevertheless, moving forward, it will be important to confirm and extend these findings with additional outcome tasks (e.g., a simpler naming task, spelling tasks, and/or tasks assessing semantic learning) to better understand whether similar patterns emerge beyond recognition-based tasks.

In summary, the current study confirms assumptions that children's prior learning facilitates learning of related complex words when later encountered during independent reading. Additionally, children capitalize on these accumulated learning experiences to support their processing of related complex words they have not previously seen or learned. Finally, effects of both learning on learning and those of accumulated learning appear on the basis of orthographic analogies rather than morphological relations, at least in a self-teaching paradigm in which children are encountering these words for the first time. We think this study has important implications for understanding how children in elementary school rapidly build their vocabulary through accumulated learning experiences that occur during independent reading.

3.6. References

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Chapter 4. The durability and quality of lexical representations acquired through children's independent reading

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4.1. Abstract

A core aspect of children's reading development lies in establishing the high-quality lexical representations that are needed for strong reading comprehension. Here we investigated whether self-teaching, effectively independent reading, is a mechanism by which children can establish lexical representations that are both high quality and durable—specifically, ones that remain one year after the initial learning experience. We did so by asking children in Grade 4 to complete a classic self-teaching task in which they read stories containing four instances of pseudowords (e.g., *feap*). We tested children's memory for the spellings and meanings of these pseudowords with spelling and meaning recognition tasks, as well as a task requiring integration of spellings with meanings. These tasks were completed immediately after the learning experience, as well as one week and one full year later. As expected, memory for these representations declined over this time period. Critically, though, the children were above chance on the recognition tasks one year after the learning experience. On the integration task, however, which tests the highest quality representations, the presence of a retrieval cue resulted in above chance performance at one year, while performance without a cue was at chance levels. Taken together, these findings suggest that self-teaching—involving independent reading of short texts with few exposures to new words—is a mechanism by which children can establish representations of spellings and meanings that are durable over time and are of reasonably high quality.

Keywords: reading; lexical quality; self-teaching; orthographic learning; semantic learning; retrieval cues

4.2. Introduction

Children's ability to understand what they read is built directly on their ability to access high-quality representations of individual words from memory. High-quality representations allow children to move beyond laborious letter-by-letter decoding to efficient sight word reading, freeing cognitive resources for text comprehension. The prominent lexical quality hypothesis (Perfetti & Hart, 2002) drives home the value of word form and meaning in these representations; representations need to integrate phonological, orthographic, and semantic information, or the sounds, spellings, and meanings of words, to be of sufficient quality to support reading comprehension. Thus, integration of these components is a key indicator of representation quality. The self-teaching hypothesis (Share, 2008) articulates a mechanism for acquiring these high-quality lexical representations: children's independent reading. Share (2008, p. 40) summarised the status of research supporting the self-teaching hypothesis, stating that "Because word-specific orthographic knowledge is acquired so quickly, even among inexperienced readers, words seem to be rapidly assimilated to a child's reading or so-called sight vocabulary". In the face of this early optimism, the assumption that fast acquisition through self-teaching results in a lasting, high-quality representation remains largely untested. This leaves it unclear as to the value of a widely used experimental paradigm for testing the kind of learning that children need in the real world. We bridge this gap by testing the durability and quality of the lexical representations that children have acquired through self-teaching one year after this initial experience.

The classic self-teaching paradigm (Share, 1999) has been widely implemented to test children's skill in acquiring new words through their independent reading. In this paradigm, children read short stories containing pseudowords (e.g., *feep*), followed by tasks assessing their learning. Multiple studies confirm that readers in Grade 1 through to adulthood learn new words with only a few exposures through this paradigm (e.g., Conrad et al., 2019; Deacon et al., 2019; Ginestet et al., 2021; Share, 2004; see also Nation & Castles, 2017). Learning of orthographic representations has been shown through above chance performance on orthographic choice tasks (e.g., *feep-feap-veep-veap*) and relatively high levels of spelling accuracy (e.g., Share, 2004). A handful of studies have revealed that children also learn the meaning of new words through independent reading (e.g., Deacon et al., 2019; Mimeau et al., 2018; Ricketts et al., 2011). As an example, after reading about new inventions (e.g., Wang et al., 2011), 6- to 8-year-old children were above chance in choosing the meanings, as well as the spellings, of the inventions (Deacon et al., 2019; Mimeau et al., 2018). Together, these studies suggest that self-teaching is a mechanism through which children can encode orthographic and semantic information about new words, two key components of high-quality representations. The core questions that remain lie in the durability and the quality of the representations that are acquired through self-teaching. We explore each of these ideas in turn, considering different theoretical perspectives on these questions.

4.2.1. Durability of Lexical Representations

The classic self-teaching paradigm has been informative in shifting attention to what children can learn on their own. This paradigm mimics learning 'in the wild' far more closely than studies of single word lexical decision or naming tasks, albeit in a brief and relatively tightly controlled task. And yet, the bulk of studies using this paradigm have assessed durability of newly acquired representations after a few days or one week after the initial learning experience (e.g., Bowey & Muller, 2005; Cunningham et al., 2002; Nation et al., 2007); this is far shorter than the duration that children likely need to retain new words for them to be useful in their reading. For some words, children have continuous exposure across texts and years, and yet for other words, like *absent* or *dismal*, children might encounter them for the first time in Grade 4, and then only a couple of times in Grade 5 (Zeno, 1995). Children's texts are rife with these kinds of infrequent words (Nagy & Anderson, 1984), far more so than the oral language they hear (Hayes & Ahrens, 1988). Further, as children move between classrooms and teachers across years, a durable representation is needed to withstand these changes in reading environment. Investigations with the self-teaching classic paradigm need to answer fundamental questions about the longer-term durability of lexical representations in a way that reflect changes over time in children's real life reading experiences.

What might we expect as to the durability of the lexical representations acquired through self-teaching? On the one hand, we might assume, like Share (2008), rapid assimilation of new lexical representations, with children acquiring representations through self-teaching that are durable over time and of high quality. To our knowledge, there is a single published study testing retention more than a week after the self-teaching experience. Share (2004) reported that children in Grade 3 retain orthographic representations for up to 30 days. In that study, correct spellings were both produced and chosen by children at a level higher than chance. Remarkably, there was no evidence of decline in the quality of children's orthographic representations from 7 to 30 days post-learning, with numerically similar values for spelling and choice tasks across these time periods. These data would suggest that children retain a representation of the orthographic aspects of new words for a relatively long time after a self-teaching experience.

On the other hand, the lexical representations that children acquire through self-teaching may not be so durable or of such high quality. Theoretical predictions call into question whether a lexical representation created from four exposures would be long-lasting. According to the lexical quality hypothesis, children solidify their lexical knowledge through repeated learning experiences, thereby creating higher-quality and more durable representations (Perfetti & Hart, 2002). This kind of experience is not typically offered in the self-teaching paradigm, in which children often have remarkably few– often just four– experiences with novel words within a single reading experience of a very short story (Cunningham et al., 2002; Wang et al., 2011) or even just a couple of sentences (Byrne et al., 2008). Even Share (1999, p. 96) wrote that, "…the process of word recognition will depend primarily on the frequency to which a child has been exposed to a particular word…" (see also Share, 2008). According to these views, the limited encounters with a novel word that is typical in the self-teaching paradigm may not result in high-quality representations that are stable over time. We do not know if this is the case, as children's retention of high-quality representations acquired through self-teaching has yet to be empirically tested beyond 30 days for orthographic information (Share, 2004), or beyond 6 to 7 days for semantic information (Mimeau et al., 2018).

There is, however, empirical evidence of longer-term durability of newly acquired representations in the oral language literature. In this domain, fast-mapping studies examine how children learn to associate words and their referents with minimal exposure using a paradigm that is strikingly alike to that of self-teaching, albeit in the oral domain.

In a typical fast-mapping task, children are presented orally with a new word and shown a picture of a novel object. Learning is assessed using tasks similar to those in the self-teaching paradigm; children are asked which one of four pictures corresponds to the orally presented word (see Carey, 2010 for review). Results from fast-mapping studies reveal that preschool-age children can maintain knowledge of the mapping between a word's name and its meaning over a delay of several days (Rice et al., 1994), one or several months (e.g., Kan, 2014; Markson & Bloom, 1997), and up to one year later (Gordon et al., 2016; Vlach & Sandhofer, 2012). The two available studies testing retention at a year after the initial learning experience show that performance remains above chance out to one year, but, critically, that it also declines over time (Gordon et al., 2016; Vlach & Sandhofer, 2012). These findings are consistent with classic evidence of decline in retrieval in the absence of re-exposure (e.g., Bjork & Bjork, 1992; Ebbinghaus, 1885/2013). At least in the oral domain, it seems then that retention of newly acquired representations is durable over time, but might also be inconsistently robust, reinforcing the need to test retention of newly acquired representations in other paradigms, such as self-teaching.

4.2.2. Quality of Representation

As we explore the durability of representations, we reflect on what it means to retain a high-quality representation. Perfetti & Hart (2002) suggest that an orthographic representation integrates three important types of information: a phonological component (a representation of its sound), an orthographic component (a representation of is spelling), and a semantic component (a representation of its meaning). They further note that high levels of integration are considered a strong metric of a high-quality representation (Perfetti & Hart, 2002). Yet few studies have tested the integration of high-quality representations established during self-teaching. In one of the few to do so, Mimeau et al. (2018) moved beyond separate assessment of spellings and meanings to get at integration of orthographic and semantic information. In Mimeau et al.'s study with 8-year-olds, children were asked to match sentences that had been divided into two parts, with one part containing an invention name (e.g., *The veap is used to…*) and the other part containing the function (e.g., *…clean fish tanks*). As such, this task assesses children's ability to integrate form and meaning information. Children were above chance in this task, suggesting that they were able to encode high-quality lexical representations integrating both orthographic and semantic information. We used this task in the present study to examine whether children encode integrated high-quality lexical representations through the self-teaching process that are durable over time.

Given the skepticism as to whether children can retain high-quality lexical representations over time, we explored the kinds of retrieval cues that support long-term recall of high-quality representations. This also offered a way to test the quality of representations in a second way. One of the most fundamental principles of human memory is that, as time goes on, the ability to retrieve information declines if re-exposure does not occur (e.g., Bjork & Bjork, 1992; Ebbinghaus, 1885/2013). However, memory cues have long been shown to enhance retention, provided the memory cue provided at the time of retrieval was present at the time of encoding (Tulving & Osler, 1968). Memory cues have been shown to enhance retrieval in the fast-mapping literature (e.g., Vlach & Sandhofer, 2012), with little parallel research in the written domain. Here, we manipulate the presence and type of retrieval cues to explore the quality of representations that remain a full year after the orthographic learning experience.

The value of retrieval cues to facilitate access to high-quality lexical representations is supported by theoretical predictions (Perfetti, 2017; Perfetti & Hart, 2002). As suggested earlier, high-quality representations include strong connections between each constituent, such that activating one aspect of a lexical representation results in simultaneous retrieval of other aspects of the representation. For instance, seeing the spelling of the word activates its sound and meaning. This theoretical prediction points to the value of manipulating cue presence in testing the strength of connections between constituents of a lexical representation. For instance, one could activate one constituent by providing a form or meaning cue for the target word and examine whether the cue facilitates retrieval of a high-quality representation. If the lexical representation is of lower quality, or weakly integrated, cueing one constituent (e.g., phonological information) would specifically facilitate access to that information alone, resulting in better pronunciation of the word, with no effects on access to orthographic or semantic information. In contrast, if the lexical representation is of higher quality, or strongly integrated, cueing for a one constituent (e.g., phonological information) would facilitate access to all components of lexical information, resulting in better pronunciation, as well as more accurate orthographic and semantic information. Investigating cueing effects evaluates the quality (i.e., the integration) of a lexical representation formed via self-teaching and retained over time.

4.2.3. The Present Study

We report here on a study in which we examined the durability and quality of the lexical representations that children acquire during independent reading. We asked children in Grade 4 to complete a classic self-teaching paradigm. We tested their retention with classic orthographic and semantic choice tasks as well as an integration task. We did so immediately after their reading, a few days later, and a full year later, when the children were in Grade 5. Testing one year out from the self-teaching experience brings the available evidence with this experimental paradigm closer to the kinds of experiences that children have with the infrequent words that are common in the texts they read in the real world (e.g., Nagy & Anderson, 1984; Zeno, 1995). This design tests the durability and the quality of the orthographic and semantic information that children learn via self-teaching over a far longer time-period than in self-teaching studies to date (e.g., Bowey & Muller, 2005; Cunningham et al., 2002; Nation, Angell, & Castles, 2007).

In terms of our first objective of examining durability, we evaluated whether children retain orthographic and semantic information one year after learning new pseudowords within the self-teaching context. Here we explored performance on the orthographic and semantic choice tasks. There are two most plausible outcomes. Based on optimism as to the durability of representations acquired through self-teaching (Share, 2008) and prior evidence of retention to 30 days (Share, 2004), children might retain some orthographic and semantic information such that they are able to perform at above chance levels on learning outcome tasks administered one-year later. In contrast, if the lexical quality hypothesis is correct in the necessity of the multiple learning experiences for the development of more stable, higher-quality lexical representations (Perfetti &

Hart, 2002), then four exposures in a single reading experience may not be enough to create quality lexical representations that are retained for a full year. Both approaches likely would predict decline over time, consistent with results from the fast-mapping literature, and so the true distinguisher lies in the extent of this decrement - whether learning (reflected in above chance performance) is retained through to one year after the learning experience.

Our second objective was to examine the quality of the retained representations; we used two approaches to answering this question. In the first, we tested integration of form and meaning, and thus quality, with an integration task in which success depends on encoding the connection between orthographic and semantic components (e.g., Mimeau et al., 2018). As with the orthographic and semantic choice tasks, there are competing predictions (e.g., Perfetti & Hart, 2002; Share, 2008) as to the durability of a high-quality representation. And yet, this task sets a particularly high bar as to the retention of a high-quality lexical representation. Indeed, we are far more likely to see decline in performance across a year on a task assessing integration in comparison to those testing orthographic and semantic information in isolation. Again, the key question lies in the degree of this decrement, specifically whether performance will remain above chance on the integration task.

Guided by theory (Perfetti, 2017; Perfetti & Hart, 2002), we designed a second approach to exploring the quality of the retained representations in which we tested the influence of different kinds of memory cues on retrieval at the one-year follow-up. We assigned children to one of three cue conditions one-year after the learning experience: the control group received no memory cue, the phonological cue group received the target pseudowords' pronunciation; and the semantic cue group received information about the target pseudowords' meanings. Certainly, we expected that children receiving any type of cue to outperform those who do not on the outcome tasks, given facilitative effects of cues on the retrieval of information from memory (Tulving & Osler, 1968; Vlach & Sandhofer, 2012). More critically, we contrast competing theoretical predictions. If children retain well-integrated lexical representations, as Share (2004) would predict, receiving any cue at all should improve performance across all tasks. For example, a cue about one constituent of the lexical representation (e.g., phonology) should lead to better performance on tasks assessing both semantic and orthographic information. In contrast, if children retain less well integrated lexical representations, as Perfetti and Hart (2002) would predict, a cue about one constituent of the lexical representation would lead to better performance only on tasks that assess that component. That is, those who receive a phonological cue, which is a form cue directly related to spelling, will do better specifically on the orthographic choice task, while those who receive a semantic cue will do better on the semantic choice task.

4.3. Methods

4.3.1. Participants

Participants for the current study were 123 Grade 4 students (M_{age} = 9.74 years, SD_{age} = 0.31; 64 males). The children were participating within a larger longitudinal study. We present relevant methods and data specific to our research questions.

The participants' sight word and phonological decoding efficiency scores on the sub-tests of the *Test of Word Reading Efficiency* (Torgesen, Wagner, & Rashotte, 1999) were both near the standardization means and standard deviations of 100 and 15 (Sight

Word Efficiency *M* = 102.34, *SD* = 12.71 and Phonemic Decoding Efficiency; *M* = 98.58, *SD* = 14.68, respectively). These scores on standardised tasks suggest that the sample was typically developing in terms of word reading ability.

The children were followed from Grade 4 to Grade 5, with 108 children remaining in the study at Grade 5 (M_{age} = 10.74 years, SD_{age} = 0.32 years; 57 males). At Grade 5, the children remaining in the study had slightly lower SWE scores than the original sample (*M* = 100.81, *SD* = 11.93; $t(106) = 2.39$, $p = .02$), and similar PDE scores as the original sample (*M* = 98.21, *SD* = 15.23; $t(106) = 2.39$, $p = .58$). The primary reasons for attrition were not returning the new consent form at Time 3 ($n = 3$), moving ($n = 10$), and consenting but not completing Time 3 testing ($n = 2$).

The children participating at Grade 5 were divided into three groups: Control (i.e., no cue), Phonological Cue (i.e., received a cue to the pronunciation of the learned words), and Semantic Cue (i.e., received a cue to what the different inventions were used for). The groups were created by first splitting the participants into three groups and then moving participants around until all three groups were matched across five variables: Grade 4 SWE scores, Grade 4 PDE scores, which version of the pseudowords they received, and their performance on the orthographic and semantic choice tasks completed in Grade 4 at Time 2 (1-6 days post-learning). Univariate analyses of variance (ANOVAs) indicated that there were no significant group differences on any of these variables (all *F*s < 0.88, all *p*s $> .42$).

4.3.2. Materials

4.3.2.1. Stories and Pseudoword Items During Learning Phase.

The stories and the items were created with the same approach as in Mimeau et al. (2018), although there was no overlap in the individual stories or items. Specifically, the 12 stories contained five sentences and ranged between 37 and 52 words. The stories adhered to the same constraints as in Mimeau et al. (2018), the stories for which were originally adapted from Wang et al. (2011). In each story, the five sentences followed the same structure: introducing a character and a problem, introducing an invention, describing the invention's function, describing how the character solved their problem with the invention, and what the character did with the invention once the problem was solved.

Each story contained four presentations of a target pseudoword. The pseudoword targets acted as the names for the inventions that were introduced in the stories, see Table 4.1 for a complete list. Consistent with prior studies (e.g., Tucker et al., 2016; Ricketts et al., 2011; Mimeau et al., 2018), all pseudowords followed strict criteria. First, all pseudowords were monosyllabic and contained four letters. Second, all pseudowords were checked using the Children's Printed Word Database (http://www.essex.ac.uk/psychology/cpwd) to ensure they were novel. Third, all pseudowords had regular spellings such that their expected pronunciations were based on typical letter-sound correspondences as per Rastle and Coltheart (1999). Fourth, there were six target sounds used in the pseudowords, with each target sound (e.g., /i/) presented in two pseudowords using a different spelling (e.g., *feap* and *weef*). Finally, half of the participants were presented with one spelling of a pseudoword (e.g., *feap*), while the other half were presented with the alternative spelling (e.g., *feep*). This was done to control for any individual preferences in spelling.

Table 4.1.

Pseudowords Used in Learning Task

Target Sound	Version A		Version B	
/eɪ/	*paib*	*vafe*	*pabe*	*vaif*
/k/	*clet*	*krid*	*klet*	*crid*
/ju/	*mewd*	*zule*	*mude*	*zewl*
/i/	*weaf*	*feep*	*weef*	*feap*
/oʊ/	*noke*	*joap*	*noak*	*jope*
/ɜ/	*burl*	*lerg*	*berl*	*lurg*

4.3.2.2. Learning Outcome Tasks

4.3.2.2.1. Orthographic Choice Task. One target pseudoword (e.g., *feap*) was presented per page, along with three related pseudowords: the alternative spelling of the target (e.g., *feep*) and two distractors that varied by one letter (e.g., *veap* and *veep*). Each page was formatted such that one pseudoword was on each corner of the page. The order of the pseudowords were randomized and the same for all participants. An orthographic choice response was scored as correct if it had the same spelling as the target pseudoword presented in the story that the child had read (e.g., if children read *feep*, then only *feep* was considered correct).

4.3.2.2.2. Semantic Choice Task. One picture of a target invention (e.g., a fish tank cleaner) was presented per page, along with three related pictures: a different invention using the same object (e.g., a fish tank painter) and two distractor inventions (e.g., a sock matcher and sock fixer). Each page was formatted such that one picture was on each corner of the page. The order of the pictures was randomized and the same for all participants. A semantic choice response was scored as correct if the child correctly identified the picture that displayed the invention engaged in its proper use as defined in the story (e.g., if the children identified the picture showing the *feep* cleaning the fish tank).

4.3.2.2.3. Orthographic-Semantic Integration Task. This task consisted of two sets of cards with sentences printed on them: one set of cards contained the beginnings of the definitions for each target invention (e.g., *The feep is used to…*), and the other set containing the ends of the definitions for each target invention (e.g., *… clean fish tanks*). The cards were separated into four sets of three definition pairs, maintaining the general order in which the stories were presented (e.g., the definitions from the first three stories were in one set). Within each group of three the order of the sentences was randomized, with this final order of sentences the same for all children. The child's response was scored as correct if the child accurately matched the correctly spelled pseudoword with the verbal definition of its use (e.g., matching the phrase "The *feep* is used to…" to the phrase "…clean fish tanks.").

4.3.3. Procedure

All testing was conducted in individual sessions in a quiet area of the children's school.

4.3.3.1. Time 1 – Learning and Immediate Recall

In the first session, children were first introduced to an inventor, Professor Parsnip, and shown his picture (adapted from Wang et al., 2011). Children were told they were going to read short stories about 12 of his latest inventions and they were asked to pay attention to the invention names as they would be asked questions about them later. The children then read the short stories aloud in sets of three, with this sequence was repeated until all 12 stories were read. Throughout the task, children were provided the correct word whenever a real word or pseudoword was mispronounced, skipped, or added. These errors were recorded by the tester.

After reading all 12 short stories, the children were asked to complete three learning outcomes tasks, in the order as in Mimeau et al. (2018): integration task, followed by orthographic and semantic choice tasks. In the integration task, the sentence cards were displayed with beginnings of sentences always being placed first on the child's left first, followed by the endings of sentences being placed on the child's right. The sentence cards were read aloud to the children as they were displayed to reduce any effect of word reading ability. When a full group of three sentence pairings were displayed, the children were asked to put them back in order (i.e., to match them). In the orthographic choice task, the tester read each pseudoword aloud, asking the children to choose the correct spelling of the pseudoword (e.g., "*Show me the spelling of feep"*). In the semantic choice task, the tester read each pseudoword aloud, asking the children to choose the picture representing that invention (e.g., "*Show me the picture of a feep"*).

4.3.3.2. Time 2 – Delayed Recall

At the second testing time, 1 – 6 days after the original learning task, the children were briefly reintroduced to the task, reminding them that they had read stories about Professor Parsnip's inventions the last time they met with the tester. The children were told that they would be doing more activities to see what they remembered about those inventions. Children then completed the orthographic choice, semantic choice, and integration tasks, in that order.

4.3.3.3. Time 3 – One-year Follow-up

At the third, and final, testing time, participants in all three conditions were briefly reintroduced to the task, noting that they would do some more activities to see what they could still remember about the inventions. The participants in the two cue groups were then provided additional information. The examiner told the children in the phonological cue group that they would review the names of the inventions, and they then read the list of twelve invention names aloud. The examiner told the children in the semantic cue group that they would review the objects that the different inventions were used with, and they then read the list of objects aloud. The participants in the control group received no further instructions. After the memory cues were provided, the children repeated the orthographic choice, semantic choice, and integration tasks.

4.4. Results

Upon data inspection, one participant was removed due to having an outlier score on the Integration Task, leaving 107 children with complete data at all three time points: 36 children in the Control group, 38 children in the Phonological Cue group, and 33 children in the Semantic Cue group. We assessed the normality of the data for each of the outcome tasks (orthographic choice, semantic choice, orthographic-semantic integration) in each of the three participant groups using Shapiro-Wilks tests. Using the criterion of $p < .001$ due to sample size and sensitivity of the measure, the analyses indicated that the assumption of normality was not violated, all Ws > 0.91, all *p*s > .004. Upon inspection, there were also no significant concerns related to skew (all values <|1|) or kurtosis (all values <|1.16|).

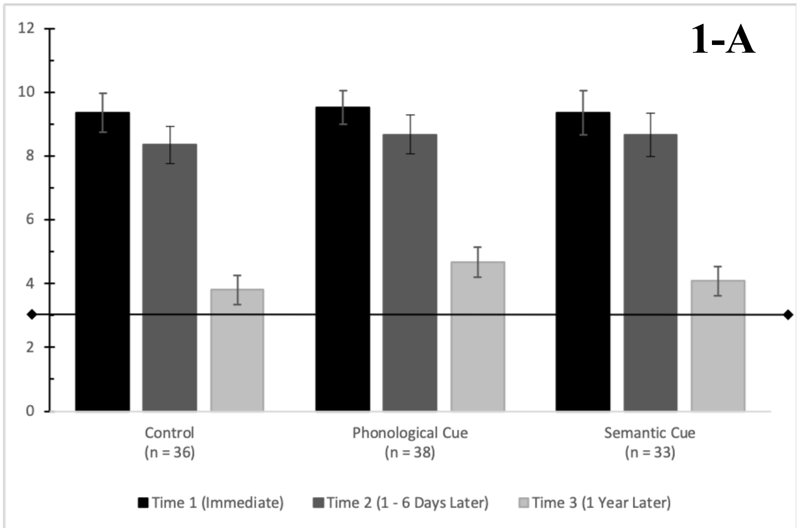
Prior to addressing our two key research questions, it was important to first consider their performance at initial testing in Grade 4. During the learning phase at Grade 4 (Time 1), the children's overall decoding level for the pseudowords was 77% ($M = 21.54$ out of a possible 28, $SD = 6.21$), with similar levels of decoding across the three groups, F (2, 104) = 0.46, $p = .63$. To establish that children were able to learn orthographic and semantic information about pseudowords at the time of learning (Time 1) and retain that information over a short period of time (Time 2, 1 – 6 days later). We did so by comparing the mean number of correct choices children made in each task against chance with one-sample *t*-tests. We found that the children were able to select correct responses at levels significantly higher than chance on all three tasks, both immediately after learning and again 1 – 6 days later (all *t*s > 9.91, all *p*s < .001). A repeated measures Analysis of Variance (RM-ANOVA) with the within-subjects variables of Time (Time 1, Time 2) and Task Type (orthographic choice, semantic choice, integration task) showed significant main effects of Time, $F(1, 106) = 15.84$, $p < .001$, $\eta^2 p = .13$ and Task Type, $F(2, 212) = 64.60$, $p < .001$, $\eta^2 p = .38$, as well as a significant interaction of Time by Task Type, $F(2, 212) = 7.28$, $p = .001$, $\eta^2 p = .06$. Additionally, paired-sample *t*-tests with Bonferroni corrections indicated a significant decline in performance between Time 1 and Time 2 for both the orthographic choice task, t (106) = 4.96, $p < .001$, and the integration task, $t(106) = 2.61$, $p = .01$. There was no significant decline in performance between Time 1 and Time 2 on the semantic choice task, $t(106) = -1.43$, $p = .16$. See Figure 4.1 for means on each task.

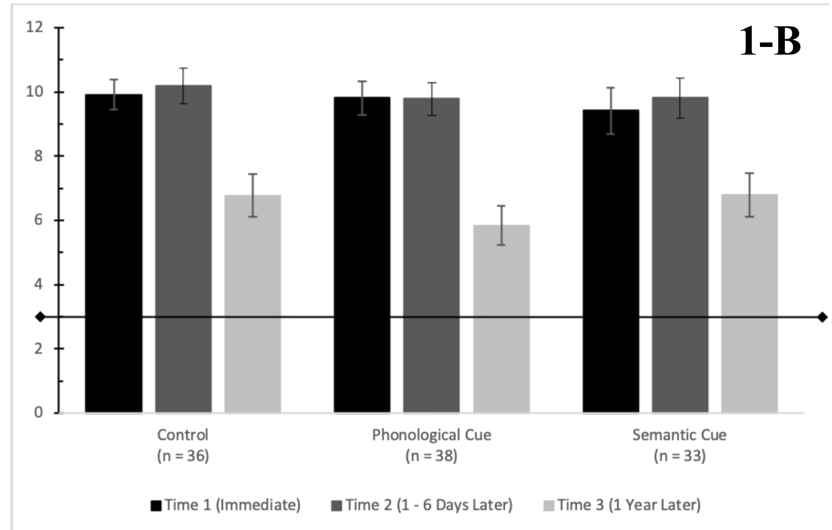
To answer our first research question, we looked at whether children retained orthographic and semantic information one year after the learning took place and whether the level of performance remained stable over time. We did so by comparing the mean number of correct choices for each task at Time 3 against chance using one-sample *t*-tests. To evaluate whether this is true in the absence of any additional support, these analyses focused specifically on the control group who did not receive any cue. See Figure 4.1 for the means on each task in this condition. At Time 3, the children in the control group were able to select correct responses at levels significantly higher than chance for both the orthographic and semantic choice tasks (all ts > 2.85, all ps < .01, all ds > 0.57). Interestingly, on the orthographic-semantic integration task, performance was not significantly better than chance, $t(35) = 1.49$, $p = .15$, one year after the learning. To examine stability of this representation over time, paired sample *t*-tests with Bonferroni corrections contrasted the control group's performance at Time 2 (1 – 6 days post-learning) and Time 3 (one-year post-learning). These comparisons show a significant decrease in performance across all tasks (all ts > 4.40, all ps < .001, all ds > 0.37), showing a decrement in performance beyond 6 – 7 days after learning. Notably, on the integration task this decrement in performance was sufficient to render performance to chance levels. Together, these results suggest that orthographic and semantic information is retained over a long period, but this information may not be sufficiently integrated to ensure a robust high-quality representation one year after the learning experience.

The analyses of the integration task presented above offer one answer to our second research question as to the quality of the representation retained. Another approach to this question comes from analyses of the influence of a memory cue on retrieval of orthographic and semantic information at the one-year follow-up. To provide this insight, we analysed data for the children in the phonological and semantic cue groups by comparing the mean number of correct choices for each task at Time 3 against chance using one-sample *t*-tests. As with the control group, the children in both the phonological and semantic cue groups selected correct responses on the orthographic and semantic choice tasks at levels significantly higher than chance (all ts > 2.85, all ps <.01, all ds > 0.50). Interestingly, and in contrast to the control group, children in the phonological and semantic cue groups selected correct responses at levels significantly higher than chance on the orthographic-semantic integration task (all ts > 3.05, all ps < .01, all ds > 0.53). See Figure 4.1 for the means on each task. This difference in performance on the integration task between the cue groups and the control group is also evident in analyses of stability; there was a decline in performance on the orthographic and semantic choice tasks for children in the two cue groups between Time 2 (1 – 6 days post-learning) and Time 3 (one-year post-learning) (all ts > 8.67, all ps < .001, all ds > 1.00), just as there was for the no cue group. In contrast to our predictions, there was no significant decline in performance on the orthographic-semantic integration task for children in either the phonological or semantic cue groups (all ts < 2.41, all ps ≥ .02, all ds < 0.06). This contrasts with the significant decline in performance for the children who received no cue. It seems that the high-quality representation formed immediately after learning may still be in the children's lexicon, but that, after a longer period of time, children need more support in accessing all constituents of it.

Further insight into children's long-term retention of a high-quality representation is provided with analyses of the effects of cueing for one constituent of a lexical representation (i.e., phonology or semantics) on access to both other constituents (i.e., orthographic and semantic information). Such effects would indicate that children remain able to access an integrated lexical representation one-year after learning new pseudowords via self-teaching. To examine specific effects of each cue on each task, we conducted a repeated measures Analysis of Variance (RM-ANOVA) on the children's responses at the final testing time (Time 3) with the between-subjects factor of cue-group (control, phonological cue, semantic cue) and the within-subjects factor of task-type (Orthographic Learning, Semantic Learning, and Integration). All additional RM-ANOVA assumptions were met, with no violations to homogeneity of variance as per Levene's test, all Fs < 1.32, all ps $> .27$, or sphericity as per Mauchley's test, $X^2(2) = 4.33$, $p = .12$.

The results of the RM-ANOVA showed a main effect of task-type, $F(2, 208) = 46.41$, $p < .001$, $\eta 2p = .31$, that interacted with cue-group, $F(2,208) = 3.72$, $p < .01$, $\eta 2p = .07$. We investigated the interaction by completing an ANOVA for each task-type separately with the between-subjects factor of cue-group (control, phonological cue, semantic cue). For the orthographic choice task, we found a significant main effect of cue-group, $F(2, 104) = 5.34$, $p < .01$, $\eta 2p = .09$. Following up with a series of independent samples t-tests with Bonferroni corrections applied, we found that the phonological cue group performed significantly better than both the semantic cue group, $t(69) = 2.92$, $p < .01$, $d = 0.70$, and the control group, $t(72) = 2.65$, $p = .01$, $d = 0.62$, with no other significant comparisons. For the semantic choice task, we found no significant main effect of cue-group, $F(2, 104) = 2.74$, $p = .07$, $\eta 2p = .05$ pointing to similarity in performance across groups. Similarly, for the integration task, we found no significant main effect of cue-group, $F(2, 104) = 1.24$, $p = .29$, $\eta 2p = .02$.





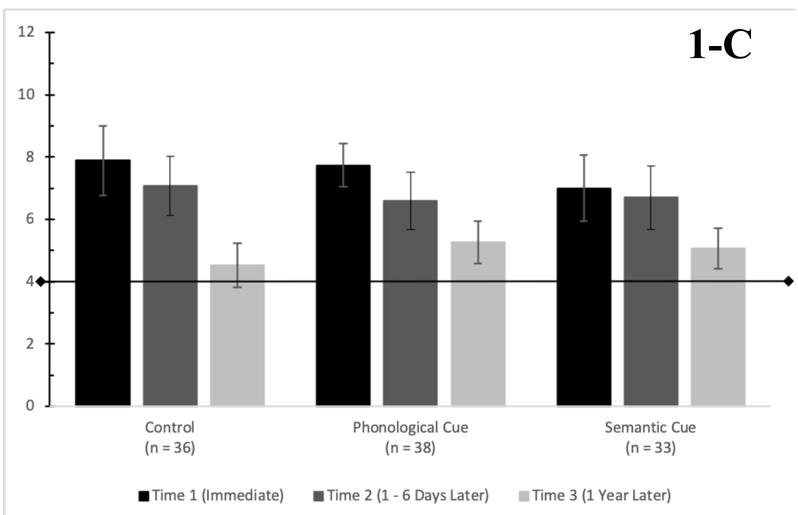


Figure 4.1.
1-A. shows the mean number of correct choices on the orthographic choice task for each cue group at each testing time. **1-B.** shows the mean number of correct choices on the semantic choice task for each cue group at each testing time. **1-C.** shows the mean number of correct choices on the orthographic-semantic integration task for each cue group at each testing time. Error bars indicate 95% CIs around the means. Solid black line indicates chance level for that task.

4.5. Discussion

We report here on a study evaluating the durability and quality of the lexical representations that children acquire during independent reading within a self-teaching context. We used the classic orthographic learning paradigm (e.g., Share, 1999), in which children in Grade 4 read a series of short stories, each containing four exposures to a pseudoword. Children then completed orthographic and semantic choice tasks, as well as integration tasks immediately after their reading, 1 to 6 days later, and then again one year later. The inclusion of an orthographic-semantic integration task, as well as a novel cueing paradigm, provides rich insight into the quality of the lexical representations retained from learning during independent reading. Perhaps most importantly, testing memory at one year after the initial learning experience extends the scope of tests of durability of learning far beyond those in prior studies, which have typically tested to one week (e.g., Cunningham et al., 2002; Nation et al., 2007), bringing it closer to children's real-world experience with infrequent words.

The first key finding was that children retain and access lexical representations of orthographic and semantic information over an extended period of time, even in the absence of additional learning experiences with the pseudowords. Specifically, elementary school-aged children performed at levels above chance on orthographic and semantic choice tasks one full year after the learning experience. This finding is consistent with previous reports of orthographic and semantic learning during self-teaching (e.g., Bowey & Muller, 2005; Conrad et al., 2019; Cunningham et al., 2002; Deacon et al., 2019; Mimeau et al., 2018; Nation et al., 2007; Ricketts et al., 2011; Share, 2004), and critically, demonstrates retention far longer than previously examined (Mimeau et al., 2018; Share, 2004). Share (2004) found retention up to 30 days for orthographic information and Mimeau et al (2018) up to 6 or 7 days for semantic information. This finding highlights the durability of both the orthographic and semantic aspects of representations established during self-teaching—these are retained one full year after only four single exposures to a pseudoword in a story context.

Performance differed on the integration task, providing insight into the quality of these retained representations. Consistent with previous reports with 8-year-old children, we found above chance performance on the integration task after the initial learning experience and 6 to 7 days later (Mimeau et al., 2018); critically though, performance fell to chance levels one year following the initial learning experience. Taking these results together, it seems that children retain orthographic and semantic information about words one year following a self-teaching experience, but this information may not be fully integrated, or not easily accessible as an integrated whole.

A second key finding gives us some insight into how children might access a high-quality representation a year after the initial learning experience; the presence of a retrieval cue appears to facilitate access to an integrated high-quality representation. On the integration task at the one-year test point, performance for both cue groups was above chance, while the control group was at chance. This pattern differs than that for the orthographic and semantic choice tasks on which all groups performed above chance and at similar levels. This finding suggests that a retrieval cue is particularly helpful when accessing an integrated high-quality representation.

Performance in these novel retrieval cue conditions also suggests the possibility that some constituents of lexical representations may have stronger connections than others; the cueing manipulation differentially impacted performance across the learning outcome measures. Receiving a phonological cue facilitated the children's retrieval of orthographic information, with no effect on recall of semantic information; in contrast, receiving a semantic cue did not facilitate retrieval of orthographic or semantic information when assessed in isolation. This finding is consistent with predictions from the lexical quality hypothesis (Perfetti & Hart, 2002) that less well integrated lexical representations facilitate access only to those components that are cued, not all components. That this cue-facilitated effect was found only for form, and not for meaning may be related to the nature of the self-teaching paradigm.

The self-teaching paradigm itself might have resulted in a stronger integration of spelling and pronunciation. According to Share's (2008) self-teaching hypothesis, the explicit and successful decoding of pseudowords provides an opportunity to set up direct connections between the pseudowords' spellings and pronunciations. The connections between the other components, although present, may not be as explicit in the short stories typical in self-teaching paradigms. Assuming this is true, learning a novel word via self-teaching with few exposures might not be sufficient for developing a stable, high-quality representation that includes strong connections between all components that facilitates access to any needed information (e.g., spelling or meaning) when activated. Our experimental manipulation provides a means to test these speculative ideas in further studies.

Yet as we consider children's experience in the real world, there might be some parallels between the phonological and semantic cues used in our study and the re-exposures children experience in the real world. For example, hearing a novel word might be helpful in retaining access to that word's representation, as might experiencing its surrounding context when one is encountering an infrequent word in a text, respectively. As such, re-exposure through oral language and reading might be important in enabling children to access a high-quality representation over a long period of time.

Finally, there was some decline in performance over time suggesting some decay of the lexical representation. This finding is consistent with widespread evidence of decline in retrieval when there is no re-exposure (e.g., Bjork & Bjork, 1992; Ebbinghaus, 1885/2013) and with results reported in the literature on fast-mapping in the oral domain that has investigated retention over one year (Gordon et al., 2016; Vlach & Sandhofer, 2012). Despite this decline in performance over time, performance at Time 3 was still above chance levels across all tasks with the exception of the integration task for the no cue group. Thus, there was long-term retention of key aspects of lexical representations one year after the learning experience, and access to the integrated, high-quality representation was facilitated by the presence of a retrieval cue. The enhanced performance on the integration task in the presence of a retrieval cue suggests that a high-quality integrated representation lasts for a year past learning, and it is access to that representation that declines over time, although this interpretation is also speculative and requires testing.

Overall, our findings have clear implications for two prominent theories of reading development: the self-teaching hypothesis (Share, 2008) and the lexical quality hypothesis (Perfetti & Hart, 2002). Our results provide novel support for the claim that it is possible to build a store of high-quality representations through self-teaching that persist over a long period of time and that facilitate word identification (Share, 2004)—key aspects of the proposed connection between orthographic learning and the transition to skilled reading in the self-teaching hypothesis. And, in relation to the lexical quality hypothesis, our results suggest that three separate constituents (phonological, orthographic, semantic) are integrated to form a quality lexical representation that can be accessed later in time, albeit with the aid of a retrieval cue. This connection between the self-teaching hypothesis (Share, 2008) and the lexical quality hypothesis (Perfetti & Hart, 2002) is an important one. Our findings demonstrate that the self-teaching context is sufficient for creating durable, high-quality lexical representations, the kind defined by the lexical quality hypothesis. Of equal importance, these lexical representations are accessible at one-year post learning, despite having few initial exposures and no exposures within the one-year follow up period. This points to independent reading of connected text as a process through which children encode and store quality lexical representations that are retained over the long-term, with just a few exposures leading to durable representations that are of reasonably high-quality. As predicted by both theories, the acquisition of such representations is likely to support reading comprehension by building a large lexicon of quality lexical representations, reducing reliance on effortful decoding and lexical access processes.

Our results also point to a critical limitation to the strength of children's learning capacity. This is particularly evident in the decline of learning, with children less able to recall both orthographic and semantic learning one year after their reading experience than after 1 – 6 days. It seems then that lexical representations may not be stable over time in contexts with few exposures and no reinforcement of learning. Given the central role a stable lexicon, or store of representations, plays in reading development (Perfetti & Hart, 2002; Share, 1999), it will be important to explore the nature of decline, as well as the potential role of re-exposure in changing that trajectory.

The current study also points to important questions for future studies. As an initial foray into the long-term durability of high-quality lexical representations established during self-teaching, we think that replication is important. Our study also employed novel methods to assess the stability of representation quality following self-teaching by focusing on integration, through the use of a matching task (Mimeau et al., 2018) as well as of retrieval cues. These methods offer insight into the durability and quality of lexical representations established through self-teaching, and yet they could also benefit from detailed investigation. For example, task order was designed to minimize cross-task influences, yet we acknowledge that possibility. In addition, incorporating a task measuring the children's ability to retain and access phonological information about the novel pseudowords (i.e., the correct pronunciations) would provide a fuller picture of all three constituents of a quality lexical representation. Answering these questions may clarify the nature of the lexical representation that is retained over time.

In summary, the current study revealed that children are able to recall both orthographic and semantic information one-year after an initial self-teaching experience involving only four exposures. Furthermore, we have shown that, with minimal additional support (e.g., a brief memory cue), children are able to access integrated high-quality lexical representations that integrate both orthographic and semantic information. In keeping with this idea, there appears to be a particularly strong connection between the phonological and orthographic constituents of a lexical representations. We think this study offers key steps towards understanding the durable and high-quality representations that can result from the learning that children can do through their independent reading.

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Chapter 5. General Discussion

5.1. Review of Dissertation Goals and Findings

The overarching goal of this dissertation is to better understand the self-teaching process to clarify its potential role in the transition from beginning reading to skilled reading. This goal was achieved through four research objectives, each motivated by one of the four core predictions of the self-teaching hypothesis (Share 1995; 2008). In this section, I review each in turn, capturing what was learned and how these ideas connect to both the self-teaching hypothesis and extend existing empirical studies.

5.1.1. Are beginner readers capable of self-teaching? This first objective was motivated by Share's (2008) prediction that beginner readers engage in basic orthographic learning through self-teaching, even when they possess limited decoding skills. I examined this objective in Study 1 by evaluating whether English-speaking children in Grades 1 and 2 are capable of self-teaching. The results of this first study suggested that beginner readers can learn the spelling patterns of novel words they encounter during independent reading, with some grade-based differences in their capacity to do so. Children in Grade 1 (around 6 years of age) demonstrated evidence of orthographic learning, through above chance choice of correct spellings for target words in the short-term (i.e., immediately after learning). However, their performance was no longer above chance when assessed a few days later, suggesting that learning was not retained over time. In contrast, children in Grade 2 (around 7 years of age) showed evidence of orthographic learning both in the short term immediately after reading and after a few days, showing that they retained the learning for longer than children in Grade 1. These findings draw a more fine-grained picture of learning than in prior studies (e.g., Deacon et al., 2019; Cunningham et al., 2002; Share; 2004;

Cunningham, 2006), demonstrating clear shifts in effects over grade. Overall, our results support Share's (2008) suggestion that beginning reading is beginning self-teaching, although they also suggest that beginning self-teaching may, indeed, be rudimentary; at the very early stages of self-teaching, any resulting orthographic learning appears to be less durable than in older children.

5.1.2. Is phonological decoding required for self-teaching to occur? This second objective was motivated by Share's (1995; 2008) prediction that the primary mechanism for self-teaching is phonological decoding, which suggests that accurate decoding is required for orthographic learning to occur. As such, I evaluated whether accurate phonological decoding is indeed required for self-teaching to occur. I examined this question in further analyses of Study 1 with English-speaking children in Grades 1 and 2. My results indicated that, across both Grades 1 and 2, children showed evidence of orthographic learning both when they had and even when they had not decoded the novel words accurately a single time while reading the stories aloud. These findings suggest that accurate phonological decoding is not required for orthographic learning to occur in young readers, consistent with prior work in both young children (i.e., Grades 1 and 2; Deacon et al., 2019) and older children (e.g., Grades 3 and 5; Tucker et al., 2016).

I built on these findings to examine whether young readers gained any benefit from accurate phonological decoding attempts. I found little evidence of improved learning when children had decoded the novel words accurately at least once during story reading over when they had not decoded them accurately at all. These findings are surprising given the prediction that phonological decoding is the mechanism of self-teaching (Share, 1995) and prior research with older children showing a facilitatory effect for accurate decoding experiences using similar methods (e.g., Deacon et al., 2019; Tucker et al., 2016). However, our findings here are in line with those of Chen et al. (2018) who found that children in Grade 1 were not more likely to answer corresponding items on an orthographic choice task correctly when they had decoded a word correctly in comparison to when they had not. Taking these findings together, it seems that the benefits of decoding on learning might be more consistent in older than in younger readers. This, of course, raises the question of why beginners may not be impacted by decoding success to the same extent as older readers. It is possible that beginner readers engage in more effortful decoding, making it difficult to focus on, and encode, the spelling patterns in a way that allows them to gain any benefit from successful decoding. It could also be that older children are more strongly impacted by unsuccessful decoding attempts, with these resulting in encoding the inaccurate pronunciation as part of the orthographic representation, which then interferes with later recall. While it is not clear exactly why accurate phonological decoding has clearer impacts on older than younger readers' self-teaching, the discovery of this difference adds nuance to how our understanding of the role of decoding in self-teaching.

5.1.3. Does self-teaching occur solely on an item-specific basis or does learning transfer beyond specific items? This third objective was motivated by Share's (1999; 2008) prediction that self-teaching results in item-by-item (i.e., word-specific) orthographic learning, with readers forming, and refining, a word-specific orthographic representation each time they encounter the same word. Share further suggested that the quality of any one orthographic representation is directly related to the number of times a child encounters, and successfully decodes, that specific word. My objective here was to evaluate whether self-teaching truly occurs on an item-specific basis or whether children will transfer their learning of one word to their future encounters with related words. I evaluated different forms of learning transfer (e.g., learning-to-processing transfer and learning-to-learning transfer) in Study 1 with children in Grades 1 and 2 and in Study 2 with children in Grades 3 through 5.

The results of Study 1 indicated that children in Grades 1 and 2 transferred their learning of a simple word (e.g., *feap*) to facilitate their processing of novel related words (e.g., *feaper, feaple*). Indeed, they were above chance in choosing the correct spelling for these novel related words, despite never having seen those specific words before, only the shorter forms (e.g., *feap*). Further, children chose these correct spellings to a similar extent for novel words that were morphologically (e.g., *feaper*) and orthographically related (e.g., *feaple*), suggesting that they likely transferred their learning via an orthographic mechanism or process. Interestingly, as with the learning of the initial forms (e.g., *feap*), I saw some differences in learning transfer between the two grades. Specifically, children in Grade 1 only showed evidence of learning transfer in the short term (i.e., immediately after learning) while children in Grade 2 showed evidence of learning transfer in both the immediate and longer term (i.e., when reassessed a few days later). In the absence of prior studies on this question of learning transfer in beginning readers, results cannot be contrasted with those of other studies. That said, these results are broadly consistent with prior research suggesting learning transfers to the processing of related words in older children (e.g., Pacton et al., 2013; Pacton et al., 2018; Tucker et al, 2016), with the caveat that such learning transfer appears to occur in the short term for our youngest readers in Grade 1. Overall, findings in Study 1 suggest that self-teaching does not occur on an item-specific basis in beginner readers in Grades 1 and 2 and that, by Grade 2, children appear to reliably engage in self-teaching with the ability to transfer the resulting learning to processing of related words over short delays.

I took this objective a step further in Study 2, assessing whether older children transfer their learning of a simple word (e.g., *lurg*) to their subsequent learning of related complex words (e.g., *relurg*), as well as the potential impact of accumulated learning on the processing of novel related words (e.g., *mislurg*, *fislurg*). In terms of subsequent learning, my results suggested that children in Grades 3 through 5 engaged in self-teaching of simple words encountered in short stories and, importantly, then transferred this to facilitate learning of related complex words that were subsequently encountered in new short stories. The impact of prior learning was particularly strong for children in Grade 3 as they reliably learn complex words encountered within stories (e.g., *relurg*) only if they had first learned a related simple word (e.g., *lurg*). In contrast, children in Grades 4 and 5 did better when they learned a simple related word first, but they were still able to reliably learn the complex words when they did not. I also found that the accumulated learning of simple words and complex words has a downstream effect on the processing of additional related words that have not been learned. Specifically, when upper elementary school aged children learn both a simple (e.g., *lurg*) and a complex word (e.g., *relurg*) during different story reading experiences, they are then better at the processing (i.e., recognizing the spelling pattern) of related complex words that they did not encounter in any of the stories (e.g., *mislurg, fislurg*). Again, the impact of accumulated learning was stronger for children in Grade 3 as they were able to reliably choose the correct spelling patterns for these novel words only when they were related to both the simple and complex words previously learned in the stories. Again, results differed for children in Grades 4 and 5 as they were able to choose the correct spelling more often when they learned both the simple and complex related words first, but they were still able to reliably do so when they had only learned the complex words previously. It is challenging to contrast these findings to prior research given that, to our knowledge, Study 2 is the first study to directly test within the self-teaching context the potential of learning-to-learning transfer, as well as the impact of accumulated learning experiences; however, these results are broadly consistent with prior research suggesting that learning transfer occurs (e.g., Pacton et al., 2013; Pacton et al., 2018; Tucker et al, 2016). And so, in summary, I found that upper elementary school aged children transferred their learning of a simple word (e.g., *lurg*) to subsequent learning of related complex words (e.g., *relurg*), with evidence of impact of accumulated learning on the processing of novel related words (e.g., *mislurg*, *fislurg*).

Taken together, this evidence suggests that self-teaching does not occur on a strictly item-specific basis. Certainly, this emerged in Study 1 with our findings indicating that even beginner readers can, to some extent, transfer their learning of a simple word to help them process related complex words. Moreover, the findings of Study 2 indicate that self-teaching is directly impacted by prior learning experiences and show how self-teaching processes, through the impact of accumulated self-teaching experiences, may contribute to the rapid development of vocabulary during the elementary school period (e.g., Anglin, 1993; Nagy & Anderson, 1984). Specifically, I have shown that children's learning of simple word (e.g., *lurg*) during an early independent reading experience can help them to read and learn a related complex word (e.g., *relurg*) when they encounter it in text, which, in turn, helps them process other complex words (e.g., *mislurg, fislurg*) before ever directly learning them. This can all occur through independent reading experiences, demonstrating the power of children's own reading and learning.

5.1.4. Does self-teaching result in durable, high-quality orthographic representations? This fourth objective was motivated by the need to test the assumption that self-teaching is a means through which children acquire the kinds of orthographic representations they need to enable reading development. This idea is inherent to the suggestion that the self-teaching hypothesis (Share, 2008) can explain the transition from beginner to skilled reader. Indeed, for self-teaching to play a key role in this transition, it would have to result in durable high-quality orthographic representations that can be reliably and quickly recalled when needed across long periods of time.

To address the question of durability, I evaluated whether self-teaching leads to the development of long-lasting quality orthographic representations that were retained across a whole year. Specifically, in Study 3 children in Grade 4 completed a self-teaching task. At that point, they completed tasks assessing their recognition of the spelling and meaning of the words, as well as their ability to integrate this information through a task on which they matched each word with the correct definition. The children completed these tasks again in Grade 5 (a year later) to assess whether they retained the information over a one-year period. Our results suggest that upper elementary school aged children retain, and access, both orthographic (i.e., spelling) and semantic (i.e., meaning) information over a full year, despite having had just four exposures to each new word and without additional exposures within the delay period. This extends prior studies in the literature demonstrating retention in Grade 3 Hebrew-speaking children for as long as 30 days (Share, 2004), further highlighting the durability of self-teaching.

To address the question of the quality of the orthographic representation being accessed after this longer duration, I introduced other tasks and design. According to the lexical-quality hypothesis (Perfetti & Hart, 2002), a high-quality orthographic representation is one that integrates three forms of information: phonological (i.e., sound), semantic (i.e., meaning), and orthographic (i.e., spelling). I included a measure designed to get at this integration. Results showed that after the one-year delay the children had more difficulty with an integration task that required them to access and use both the orthographic and semantic information about the words simultaneously. This in contrast to the findings that children were still able to access orthographic and semantic information separately after the one-year delay. As such, it appeared that their orthographic representation may not have been of the highest quality after a year delay.

I then explored what may support recall of a high-quality orthographic representation over a long period of time. I did so by adding a manipulation of memory cue groups. Results showed that children who received memory cues, regardless of whether these were phonological (i.e., cues regarding the sounds of the words) or semantic (i.e., cues regarding the meaning of the words), were able to complete the integration task at levels above chance. This suggests that a high-quality representation, with integrated orthographic and semantic information, formed immediately after learning was likely still in the children's lexicon; however, children appear to need a little support to access all constituents of it after a longer period of time with no additional exposures to the word.

Together, these results provide novel support for Share's (2004) suggestion that it is possible to build a store of high-quality representations through self-teaching that persist over a long period of time with the potential to facilitate word identification. Further, our results suggest that, within the self-teaching context, it is possible for three dimensions of a lexical representation (phonological, orthographic, semantic) to be integrated to form a high-quality representation that can be accessed later in time, albeit with the aid of a retrieval cue. Both conclusions are key to the proposed role of self-teaching in the transition to skilled reading, as proposed by Share (2004; 2008). For this to be the case, self-teaching needs to be a process through which children can form long-lasting orthographic representations that are of high enough quality to access efficiently when needed; I provide novel evidence that this is the case.

5.2. Theoretical Implications and Proposed Framework

My findings across these three studies provide support for some aspects of the key predictions of the self-teaching hypothesis (Share, 2008), while challenging others. Specifically, my results support the predictions that beginning readers are capable of some degree of self-teaching, that accurate phonological decoding plays a role in self-teaching, and the fact that self-teaching is a learning process capable of forming durable orthographic representations that support reading development over time. In contrast, my findings challenge self-teaching as a life-long process that is simply less accurate in beginner readers, as requiring accurate phonological decoding, and as occurring solely on an item-specific basis. In the context of these challenges, I put forward three key principles that I believe more accurately describe the self-teaching process in both beginner and more skilled readers.

5.2.1. Principle 1: Phonological decoding is relevant but not required.

While the evidence presented here converges with Share's (1995) prediction that phonological decoding is involved in self-teaching, my findings specify this involvement as relevant to the strength of learning that occurs but not required for learning to occur. As such, these findings suggest moving away from considering phonological decoding as the "sine qua non" (Share, 1995) of self-teaching. Instead, I suggest that phonological decoding is relevant but not required for orthographic learning to occur.

Let's step back to consider what this might mean. By describing accurate phonological decoding as relevant, I agree with original suggestions (Share, 1995; 2008) that it has a role to play in the self-teaching process. This is evident in prior research showing that phonological decoding appears to facilitate stronger orthographic learning in older children (e.g., Tucker et al., 2016). However, here I found little evidence that accurate decoding led to improved self-teaching in beginning readers. Notably, even in prior research with older readers (e.g., Tucker et al., 2016), the detected facilitation effects do not appear to be as large as one would anticipate based on the predictions of the self-teaching hypothesis giving it a central role in how orthographic learning occurs. As such, phonological decoding is clearly not a silver bullet that determines whether self-teaching occurs. This leads to the second part of this principle, according to which accurate phonological decoding is not required for self-teaching to occur. The results reported in this dissertation demonstrated that children show evidence of orthographic learning for novel words that they did not accurately decode during reading. Taking these ideas together, I put forward that phonological decoding is relevant but not required for orthographic learning to occur.

I think that these findings point to the need to examine other processes or components of self-teaching that lead to orthographic learning beyond phonological decoding. For example, it may be that the secondary orthographic component proposed by Share (2008) plays more of a role than initially thought. It is also possible that other skills and processes may account for some portion of the orthographic learning that occurs via self-teaching. This possibility aligns with key tenets of the print learning theoretical framework. In this new conceptualisation, Conrad and Deacon (2023) discuss orthographic learning as a component of print learning, noting that phonological decoding and statistical learning are two mechanisms through which children learn about print. Clearly there are repeated calls for identifying the mechanisms that contribute to orthographic learning, with the question of exactly what contributes to variability in orthographic learning having been called the “black box” of reading research (Share, 2008; Nation & Castles, 2017), and I amplify those calls here, with evidence that we need to move beyond decoding in this line of inquiry.

In moving forward in understanding phonological decoding as relevant but not required for self-teaching to occur and the mechanisms by which this is the case, two key findings need to be explored in further detail. Specifically, we need to better understand why accurate decoding appears to have a relatively small impact on the self-teaching process, given the apparent importance of phonological decoding to many theories addressing mechanisms of orthographic learning (e.g., Conrad & Deacon, 2023; Ehri, 2005; 2014; Perfetti & Hart, 2002; Share, 1995). Relatedly, we need to further explore the value of unsuccessful decoding attempts and whether there is a threshold of partial decoding that is required for self-teaching to occur, as well as taking a more nuanced look at the impact of mixed decoding experiences (i.e., when children decode the same word accurately for some exposures and inaccurately for others). Further, given this smaller than expected impact, we also need to examine how children engage in self-teaching during independent reading if they are decoding novel words incorrectly, focusing on understanding what other skills contribute to their ability to form an accurate orthographic representation (e.g., determining what the orthographic component of self-teaching entails). An important first step to answering these questions is to consider the role that phonological decoding plays in self-teaching in a more nuanced way, focusing on understanding exactly when and how decoding, regardless of accuracy, affects the self-teaching process.

I suspect that phonological decoding likely impacts orthographic learning at several points in the self-teaching process. Specifically, I propose that there are two different ways that decoding may be contributing to self-teaching, each of which would be differentially impacted by decoding success. One such possibility, as proposed by Share (1995), is that phonological decoding works because it draws a reader's attention to the word in a letter-by-letter manner. In this case, inaccurate decoding may not impact self-teaching to a significant degree because the decoding process itself would likely help cement the spelling pattern even in cases of inaccurate decoding. Another possibility is that accurate phonological decoding helps to integrate phonological information into the orthographic representation, which is an important part of encoding, and accessing, high-quality orthographic representations in theories such as the lexical quality hypothesis (Perfetti & Hart, 2002). Of course, if it is the encoding and integration of the phonological part of the representation that drives the importance of phonological decoding, then more negative impacts related to inaccurate phonological decoding attempts would be expected. For example, if a reader encodes inaccurate phonological information as part of the orthographic representation it may result in difficulties with efficiently accessing the correct orthographic representation when needed and/or difficulties pronouncing the word on future attempts. Notably, it could also be that phonological decoding plays a role in self-teaching through both of these pathways. Indeed, I would suspect that this is the case, with phonological decoding contributing to both the original processing of a novel word to provide an opportunity to form an orthographic representation and providing important information for the formation of a high-quality orthographic representation. Taken together, while it is clear that phonological decoding is just one piece of the self-teaching puzzle, we certainly still need to figure out what the other pieces are and how they all fit together to lead to these important learning experiences.

5.2.2. Principle 2: Self-teaching is a powerful process with an important role to play in reading development. I put this principle forward based on the clear evidence from Studies 1 and 2 that, contrary to the prediction that self-teaching occurs on an item-specific basis, children do indeed transfer their learning to both their processing and learning of related words. Furthermore, Study 3 provides clear evidence that, for older children with reading experience (e.g., those in later elementary grades), self-teaching results in high quality long-lasting orthographic representations. Together, these findings suggest that self-teaching is a powerful learning process with strong potential to play a key role in the transition to skilled reading. Specifically, I think that self-teaching is a key part of the explanation as to how vocabulary develops at a rapid pace in elementary school (e.g., Anglin, 1993; Nagy & Herman, 1987), a pace that is far more rapid than the opportunities offered solely through explicit teaching. Importantly, our evidence indicates that children's independent reading experiences may contribute to this rapid development of children's lexicons, which has been suggested as an important aspect of reading development more generally (see Share, 2008; Perfetti & Hart, 2002; Ehri, 2005; 2014; Hoover & Gough; 1990; Gough & Tunmer, 1986). As such, I suggest that self-teaching has an essential, and powerful, role to play in how vocabulary can develop so rapidly. Here I provide a more detailed review of two important features of self-teaching—learning transfer and learning durability—that likely contribute to its power as a long-term learning process that contributes to the transition to skilled reading.

5.2.2.1. Feature 1: Learning transfer, and the impact accumulated learning experiences, means that self-teaching has far-reaching impacts. Results of Studies 1 and 2 in this dissertation show that learning one word during independent reading does not just contribute to the ability to read that single word when later encountered, but rather learning of that one word also transfers to support later learning and processing of several related words as well. The quote from Nagy and Anderson (1984) helps to better understand the importance of this; they note that "…for every word a child learns, we estimate that there are one to three additional related words that should also be understandable to the child." (p. 311) I suggest that self-teaching and subsequent learning transfer are key to this phenomenon, empowering its ability to explain how a child can learn so many words so rapidly. The fact that children can gain so much from independent reading of a single novel word may also be related to how children who have strong reading skills become even stronger readers in comparison to children who have more difficulty with reading (Stanovich, 2009; Cain & Oakhill, 2011). Specifically, children who are stronger readers are likely better able to capitalize on these self-teaching experiences, which helps to build fuller and more reliable orthographic representations that then help facilitate their reading of those words and related ones. In turn, these better orthographic representations likely lead to better reading and orthographic learning in the future. In fact, this is directly related the second aspect of self-teaching that contributes to its power as a learning process: the durability and quality of the orthographic representations that children form.

5.2.2.2. Feature 2: The durability of the high-quality orthographic representations formed means self-teaching has long-lasting impacts. Results of the studies here also show that children form durable, high-quality orthographic representations through self-teaching. This is important because this focuses on the fact that children need just few exposures to a new word in text before they are able to form a high-quality orthographic representation that is durable for a full year. Knowing that these self-teaching experiences can result in such durable orthographic representations is an essential addition to understanding how self-teaching can support reading development over time. Indeed, encountering a novel complex word in text just a couple of times before encountering it again after a year of learning other concepts and words likely approximates real-world reading experiences for children in elementary school, especially when considering irregular words.

Taken together, these two aspects of self-teaching form a powerful process that can help to explain the rapid vocabulary development during elementary school, which, in turn, supports the transition to skilled reading over time. Coupled with the ability to transfer learning-to-learning and benefit from accumulated learning experiences, the long-lasting and high-quality nature of the orthographic representations formed with few exposures is key to this power. In fact, aspects of two theories can be combined in a novel way: the self-teaching hypothesis (Share, 2008) and the lexical quality hypothesis (Perfetti & Hart, 2002). Similar to the lexical quality hypothesis, I propose that children need long-lasting high quality orthographic representations to support their reading development, defined as representations for which three types of information about the word (i.e., its sound, meaning, spelling) are well-integrated. Importantly, I suggest that self-teaching is a process through which these orthographic representations can be encoded for later recall, even after just a few exposures and across long periods of time. This combination of orthographic quality and durability is essential to its role in supporting future reading experiences, as well as reading development more generally. Bringing these two aspects of two important theories of reading development together provides a fuller understanding of exactly how children can rapidly build their vocabulary such that they can transition into being a more skilled, fluent reader of connected text.

Let's explore what this looks like with an example. If a child comes across one word, such as *magic*, in a story, this principle implies that children are able to rapidly form an orthographic representation with just a few encounters. After forming the orthographic representation for *magic*, they can then use that orthographic representation to help them learn a related word, such as *magical*, even more effectively. Further, children's learning is likely to then extend to other words, with these accumulated learning experiences with both *magic* and *magical* also helping them to efficiently process additional related words, such as *magically* and *magician*, when seen the first time. Based on the results the results presented, I propose the same process would likely occur when there are no morphological connections between the words: first learning the word *car*, then using it to help learn a similarly spelled word such as *card* and, extending further to the processing of additional words such as *carpet*, and *caramel*. Importantly, it appears that when children form these orthographic representations with just a few encounters, the representations last for long periods of time with no further encounters and just minor support needed to access integrated orthographic and semantic information. Practically speaking, this means that when a child first learns the words *magic* or *car* via self-teaching, it may still impact their reading and learning of many related words even a year later. Self-teaching appears to be an efficient and powerful mechanism for learning many words within a short period of time.

Moving forward, there are still many questions that need answering to more fully understand the principle that self-teaching is a powerful process with the potential to support reading development. First, it would be important to determine the degree of learning that can transfer and how it can be used beyond identifying spelling patterns. For example, do children transfer their semantic learning, or their learning of the meaning of a word, to help understand related words when they first encounter them in text? Given my findings of both transfer and long-term retention of semantic and orthographic information, I predict that they would be able to do so to some degree. Practically speaking, I suggest that if a child learns a base word (e.g., *magic*), this could help them not just to identify the spelling of a related word (e.g., *magical*) but also to make an informed attempt at understanding its meaning. Further, it will also be important to investigate just how powerful self-teaching is across longer periods of time. For example, while it seems that children can retain orthographic representations for a full year with just a few exposures, it would be interesting to test if learning transfer also results on representations retained for such a long time. Given the results of the current studies, I would predict that transfer could still be possible, although to a lesser extent, in older children. Practically speaking, this would tell us more about just how long children could access the first representation of a simple word (e.g.*, magic*) to help them with learning and/or processing more complex related words (e.g.*, magical, magician*) that are likely seen in subsequent school years or later reading materials. Overall, taking these next steps towards understanding the potential power self-teaching has regarding its far-reaching and long-lasting impacts is essential to the goal of understanding its potential relationship with reading development and knowing how best to support that process at key developmental stages.

5.2.3. Principle 3: Self-teaching is a developmental process. I agree with Share (2008) that self-teaching begins early, with even beginner readers showing evidence of some level of orthographic learning; critically, I suggest that this self-teaching looks different in early versus older readers in all aspects tested: the role of decoding, the quality and durability of the learning that occurs, the presence of learning-to-learning transfer, and the impact of accumulated learning. As such, I believe that self-teaching should be explicitly described as a developmental process, with research attention devoted to discovering how it changes across developmental periods.

First, younger readers tend to retain orthographic learning acquired via self-teaching differently than older readers do in terms of the quality and durability of orthographic learning. Broadly, our results suggest that younger children likely form orthographic representations that are lower in quality and/or less durable than older children. For example, children in Grade 1, unlike those in Grade 2, were not able to retain their orthographic learning of simple words across time. As another example, children in Grade 3 struggled to learn novel complex words in text if they had not learned the base word first while children in in Grades 4 and 5 were able to do so. These differences in degree of learning across ages is in line with prior research that provided more inconsistent evidence of orthographic learning in beginner readers (e.g., Deacon et al., 2019; Chen et al., 2018; Cunningham et al., 2002; Share; 2004; Cunningham, 2006) than for more experienced readers (Nation et al., 2007; Share, 1999; Tucker et al., 2016; Wang et al., 2011). Overall, this would suggest that, while beginning reading can result in some degree of self-teaching, it may not be the same quality or durability as the self-teaching in older readers. Specifically, there appear to be developmental shifts throughout the elementary school grades regarding the extent of learning that is possible, the durability of that learning, and the types of words that can be learned efficiently through self-teaching (e.g., simple versus more complex words). I propose that it is important to consider, and investigate, the nature of this developmental shift across elementary grades to specify exactly the kind of self-teaching possible at different stages.

Second, the role of decoding in orthographic learning appears to change over time. Based on our findings, in combination with prior research (e.g., Deacon et al., 2019; Chen et al., 2018; Tucker et al., 2016), I suggest that there is a shift in the extent to which the accuracy of a child's phonological decoding impacts their ability to form orthographic representations during self-teaching. Specifically, the success of the decoding attempt(s) appears to be more important for older readers than for beginning readers. There was no statistically significant impact of accurate decoding for children in Grades 1 and 2 in the studies reported in this dissertation, while other research has found clear impacts of successful decoding in older children (i.e., Grades 3 and 5; Tucker et al., 2016). Combined with prior evidence on decoding being less consistent in younger grades (Deacon et al., 2019; Chen et al., 2018), I believe that accurate decoding is increasingly important for self-teaching as children get older and gain more reading experience. Clearly, more research is needed to better understand what underlies this shift; for instance, it would be useful to know why accurate decoding attempts do not appear to impact younger readers as much as older readers. As noted above when talking about the role of decoding more generally, it is possible that this is related to the effortful nature of decoding in young readers interfering with any potential benefit that accurate decoding provides.

Another thing that will be important to explore further is where in the process the phonological decoding is, or is not, exerting its effects. This could be related to both its impacts on the initial learning process (i.e., by drawing attention to the letters in order) and its contributions to encoding phonological information as part of the orthographic representations will impact the efficiency of accessing the orthographic representation when needed. Notably, the importance of each of these mechanisms may also change throughout development based on reading skill and its impacts on the formation of quality representations and the interference that can occur when less-skilled readers have incomplete representations (e.g., Perfetti & Hart, 2002). Despite these open questions, it is clearly important to consider developmental shifts in the role of phonological decoding in self-teaching as it suggests important considerations regarding when, and how, it is focused on as a learning tool.

Third, the extent to which learning transfer is possible also appears to change with age, with younger readers showing less consistent learning transfer than older readers. Considering the evidence regarding learning-to-learning transfer, as well as the impact of accumulated learning experiences, there appears to be more benefit more from learning a base word before learning a complex word for children in Grade 3 than for those in Grades 4 and 5. Similarly, looking at the simpler learning-to-processing transfer in our youngest readers, children in both Grades 1 and 2 were able to transfer their learning in the short term while only children in Grade 2 were able to do so after some delay. Specifically, the results from children in Grade 2 were more similar to those previously seen in older children (Tucker et al., 2016) than were the results in Grade 1. Taken together, these results point to a developmental shift in the extent to which children can capitalize on their learning of one word (e.g., *magic*) to help with learning another (e.g., *magical*), as well as to whether their learning will help with processing future items they have not yet learned (e.g., *magically, magician*). Specifically, I put forward that beginning readers are less able to transfer their learning overall; however, there may be a key developmental period around Grade 3 in which it becomes more beneficial to learn a base word before learning a related complex word and after which it becomes less important again as children become more skilled readers. Of course, additional research can explore this shift, including what is driving increased learning transfer in older readers. For example, less transfer might emerge in beginning readers because they are not able to form a long-lasting orthographic representation of high enough quality to support learning transfer. Alternatively, it may be that, regardless of the quality of the orthographic representation, older children are better able to transfer learning from one word to another due to an increase in related skills (e.g., increased skills with analogy-based reasoning). Shifts in reading skill and/or experience could also explain findings that children in Grade 3 benefit more from learning a base word first than do older children. For example, children in Grade 3 may need the additional lexical support that comes from knowing a related base word to help them read complex words because of their limited experience with complex words; similar effects might emerge for older readers should the words increase in complexity. Although this process needs to be detailed through empirical study, developmental change will be key in understanding transfer of learning between items and its impacts on the self-teaching process.

Taken together, I suggest that there are developmental changes in all aspects of self-teaching that tested, with two transitions that emerged as particularly distinct in the studies reported on here. These would be between Grades 1 and 2 for both decoding and durability of learning and between Grades 3 and 4 for the impacts of learning transfer and accumulated learning experiences. The idea that orthographic learning is a developmental process is not necessarily a new one. For example, Conrad and Deacon (2023) proposed that print learning (including orthographic learning) is a developmental process that begins even before independent reading or decoding and continues throughout reading development as children learn about increasingly complex aspects of print. Here, however, I apply this concept to self-teaching specifically and propose that this orthographic learning process itself changes across development in relation to changing reading skill and text demands. As such, it will be important explore these developmental changes, including fleshing these out both earlier and later in development. For example, this could include investigating orthographic learning in earlier readers (e.g., preschool aged children). At the other end of the developmental process, adolescents and adults come across new words while reading, such as a high school student reading a new book or play for the first time, a university student reading a textbook for class, or an adult reading newspaper article about a new topic. It is likely that adolescents and adults engage in self-teaching in these instances, but it is not clear what that looks like or what factors may impact the orthographic learning at these ages (e.g., context, reading level, reading and/or language history). Investigating aspects of self-teaching, including the role of accuracy decoding, the nature of learning transfer, and the durability and quality of orthographic representations formed, across the lifespan in this way will provide more information about the developmental nature of the process.

5.3. Educational Implications

My findings have several educational implications, providing some insight into ways we may be able to make the most of children's independent reading experiences and reinforce self-teaching as a learning process. Across our four research objectives our findings consistently support the current recommendations calling for having children engage in independent reading as one way to improve reading skills (see McQuillan, 2019). This key recommendation can be further specified with three considerations that help better understand exactly when and how to capitalize on independent reading to improve orthographic learning, which provide ideas for future research that will help identify the specific educational practices and/or interventions that may be most useful to implement.

First, my results show the potential impact of providing independent reading experiences on long-term learning of new words. I provide evidence that even few exposures to a word during independent reading can result in long-term learning that may impact reading experiences as much as a year later. As such, this supports the recommendation that independent reading experiences are a helpful way to improve reading skills in the long-term (McQuillan, 2019). Given this, it will be important to encourage independent reading for children across ages, with teaching focusing on the skills that will help children become more engaged independent readers. For example, it may be that, by increasing basic skills in reading, children will be more likely to engage in independent reading activities, either for school activities or for enjoyment. Indeed, evidence has shown that there are relationships between reading confidence and word reading skills (e.g., McGeown, Johnston, Walker, Howatson, Stockbyrn, & Dufton, 2015), as well as child-reported reading comprehension and fluency difficulties acting as a barrier to reading more often (e.g., Merga, 2017). As such, instruction in early skill such as phonological decoding may be one way that we can encourage continued independent reading. Another example is creating an environment that encourages interest in reading even earlier, such as providing early access to books, shared reading, and teaching important aspects of print in books early in development, all of which also impacts later reading outcomes (e.g., Conrad & Deacon, 2023). Taken together, these recommendations can set the stage for children to engage in independent reading more often, providing opportunities for self-teaching to occur.

Moving forward with this recommendation to encourage independent reading experiences, it is also important to consider how we can tailor the experiences across development based on when and how children can make the most of them, at least in terms of the ability to engage in orthographic learning. For example, evidence of significant orthographic learning is less consistent for younger readers, (e.g., those in Grade 1) and, as such, it may be less effective to rely heavily on independent reading as a way to increase vocabulary in these beginning readers. That is not to say it is not helpful, just that it may be less consistent as a means for building up a store of durable, high-quality orthographic representations. As such, it will likely be important to further investigate how we can then encourage orthographic learning in these young children. For example, testing the extent of orthographic learning in shared book reading (e.g., Shakory et al., 2021) as compared to independent reading is one important avenue to consider as we flesh out when independent reading can result in durable orthographic representations that transfer to the processing of new words. As another example, our results also support the fact that it is important to consider features of the text (e.g., word complexity, text complexity) when suggesting the books children use for independent reading (e.g., Kearns & Hiebert, 2022; Amendum et al., 2018). For example, children in Grade 3 will benefit more from first having access to simpler texts that are more likely to have new base words prior to reading more complex texts with a higher number of complex words included. This gradual increasing of complexity may be best for children in this grade to capitalize on learning transfer as much as possible. This is, again, something we see reflected in general education approaches such as emphasis on choosing the right reading level of text, as well as the difference in how much we expect younger versus older readers to engage in independent reading and how much they need support/scaffolding to do so (e.g., National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010).

Second, my results show potential strategies for helping to facilitate recall of orthographic representations during future reading experiences, which may support orthographic learning as well as general reading by helping to more efficiently identify, and decode, less familiar words. Specifically, providing, or directing the children to, some form of cue may be helpful for accessing a full representation that integrates both spelling and meaning information. One way to do this could be to show them how using context cues helps with accessing a complete representation when they recognize a word but need some help in identifying it fully. Practically speaking, if a child has previously learned the word *magic* during independent reading and then comes across it again while reading at a later date, it may help to encourage them to look for cues to the word's meaning or sound to help them remember more information about the word as a way to facilitate learning and learning transfer. This recommendation is in line with existing research regarding the use of context cues for supporting partial word decoding (see Share 1995 for a discussion on this, as well as Tunmer, 1989). It is also consistent with a recommendation found in the common core state standards for reading education in the United States of America (USA) that suggests children in elementary school grades "Use context to confirm or self-correct word recognition and understanding, rereading as necessary" (e.g., standard

CCSS.ELA-LITERACY.RF.3.4.C; National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010).

Third, my results provide some initial suggestions for how we can support children in making full use of their orthographic learning that occurred during earlier independent reading experiences. Specifically, I have shown the impact of independent reading experiences on future encounters with related words via the learning transfer that occurs in children across elementary grades to varying degrees. As such, to capitalize on the presence of this learning transfer, it may help to encourage children to identify, and make use of, orthographic similarities between new words they encounter and ones they already know. Again, this is broadly consistent with common core standards for both reading and writing education in the USA, although I would suggest some changes that would be specific to the self-teaching context. For example, one of the English language arts standard suggests children should be able to "use spelling patterns and generalizations (e.g., word families, position-based spellings, syllable patterns, ending rules, meaningful word parts) in writing words" (standard CCSS.ELA-LITERACY.L.3.2.F; National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). Additional core standards address the use of morphological information to support word analysis and decoding (for example, see standards CCSS.ELA-LITERACY.RF.3.3.A and CCSS.ELA-LITERACY.RF.5.3.A; National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). I suggest that a strategy combining these two aspects, encouraging children to use orthographic strategies (e.g., capitalizing on spelling similarities between words, known spelling patterns, etc.) not only during writing but also during independent reading, could be helpful to support orthographic learning when encountering a novel word that looks similar to previously learned words. Practically speaking, if a child comes across novel words while reading (e.g., *magical*, *magician*), it may help to encourage them to look for orthographic similarities between the new words and the simple word they have already learned (e.g., *magic*). Importantly, it would also help to encourage them to look for orthographic similarities between these new words and a simple word they have already learned even when those words are orthographically similar but do not share a morphological connection (e.g., *car/caramel*, *add/address*, *pea/peanut*). This suggestion is also consistent with prior research on the impact of clue words and orthographic pattern recognition (e.g., Conrad & Levy, 2011; Deacon & Bryant, 2006; Goswami,1986; 1990), as well as recommendations regarding training in orthographic pattern recognition and the use of orthographic analogies (e.g., Conrad & Levy, 2011; Goswami, 1999).

In summary, my results suggest three key educational considerations related to supporting self-teaching as an efficient orthographic learning process: encouraging independent reading in readers with consideration of developmental abilities, encouraging the use of cues (e.g., context) to help access a complete representation when a word is recognized but more help is needed for full identification, and encouraging the identification of orthographic similarities between new words and those that were learned before. Certainly, studies directly testing all of these educational implications are required to make any firm conclusions or recommendations regarding specific strategies. However, I think that the current research provides some important insights for how to best support reading development in elementary-aged children and what kinds of educational or intervention studies may be warranted with regard to self-teaching.

5.4. Conclusion

This dissertation was designed to achieve four research objectives that address important predictions of an important theory of reading development, the self-teaching hypothesis (Share, 2008). Across the included studies I have provided evidence that beginner readers do engage in self-teaching to varying degrees, that accurate phonological decoding is not required for self-teaching to occur, that self-teaching is not a strictly item-specific process as learning transfer does occur, and that self-teaching results in long-lasting high quality orthographic representations. These findings have significant theoretical findings for how we view self-teaching and its role in reading development. As such, in this dissertation I have outlined three new principles regarding the nature of self-teaching: accurate phonological decoding is relevant, but not required, for self-teaching to occur; self-teaching is a powerful learning process that has an important role to play in reading development; self-teaching is a developmental process. I suggest that these three principles of self-teaching provide an essential base for informing future research as we continue to investigate self-teaching and its potential for explaining the transition from beginning to skilled reading. Ideally, this will also help to provide a solid base for informing educational practices that can help children make the most of this powerful learning tool as they develop into fluent readers.

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