

WORD LEARNING OF READERS WITH DYSLEXIA: A TEST OF THE SELF-
TEACHING HYPOTHESIS

by

CHRISTINA NOVELLI

(Under the Direction of Scott P. Ardoyn)

ABSTRACT

Purpose: Self-teaching is one mechanism known to facilitate orthographic and semantic learning of unknown words, primarily via phonological recoding during independent reading. However, the extent to which students with dyslexia acquire lexical representations via self-teaching is unclear. To that end, this study employed the self-teaching paradigm to investigate word-learning outcomes of Grade 3 students with dyslexia.

Method: Fifty-seven students with dyslexia read eight short stories with pseudoword targets embedded four or eight times. Immediately following independent reading, and 3–7 days later, students completed nine word-learning tasks (e.g., orthographic choice, semantic choice, pronunciation choice, spelling, definition production, picture naming, word naming, picture spelling, word-picture matching) to measure the extent (i.e., quality) of lexical representations acquired for the eight target pseudowords.

Results: There was clear evidence that students with dyslexia acquired orthographic and semantic knowledge of words following independent reading. However, students did not acquire high-quality lexical representations. Quality was affected by weaker development of phonological form knowledge. The number of exposures to target words in the text did

not affect word learning outcomes. Text reading fluency, but not target decoding accuracy significantly predicted the quality of lexical representations acquired.

Conclusion: Although observed gains in orthographic and semantic knowledge suggest some ability to develop lexical representations, the lack of strong phonological learning, evidenced by weak target decoding accuracy and poor performance on the pronunciation choice task, indicates that the reliance on phonological recoding impairs lexical learning for students with dyslexia.

INDEX WORDS: word learning, dyslexia, self-teaching hypothesis, orthographic learning, semantic learning

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DEDICATION

For my princess angel baby, Lola. My constant companion for this entire journey. You have been by my side—through the long nights, the chaos, the walks that cleared my head, and the quiet moments that brought peace. You have offered more love, comfort, strength, and unwavering loyalty than anyone could ever know (even if you act like you love others more than me). I would not be the same without you.

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CHAPTER 1

INTRODUCTION

Reading comprehension—the ultimate goal of reading—is a complex construction process that relies on the coordination of several cognitive processes (Perfetti & Stafura, 2014). The processes are devoted to identifying words and integrating the words within the overarching context (Perfetti & Helder, 2022). Take the following excerpt from a passage written at a Flesch-Kincaid kindergarten level (Kincaid et al., 1975) as an example. *Lin had a messy bedroom, and her mom told her to clean it. So, Lin got the tool.* To construct meaning or a mental model of the text (see *A* in Figure 1.1), the reader must engage in multiple reading processes (see Figure 1.1), some of which include:

1. Identifying the 18 words.
2. Connecting the pronouns to the correct references. *Her mom* and *her* refer back to Lin. *It* refers to the bedroom.
3. Recognizing the syntax of each sentence as subject–verb–object. In Sentence 1, Lin is the subject, *had* shows possession, and *bedroom*, the direct object, relates back to the simple declaration *Lin had*. In Sentence 2, Lin is the subject, *got* is the action, and *the tool* is the direct object specifying what Lin got.
4. Recognizing and making semantic connections between words and phrases. *Messy* and *clean it* refer to the bedroom. *So* establishes a causal connection indicating the action following it is a result of the previous action (i.e., *told to*

clean it). The *tool* is ambiguous in isolation but semantically relates to the prior sentence, leading to an inference about the type of tool (i.e., cleaning).

5. Recognizing the temporal sequence of the passage: Lin's room is messy. Her mom tells her to clean. Lin takes action by getting a cleaning tool.

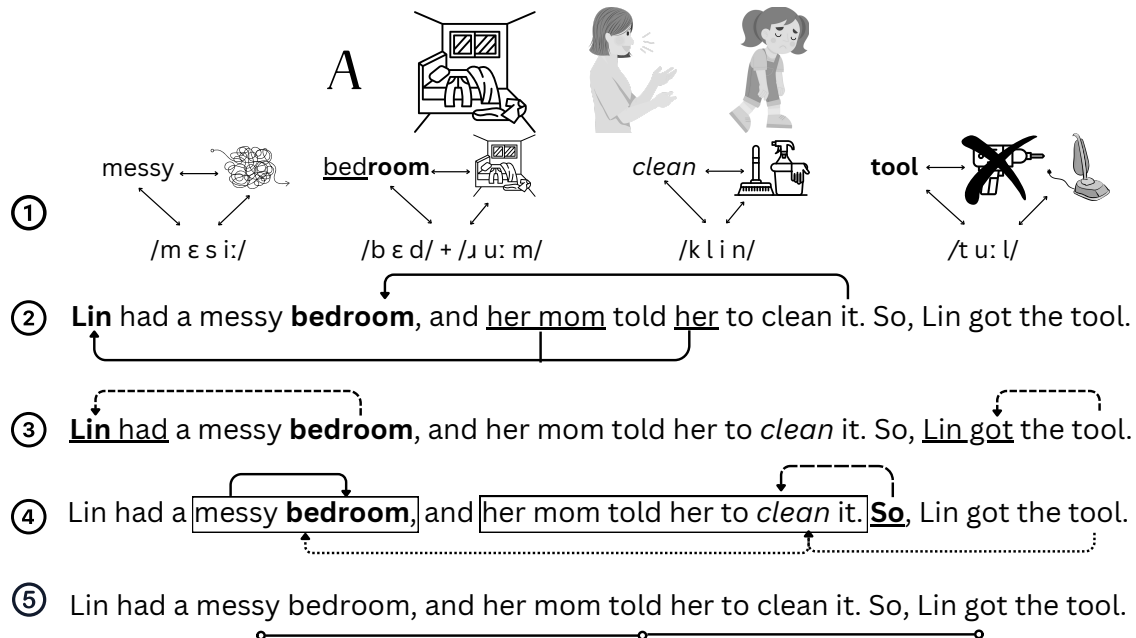


Figure 1.1. *Illustration of Processes Required for Text Comprehension*

All of these processes, and more, are needed to construct meaning. However, it is not necessary for these processes to require cognitive effort. In fact, reading, at any given time, involves both automatic and attention-demanding processes (Walczyk, 2000). For a skilled reader, constructing meaning from the above passage happens automatically—effortlessly with minimal cognitive demand—due to their knowledge about those 18 words enabling automatic word identification which leads to succinct word-to-text integration (Perfetti, 1985). The excerpt may, however, overwhelm a struggling reader due to their lack of or incomplete word knowledge. Thus, the struggling reader must

consciously work to identify the words, consuming their available cognitive resources, in turn, impeding their ability to make connections between the words or to make inferences when information is missing (Walczyk, 2000).

The allocation of resources for the processes required for a reader to comprehend a passage is fluid. That is, the coordination between automatic and attention-demanding processes changes as a function of the text and the reader's knowledge. For instance, changing one word in the previous excerpt alters the demands of the text. *Lin had a messy bedroom, and her mom told her to clean it. So, Lin got the zail.* The reader still has to engage in the reading processes explained above, but now a skilled reader only has knowledge of 17 of the 18 words. Because *zail* is not a word with which a skilled reader is likely familiar, the cognitive resources required to extract meaning from the passage have shifted.

The skilled reader employs automatic processing for most of the passage but will need to actively work to secure an understanding of *zail*. Skilled readers likely do not require cognitive effort to phonologically recode the word due to the orthographic neighbors of *zail* like *sail* and *mail* and instant recognition of the *z—/z/* mapping. However, because the skilled reader does not have existing knowledge (i.e., schema) of a semantic form to connect to the sound (/zeɪl/) or spelling (*zail*), the reader must build a schema for the new word. The skilled reader will make the same inferences they made for *tool* but now connect those inferences to *zail* as they begin to develop a lexical representation of the new word. This burgeoning lexical representation will be evoked when the skilled reader encounters *zail* again. Studies of orthographic learning and incidental vocabulary learning provide evidence to suggest that typically developing

readers acquire lexical representations through independent reading (e.g., Cunningham et al., 2002; Share, 1999; Smejkalova & Chetail, 2023). But what about readers who experience word reading difficulties?

Although skilled readers seemingly develop knowledge about many words with relative ease, this is not necessarily the case for novice or struggling readers, especially those with dyslexia (Johnston, 1982; Johnston & Anderson, 1998). Depending on one's individual word knowledge, a struggling reader may solely engage in attention-demand processes to attempt to comprehend both texts above. Therefore, changing one word may not affect a struggling reader because they were already cognitively taxed and unable to engage in processes above and beyond those required to decode the 18 words. Clearly, comprehension is stifled when readers are continuously taxed during reading due to a lack of or incomplete word knowledge (Perfetti, 1985). The examples above illustrate that reading words with automaticity (i.e., accurately and quickly) creates a greater probability of successful comprehension (Perfetti, 2017). However, developing word-reading efficiency seems unattainable for many readers (Alt et al., 2017; Wolf & Katzir-Cohen, 2001). Therefore, investigations need to understand further the mechanisms underlying word-reading efficiency—how readers acquire robust lexical representation—to design interventions to support struggling readers.

Word Learning

At the foundation of most reading theories (cf. Ehri, 1980, 2005; Nation, 2017; Perfetti et al., 2001, 2022; Share, 1995) and computational processing models (cf. Coltheart et al., 2001; Perry et al., 2007; Seidenberg & McClelland, 1989), there is a general consensus that reader transition from laborious decoding—relying on sublexical,

attention-demanding processes—to identifying words quickly and accurately. This transition describes the collection of high-quality lexical representations—or orthographic learning—facilitating increased rapid word learning while reading (Castles et al., 2018; Perfetti, 2017). The self-teaching hypothesis (Jorm & Share, 1983; Share, 1995) presents a compelling framework for understanding the mechanisms underlying the acquisition of lexical representations.

The Self-Teaching Hypothesis

The self-teaching hypothesis (Jorm & Share, 1983; Share, 1995) posits that readers acquire orthographic representations during independent reading as a function of phonological recoding. Termed the *sine qua non* (or necessary skill) for word reading acquisition, the hypothesis suggests that engaging in the independent process of translating print to speech, the act of phonological recoding¹—without feedback—provides rich opportunities for readers to acquire lexical representations. Readers who successfully convert print to speech have the opportunity to refine or add to a current lexical representation by assimilating the word-specific orthographic and phonological forms with semantic form(s) already stored in long-term memory or form a new lexical representation by building knowledge of the forms (Share, 1995, 2004).

Further, the self-teaching hypothesis (Jorm & Share, 1983; Share, 1995) purports that each successful encounter with an unfamiliar word provides critical opportunities for readers to strengthen their lexical representation. With repeated successful decoding experiences of a new word, readers gradually construct a more refined lexical representation. This refinement allows the reader to identify the word without continued reliance on phonological recoding or taxing cognitive effort (Perfetti, 1985; Share, 1999).

Collective ongoing experiences with many new words enable readers to build a store of lexical representations in long-term memory. Thus, the self-teaching hypothesis suggests that readers independently develop an autonomous lexicon—an independent store of high-quality lexical items in long-term memory that can be retrieved automatically—primarily as a function of decoding and supported by one’s current orthographic knowledge.

Researchers have tested the self-teaching hypothesis (Jorm & Share, 1983; Share, 1995) with typically developing students, in grades two and up, reading Hebrew (Share, 1999, 2004), Dutch (de Jong & Share, 2007), Chinese (e.g., Li et al., 2020), and English (e.g., Cunningham et al., 2002; Nation et al., 2007) text. Most empirical evidence (see Share, 2008; Castles & Nation, 2006) supporting this hypothesis is derived from data gathered using orthographic learning measures (i.e., orthographic choice, word naming latency, and spelling) providing general evidence that *orthographic learning* occurs during independent reading.

Although extensive evidence supports the underlying stipulations of the self-teaching hypothesis (Jorm & Share, 1983; Share, 1995), it was conceptualized 30 years ago and has thus been challenged. Seidenberg et al. (2022) acknowledge the seminal contribution of the hypothesis as the only mechanistic account of acquiring lexical representations but also parallel the hypothesis to broader statistical learning phenomenon that may not be specific to reading but rather reflect learning mechanisms (see also Compton et al., 2022; Steacy et al., 2017). Specifically, Seidenberg et al. identified the self-teaching hypothesis as a forward model (Plaut & Kello, 1999), reflecting just one pathway to lexical learning (e.g., orthography to semantics, mediated by phonology).

This criticism seemingly stems from the fact that initial studies supporting the self-teaching hypothesis purely examined orthographic learning (e.g., Cunningham et al., 2002; Share, 1999). However, researchers have expanded the scope of the self-teaching hypothesis to encompass additional pathways of word learning.

Instance-Based Framework for Learning Word Meanings

Recent vocabulary research (e.g., Deacon et al., 2019, 2024; Hulme et al., 2022) extends the general premise of the self-teaching hypothesis (Share, 1995) from orthographic learning to semantic learning. Although the idea that readers learn word meanings through independent reading (McKeown, 1985; Nagy et al., 1985, 1987) was hypothesized prior to the self-teaching hypothesis (Share, 1995), the hypotheses lived in relatively siloed areas of research. For example, the instance-based framework for learning word meanings (Reichle & Perfetti, 2003) posits that semantic learning from discourse happens incrementally through the gradual refinement of meaning gained from the amalgamation of multiple exposures to words in context, a direct parallel to the self-teaching hypothesis. Indeed, Bolger et al. (2008) found that skilled readers learned the meaning of new words better when encountered across varying contexts compared to an equivalent number of exposures in a single context. Further, Smejkalova and Chetail (2023) found that the semantic learning of pseudowords by skilled readers improved when the varied contexts included both informative and uninformative contexts, mirroring the results of Eskenazi et al. (2018). As part of these vocabulary studies, researchers concluded that context helps resolve ambiguities encountered by the reader related to new words and guides the reader to plausible interpretations of these new words, particularly if the words have inconsistent or low-frequency spellings.

To date, the coordination of both orthographic and semantic learning is understudied, particularly in students with dyslexia (Compton et al., 2014). In one of the few self-teaching studies to study these constructs together, Deacon et al. (2019) examined the extent to which young readers acquire both the spellings *and* meanings of novel words during independent reading. Grounded in the lexical quality hypothesis (Perfetti & Hart, 2001, 2002), which emphasizes the importance of semantic information in acquiring high-quality lexical representations (Perfetti, 2017), Deacon et al. sought to bring together previous self-teaching (e.g., Cunningham et al., 2002) and vocabulary (e.g., Cain et al., 2004) experiments, using two measures employed in Chapter 3 of this dissertation (i.e., orthographic choice and semantic choice). The results confirmed that scores were above chance for each task at each time point, providing evidence of both orthographic and semantic learning via self-teaching. Unfortunately, evidence of word learning via self-teaching is limited to just six experiments within four studies (Adlof et al., 2016; Brusnighan et al., 2014; Deacon et al., 2019; Lowell, 2012). Thus, more experiments are needed to explore word learning as the amalgamation of orthographic and semantic learning.

Word Learning by Students with Dyslexia

Theoretically, the self-teaching mechanism for word learning is applicable to readers at all levels, from beginners to experts (Share, 1995). However, to date, the evidence of self-teaching as a mechanism for word learning in students with dyslexia and other learning disabilities is mixed (e.g., Martinez-Garcia et al., 2019; Share & Shalev, 2004). Recently Li and Wang (2023) conducted a systematic review of orthographic learning outcomes from self-teaching studies and highlighted readers with reduced

decoding skills acquired less robust learning from self-teaching than typically developing students. That is, readers with dyslexia may only acquire low-quality representations from independent reading, which may be one cause of sustained difficulties (for review, see Li & Wang, 2023). However, these claims stem from just five studies (Bar-Kochva et al., 2016; Martínez-García et al., 2019; Share & Shalev, 2004; Staels & van den Broeck, 2015; Suárez-Coalla et al., 2016), none of which included participants whose first language was English. Therefore, generalizable claims about word learning as a result of self-teaching for students with dyslexia should not yet be drawn.

Current Study

Self-teaching is one mechanism known to facilitate orthographic and semantic learning of unknown words, primarily via phonological recoding during independent reading. In the seminal self-teaching study, Share (1999) examined the orthographic learning outcomes of Grade 2 students following their independent reading of short texts containing target pseudowords. Orthographic learning was evident and thus provided the first empirical support for the self-teaching hypothesis. However, the extent to which students with dyslexia acquire word-specific representations via self-teaching is unclear. To that end, I aimed to address the gaps in the self-teaching literature by employing the self-teaching paradigm to investigate word-learning outcomes of Grade 3 students with dyslexia.

In Chapter 2, I will unpack the current level of evidence for the self-teaching hypothesis as the mechanism behind the word learning of readers of alphabetic scripts. As will be evident from the review, there is a lack of empirical evidence to support the self-teaching hypothesis as the mechanism for the word learning of those with reading

disorders. Therefore, in Chapter 3, I present a manuscript describing my study that employed the self-teaching paradigm Grade 3 readers with dyslexia guided by the following research questions:

1. To what extent do students with dyslexia acquire *high-quality* lexical representations of regular words following independent reading?
2. Is the quality of the acquired lexical representations a function of the number (4 vs. 8) of exposures to targets?
3. Does reading accuracy at the target level and/or text reading fluency during independent reading predict the quality of acquired lexical representations?

Understanding how students with dyslexia acquire the coherent and stable lexical representations fundamental to skilled reading comprehension (Perfetti & Hart, 2002) is central to developing robust interventions. To date, the extent to which students with dyslexia engage in word learning through this mechanism is not understood. The current study was designed to clarify how these processes might work in Grade 3 students with dyslexia.

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CHAPTER 2

UNPACKING THE SELF-TEACHING HYPOTHESIS

Words—fundamental units of language—are the basic elements of written text. Successful reading requires processing written words both individually and within the context of sentences in which they are situated (Perfetti & Stafura, 2014). Given a string of letters, readers must retrieve information stored in memory (i.e., lexical representation) to identify the specific word. Then, they must situate the identified word within the text to create a coherent understanding of what they read. Consequently, word knowledge serves as the bedrock of reading—to become a skilled reader, one must be a skilled *word* reader (Gough & Tunmer, 1986; Perfetti, 1985; Perfetti & Helder, 2022). Skilled word reading is characterized by rapid and effortless retrieval of a lexical representation stored in memory. This lexical representation includes all aspects (spelling, pronunciation, and meaning) of a word’s identity (Ehri, 1980; Perfetti, 1992). Therefore, readers must acquire knowledge of a word’s identity (see Figure 2.1).

A word’s identity is composed of defining variables or constituents (i.e., orthographic, phonological, and semantic forms). The orthographic form (i.e., spelling) is an invariant sequence of letters that connects to linguistic specification (i.e., pronunciation and grammatical features) and connects to semantic (i.e., meaning) and pragmatic features (Ehri, 2005; Perfetti, 1985, 1992, 2017). It is hypothesized that successful readers efficiently activate all constituents of a word’s identity synchronously when presented with any single form (Perfetti, 1985; Perfetti & Hart, 2001, 2002).

Therefore, robust word learning—acquiring knowledge of and the mappings between a word's orthographic, phonological, and semantic variables—is critical for reading fluency and, in turn, reading comprehension (Cunningham & Stanovich, 1997).

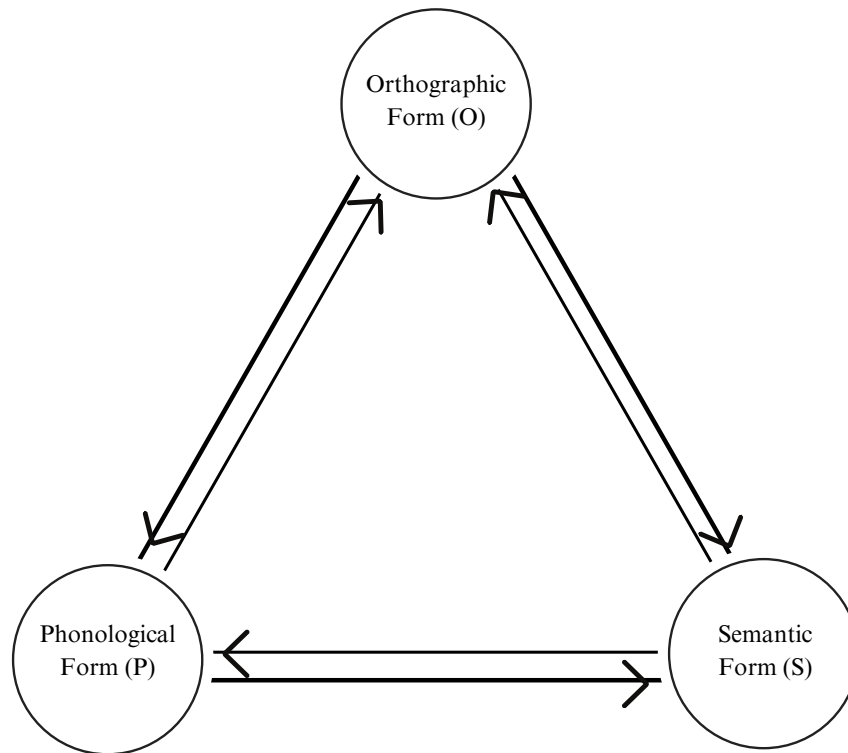


Figure 2.1. *Word Identity (adapted from Perfetti, 2017)*

Lexical Representations

Lexical representations are constructed from knowledge of the specific constituents of word identity, including its orthographic, phonological, and semantic forms (Perfetti, 1992, 2017) *and* the bindings between those constituents. The bindings are bidirectional and exist between all three constituents. Therefore, lexical quality refers to a reader's current knowledge of the three constituents and the bindings between constituents of a word's identity (Perfetti, 1985; Perfetti & Hart, 2001, 2002). Lexical

quality is an item-based measure that varies across individuals and words. High-quality lexical representations are fully specified, *precise* orthographic representations mapped to *redundant* lexical forms and generalized meaning (see example in Figure 2.2). A stored high-quality lexical representation enables a reader to automatically produce any constituent form in response to another constituent form. However, all aspects of word identity are required to produce and identify correct forms efficiently.

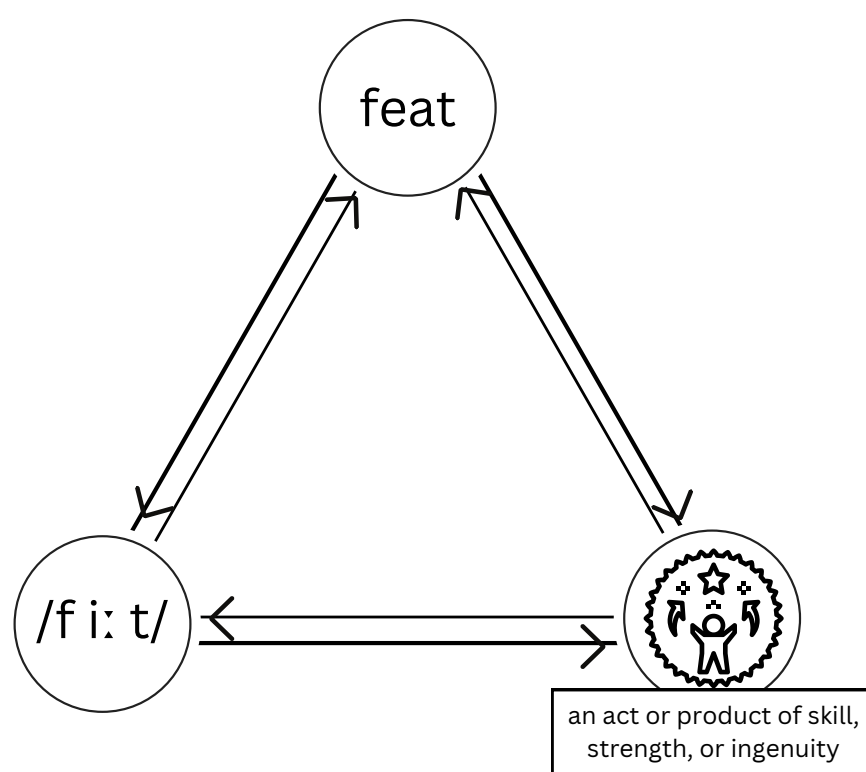


Figure 2.2. *Example of High-Quality Lexical Representation*

For example, a reader sees ...*feat*... in a text. The reader can use sublexical processing to correctly produce the phonological form (i.e., pronunciation): /f/ /i:/ /t/ via decoding. The reader may have a developed representation binding the orthographic (O) and phonological (P) forms. If this O–P binding is well-established or strong, the reader can accurately and quickly produce the phonological form without decoding. This

describes word recognition. The text continues: *The dog won the race*. If the reader has a high-quality lexical representation of *feat*, the semantic form was also activated upon word recognition, making the next sentence conform to the reader's developed understanding of the text. This represents word identification—the synchronous activation of word recognition and meaning. However, if the reader has a lower quality lexical representation due to missing knowledge of constituent bindings, then the reader may experience disruption to their comprehension. If the reader does not possess a high-quality lexical representation specific to *feat*, then other connections between constituents may be activated, so instead of the correct semantic form activating, the reader may think of the semantic form for *feet—the plural of foot*. This mismatch disrupts the reader's meaning-making processes and requires the reader to either (a) engage in attention-demanding processes to resolve the mismatch, taxing the student's cognitive resources or (b) continue decoding without making meaning, thus defeating the goal of reading. When readers have developed a high-quality lexical representation—all six pathways tightly secured—efficient word reading or word identification can transpire (Cunningham & Stanovich, 1997; Perfetti, 1985, 2017), paving the way for successful reading comprehension.

As illustrated above, high-quality lexical representations allow for quick and accurate retrieval of words (i.e., word identification). Conversely, lower-quality representations require (a) more resource-intensive retrieval, leading to inefficient word recognition or (b) the reader to engage in attention-demanding monitoring processes, leading to dysfluent word identification. Both ultimately drain cognitive resources and have cascading effects on reading comprehension (Kim, 2020, 2022; Perfetti, 1985).

These cascading effects impact readers' comprehension abilities and are encapsulated in the lexical quality hypothesis (Perfetti, 1992; Perfetti & Hart, 2001, 2002). The lexical quality hypothesis postulates that readers vary in their *lexical knowledge*, thereby affecting the quality of lexical representations, and this variance explains some differences in reading ability (Perfetti, 2017). Lexical knowledge is thought to play a causal role in word identification and word learning (Taylor & Perfetti, 2016). The lexical quality hypothesis shifts the account of individual differences in reading from inefficient processes (e.g., Elbro, 1996, 1998; Oakhill et al., 2003; Wolf et al., 2002) to lexical knowledge representation. Thus, how readers acquire lexical representations is an important research area.

Lexical Learning

Researchers (e.g., Perfetti, 2007; Steacy et al., 2017) define word learning as the process of acquiring lexical representations. Lexical representations are built through the integration of the bindings between constituent forms. Therefore, word learning can be more precisely conceptualized as the dynamic and reciprocal amalgamation of orthographic learning—how a word looks and sounds—and semantic learning—what a word means and how it is used. This conceptualization emphasizes that skilled word learning involves the coordination of form and meaning, resulting in robust lexical representations that support reading efficiency and comprehension (Perfetti, 2017).

Orthographic Learning

Orthographic learning describes how a reader learns and retains the invariant letter sequence of individual words. Depicted in Figure 2.3, orthographic learning encompasses the O–P bindings (Castles & Nation, 2006) and refers to the mapping of

orthographic forms to phonological forms (i.e., word recognition) and phonological forms to orthographic forms (i.e., spelling).

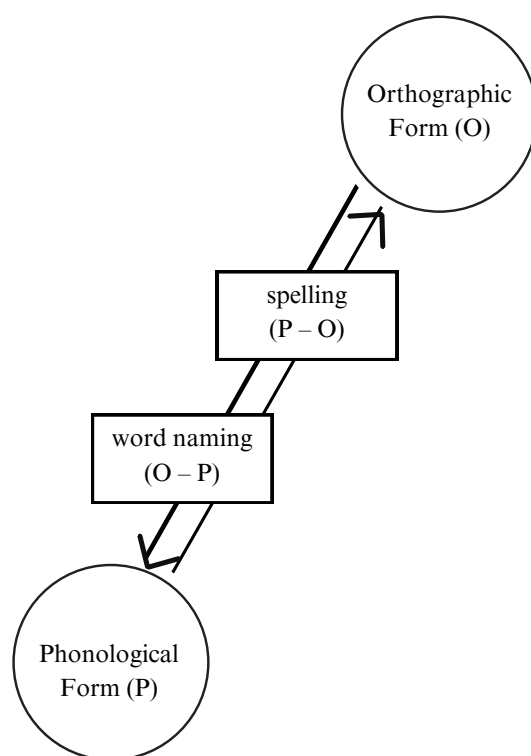


Figure 2.3. *Orthographic Learning*

Orthographic learning is typically measured using three types of tasks: orthographic choice, spelling, and word naming. An orthographic choice task requires one to choose the correct spelling of a target when presented with closely related foils (Compton et al., 2022). In some iterations, the target is only presented with a pseudo-homophone foil (e.g., *rain-rane*), representing a mismatch between the specific orthographic and phonological forms. Alternatively, additional foils related to letter formation or position may be presented (e.g., *rain-rane-rait-rian*). Although some have critiqued orthographic choice tasks as a redundant measure of word naming skill (e.g., Castles & Nation, 2006), Compton et al. (2020) found that the performance on orthographic choice tasks of students in Grades 3–12 was not fully dependent on their

word naming performance of the same words, and thus, represent unique orthographic processing skill. In contrast, word naming and spelling are direct measures of the O–P and P–O bindings. In these tasks, participants are given either the orthographic (i.e., written word) or phonological (i.e., pronunciation) form and asked to produce the other form (Share, 1999).

Semantic Learning

Semantic learning, often referred to as vocabulary learning, describes how a reader learns and retains the meaning and use individual words (Ouellette, 2006; Steacy et al., 2017). Depicted in Figure 2.4, semantic learning encompasses the mapping of semantic forms (including morphological forms) to either phonological forms (i.e., oral vocabulary) or orthographic forms (i.e., reading vocabulary; Fowlert et al., 2004; Hall et al., 2014).

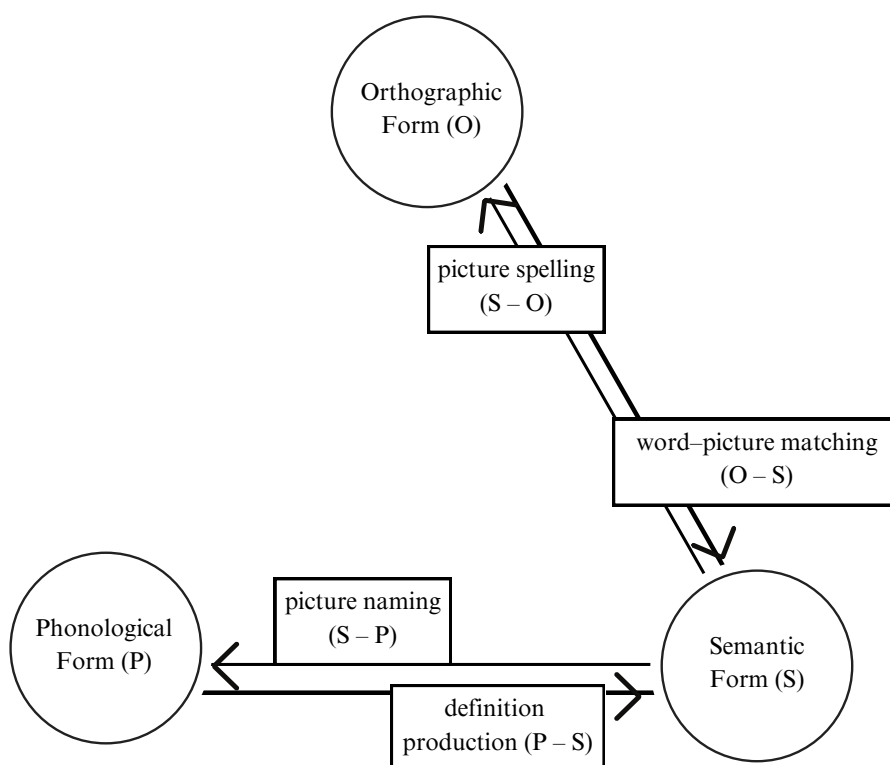


Figure 2.4. *Semantic Learning*

The outcome of semantic learning refers to what readers know about the meaning of words. Semantic learning is typically measured using either receptive or expressive tasks (Ricketts et al., 2021). Receptive tasks require the reader to recognize or match the meaning of a written or spoken word. Expressive tasks require the reader to produce the name or spelling when given the meaning or, conversely, produce the meaning when given a written or spoken word. Alternatively, some researchers have used dynamic assessments implementing a cueing hierarchy approach (e.g., Ricketts et al., 2021). These dynamic assessment tasks start as expressive tasks, but if needed, through systematic cueing become receptive tasks (e.g., choice). Dynamic assessments measure partial or developing semantic knowledge.

The Self-Teaching Hypothesis

The self-teaching hypothesis (Jorm & Share, 1983; Share, 1995) provided the first mechanistic theory of word learning. It suggests that readers acquire new lexical representations through a two-step process. First, by phonological recoding—converting letter sequences into sounds (i.e., decoding)—readers independently deduce unknown words without direct instruction. Second, this decoding establishes a connection between the written and spoken forms. The core claims of the self-teaching hypothesis are:

1. Phonological recoding is the primary mechanism for acquiring orthographic knowledge by transforming letter sequences into recognizable sounds.
2. Orthographic knowledge, which links phonology and orthography, can be acquired without direct instruction (Ehri, 1998; Perfetti, 1992; Share, 1995).

In the original hypothesis, Share (1995) explained self-teaching as a mechanism for word learning. He explained that readers progressively build a more refined lexical

representation through repeated successful decoding (Share, 1999, 2008). He further purported that collective ongoing experiences with many unknown words allow the reader to accumulate a lexicon full of word-specific representations (Castles & Nation, 2006; Share, 2008). In the past, the absence of semantic learning from the hypothesis has been a criticism; however, vocabulary research (e.g., Deacon et al., 2019; Hulme et al., 2022; Ouellette & Fraser, 2009) extends the original self-teaching hypothesis (Share, 1995) from orthographic learning to semantic learning.

A parallel theory to the self-teaching hypothesis, the instance-based framework for learning word meanings, was introduced by Reichle and Perfetti (2003). It posits that semantic learning from discourse happens incrementally through the gradual refinement of meaning gained from amalgamating multiple exposures to words in context. That is, students refine word representations from reading connected text. Results from recent experiments (e.g., Deacon et al., 2024) confirm the extension of the self-teaching hypothesis to semantic learning. The extent to which this research body (see Li & Wang, 2023; Nation & Castles, 2017; Share, 2008, 2011) explains individual differences in word learning, however, is not yet well understood.

The self-teaching hypothesis purports two self-teaching components (i.e., phonological recoding and orthographic knowledge) that work in a *weighted* tandem as a mechanism for independently acquiring lexical representations (Share, 2011). For decades, researchers have tested this hypothesis with resulting studies (e.g., Cunningham et al., 2002; Deacon et al., 2019; Share, 1999; Wang et al., 2011) providing general evidence that self-teaching occurs during independent reading and results in orthographic and semantic learning. To orient you to this research base, I will first (a) define the

methodological paradigms used in self-teaching research, (b) provide an in-depth description of the seminal self-teaching study, and (c) synthesize results from 43 experiments (Table 2.1) presented within 36 studies identified as employing a self-teaching paradigm to examine the word learning outcomes of readers of an alphabetic script.

Methodological Paradigms of Self-Teaching

A self-teaching experiment can be operationalized as one that measures at least one dimension of word learning (i.e., orthographic or semantic learning) following the *independent* reading of connected text. The definition encompasses two common paradigms used in reading acquisition research: self-teaching (e.g., Share, 1999) and orthographic learning (e.g., Wang et al., 2011). In his seminal study, Share (1999) introduced a self-teaching experimental paradigm to examine orthographic learning outcomes following independent reading. The paradigm consisted of the following key elements: (a) selection of targets that represent conceptual meanings, (b) presentation(s) of target words embedded in connected texts, (c) students independently read the connected texts, (d) no assistance or feedback provided during the reading task, and (e) administration of word learning measure(s) following the reading task. Over the decades following Share, various experimental manipulations have been used alongside his original paradigm; however, the five core elements identified above continue to serve as the foundation for these experiments.

Table 2.1. *Self-Teaching Experiments by Alphabetic Script*

Citation	Participants			Manipulations	Targets				Word-Learning Measures						Delay ^a	
	N	Gr	RD		N	Type	POS	Pre-Exp.	Text	Exp	OC	S	WR	EV		RV
Dutch																
de Jong & Share, 2007	65	3	NR	target spelling, exp.	12	monosyllabic homophonic pseudowords	N	0	116–132-word stories	1 v 6	✓	✓	✓			3
de Jong et al., 2009 ₁	56	2	NR	overt v covert, target spelling, exp.	24	homophonic pseudowords	N	0	116–132-word expository texts	3 v 6	✓		✓			2
Staels & Van den Broeck, 2015	65	4–5	30	ind. read v text-to-speech, length of delay	8	homophonic pseudowords	N	0	102–164-word stories	6	✓	✓	✓			3 v 7
English																
Adlof et al., 2016 ₁	56	4–6; UG	NR	pre-exp., context	30	rare words	A, N, V	0 v 1 v 4	10-word sentences	2	✓			✓	✓	7
Adlof et al., 2016 ₂	20	4–5	NR	pre-exp.	16	rare words	N, V	0 v 4	10-word sentences	3	✓			✓	✓	7
Bowey & Miller, 2007	52	3	NR	target spelling	10	homophonic pseudowords	NR	0	106–142-word stories	6	✓		✓			2
Bowey & Muller, 2005	63	3	NR	target spelling, exp., delay length	12	homophonic pseudowords	NR	0	125–128-word texts	4 v 8	✓		✓			0 v 6
Brusinghan et al., 2014 ₁	48	UG	NR	familiarity, homophony	16	sets of 4 real + nonwords	N	0	8–12-word sentence pairs	1		✓			✓	0
Conrad et al., 2019	48	2	0	read v spell, target spelling	6	homophonic pseudowords	N	vocab training	short stories	4	✓	✓	✓			1
Cunningham et al., 2002	34	2	NR	target spelling	10	homophonic pseudowords	N	0	133–234-word stories	6	✓	✓	✓			3

Citation	Participants			Manipulations	N	Targets				Word-Learning Measures						Delay ^a
	N	Gr	RD			Type	POS	Pre-Exp.	Text	Exp	OC	S	WR	EV	RV	
Cunningham, 2006	35	1	0	context, target type	8	real word paired with homophonic pseudoword	A, N, V	0	99–120-word stories	6	✓	✓				3
Deacon et al., 2019	66	1–2	0	target spelling	12	homophonic regular pseudowords	N	0	5-sentence stories	4	✓				✓	5–9
Gebremedhen, 2021 ₁	18	UG	NR	overt v covert, target spelling	24	homophonic pseudoword pairs	N	0	133–157-word stories	6	✓	✓				7
Gebremedhen, 2021 ₂	48	UG	0	target spelling, overt v covert, environment	48	homophonic pseudowords	NR	0	stories	1	✓	✓	✓			7
Ginestet et al., 2021	45	UG	NR	target type	16	complex homophonic pseudowords	N	0	5-sentence stories	4	✓	✓				0
Kivrak, 2019	23 6	UG	NR	task load	16	real words	A, N, V	pre-test	600–1170-word text or video	1–3				✓	✓	7
Li et al., 2021	40	5	0	context structure, exp.	16	homophonic pseudowords	N	0	50-word stories	4 v 6	✓	✓	✓			3
Li et al., 2022	21	3	NR	context, exp.	8	homophonic pseudowords	N	0	50-word stories	4 v 6	✓	✓				7
Lowell, 2012 ₁	48	UG	NR	context	60	pseudowords	N	0	sentences	1	✓			✓		0
Lowell, 2012 ₂	44	UG	NR	context, target type	60	pseudowords	N	0	sentences	1	✓			✓		0
MacEachron, 2008	92	1	0	target spelling, target type	24	homophonic pseudowords	N	0	short stories	4	✓	✓	✓			7
Martin-Chang et al., 2017	23	2	NR	context, feedback	12 5	challenging words	A, N, V	pre-test	130–150-word texts	10	✓	✓	✓			7
Nation et al., 2007	42	2–3	NR	context, exp.	9	homophonic pseudowords	N	0	94-word stories	1 v 2 v 4	✓		✓			7

Citation	Participants			Manipulations	N	Targets				Word-Learning Measures						Delay ^a
	N	Gr	RD			Type	POS	Pre-Exp.	Text	Exp	OC	S	WR	EV	RV	
Schwartz et al., 2014	86	6	NR	target spelling	12	homophonic pseudowords	N	0	5-sentence texts	4	✓		✓			7
Tucker et al., 2016	13 3	3, 5	NR	target type	8	homophonic pseudowords	N	0	57-word stories	4	✓		✓			2–3
Wang et al., 2011 ₁	19	2	NR	context	8	homophonic regular pseudowords	N	vocab training	57-word stories	4	✓	✓	✓	✓		10
Wang et al., 2011 ₂	22	2	NR	context	8	homophonic irregular pseudowords	N	vocab training	57-word stories	4	✓	✓	✓			10
Wang et al., 2012	34	2	NR	regularity	8	monosyllabic pseudowords	N	vocab training	short stories	4			✓	✓	✓	10
Wang et al., 2013	45	2–3	NR	regularity	8	monosyllabic pseudowords	N	vocab training	short stories	4			✓	✓	✓	10
Wang et al., 2023	49	2	NR	exp. type	12	monosyllabic pseudowords	V	0	84-word stories	4	✓	✓	✓			0 + 1
Wegener et al., 2022	37	3–4	NR	spaced v mass practice	16	monosyllabic homophonic pseudowords	N	0	single-line sentences	4	✓		✓			7 min
Wegener et al., 2023	12 0	UG	NR	spaced v mass practice	16	monosyllabic homophonic pseudowords	N	0	single-line sentences	4	✓		✓			7 min
French																
Sabatier et al., 2023	58	2–8	29*	DHH v TH	10	pseudowords	N	0	45–55-word stories	3	✓		✓			0
Pointed Hebrew																
Ben-Uriel, 2010	48	2	NR	context	18	real words paired with pseudowords	NR	0	5–6-line stories	2	✓		✓	✓		7
Share & Shalev, 2024	80	2 4–6	40	target spelling, exp.	10	homophonic pseudowords	N	0	31–86-word texts	2 v 6	✓		✓	✓		3
Share, 1999 ₁	40	2	0	target spelling, exp.	10	homophonic pseudowords	N	0	94–170-word texts	4 v 6	✓		✓	✓		3

Citation	Participants			Manipulations	Targets					Word-Learning Measures						Delay ^a
	<i>N</i>	Gr	RD		<i>N</i>	Type	POS	Pre-Exp.	Text	Exp	OC	S	WR	EV	RV	
Share, 2004 ₁	36	3	NR	target spelling, exp., delay length	9	homophonic pseudowords	N	0	94–170-word stories	3 v 7 v 30	✓	✓	✓			3
Share, 2004 ₂	32	1	NR	target spelling, exp., delay length	8	homophonic pseudowords	N	0	51–77-word stories	1 v 2 v 4	✓	✓	✓			3
Share, 2004 ₃	61	1	NR	word type target spelling, exp.	16	homophonic pseudowords	N	0	65–84-word texts	4 v 8	✓	✓	✓			3
Shoam, 2015 ₂	50	3–4	NR	read first v spell first	10	homophonic pseudowords	N	0	4–7-word sentences	2	✓		✓			3
Zorea, 2010	35	2–4	NR	target spelling	12	pseudo-homographs	N	0	52–81-word texts	4	✓		✓			7
Spanish																
Pulido, 2003	99	UG	NR	familiarity, delay length	32	pseudowords	N, V	0	164–174-word narratives	NR				✓	✓	2 v 28

Note. Subscript indicates experiment number detailed in article

^aLength of delay (in days unless otherwise noted)

Gr. = grade; RD = participants identified with reading disability or difficulty

POS = part of speech, N = noun, V = verb, A = adjective

Exp. = exposures

OC = orthographic choice; S = spelling; WR = word reading; EV = expressive vocabulary; RV = receptive vocabulary

NR = not reported

* = deaf/hard-of-hearing (DHH) students

TH = students with typical hearing

More recently, Wang et al. (2011) introduced a refined self-teaching paradigm known as the orthographic learning paradigm. This paradigm incorporates phonological and semantic exposure (i.e., vocabulary) to the targets before students encounter the orthographic form during the self-teaching task. In essence, these orthographic learning paradigm studies (e.g., Deacon et al., 2019; Wang et al., 2012, 2013; Wegener et al., 2022) examining self-teaching include all components of the self-teaching paradigm *plus* a pre-exposure phase where the pronunciation and conceptual meaning are taught to the reader. Providing vocabulary exposure before independent reading may create a learning environment that aligns more closely with authentic reading experiences, as readers often have phonological and semantically bound representations stored before they are exposed to a word's orthographic form (Wegener et al., 2022).

Pseudowords are commonly used as target stimuli, in both the self-teaching and orthographic-learning paradigms, to control for students' prior knowledge of words and create an environment in which lexical learning would be necessary. However, some studies (e.g., Adlof et al., 2016; Cunningham, 2006; Martin-Chang et al., 2017) employ real words—incorporating a pre-test or rare, real words to control for prior word knowledge. Additionally, targets are generally created in pairs so that one phonological form is shared between two orthographic forms (e.g., *yait/yate*). The pairs are randomized between participants to ascertain if the specific lexical representation presented is learned rather than readers relying on sublexical processes during outcome learning tasks.

The Seminal Study of the Self-Teaching Hypothesis

In 1999, Share empirically tested the self-teaching hypothesis, by examining the orthographic learning outcomes of 40 Grade 2 students learning Hebrew, following

independent reading. Employing the elements of self-teaching studies identified above, he selected 10 homophonic pseudowords as targets. These target pseudowords were embedded in short texts either four or six times to examine if outcomes varied as a function of number of exposures to the target pseudowords. The distribution of target spelling and number of exposures were randomly counterbalanced across students. During the experiment, students independently read five texts aloud and answered three simple reading comprehension questions for each text. Three days later, orthographic learning tasks (i.e., orthographic choice, naming, spelling) were administered to measure the extent of learning that occurred due to self-teaching. This procedure was then repeated, with the remaining five target homophonic pseudowords.

Overall, text reading accuracy during the reading task was high at 98.5%, as was target word decoding accuracy, at 84.4%, ignoring vowel errors—vowels have a relatively inconsequential status in Hebrew according to Share. The orthographic learning measures provided evidence of word learning. For the orthographic choice task, the target pseudoword was selected significantly more often (73.5% of the time) than the three foils. There was not, however, a significant difference between the number of exposures (4 vs. 6), suggesting that robust orthographic learning occurred with as few as four exposures. For the naming task, there were no significant differences in accuracy between the target and its homophonic foil; however, there was a significant difference in latency—or speed with targets named, on average, 58 ms faster than homophonic foils. For spelling, which requires a fully specified representation that matches letter for letter with the target, the targets were spelled correctly 67.1% of the time, which was twice as often as the homophonic foils; these differences were all significant ($p = .01$). Consistent

with the orthographic choice data, there were no differences in spelling accuracy as a function of number of exposures. Overall, orthographic learning was evident following independent reading, resulting in the first empirical study to directly test and confirm the self-teaching hypothesis.

Current Evidence

A large body of self-teaching research followed Share (1999). The accumulated findings suggest that readers acquire lexical representations following independent reading, as evidenced by orthographic learning and/or semantic learning measures (e.g., Deacon et al., 2019; MacEachron, 2008; Nation et al., 2007; Staels & van den Broeck, 2015; Wegener et al., 2022). Within this literature, phonological decoding accuracy and prior orthographic knowledge have been key predictors of word learning success as predicted by the self-teaching hypothesis. However, these factors can vary markedly among readers. Therefore, it is important to further define the self-teaching mechanism for word learning and explore how it might explain individual differences. Understanding these dynamics is crucial for developing tailored instructional strategies or interventions to enhance the efficacy of word learning for all readers. To do this, a review of the current body of research is necessary

It is important to note that the 42 experiments across 36 studies synthesized below do not encompass the breadth of self-teaching studies. Several studies were not included in this review for violating the foundational premises of self-teaching ($k = 76$) or only including one word-learning measure ($k = 12$). Common examples of deviations from a self-teaching paradigm included providing corrective feedback to students during the reading task ($k = 42$) or presenting the targets in isolation (e.g., lists; $k = 14$).

Furthermore, only studies that involved an alphabetic script were included. The three main orthographic systems—alphabetic, syllabic, and logographic, as well as scripts that combine features of the three—vary significantly in terms of basic units, the mappings between sound and symbols, and visual complexity (Frost et al., 2005). To draw conclusions related to lexical acquisition, it is important that the type of orthographic system remains constant. Currently, there is a general consensus that despite the significant variation in complexity and consistency of sound-to-symbol relationships within the alphabetic orthographies universal principles and patterns of development exist (see Caravolas, 2022); therefore, studies across alphabetic scripts can provide insights into the mechanisms of word learning, of which cannot be drawn from studies of other orthographic scripts (e.g., Chinese; $k = 14$).

In the remaining sections, I synthesize the evidence of a self-teaching mechanism for orthographic and semantic learning in alphabetic scripts. I describe current limitations that may impede our full understanding of the self-teaching mechanism. These limitations lend themselves to future directions, discussed at the conclusion of the chapter.

General Study Characteristics

Self-teaching experiments included in this review were conducted across 10 countries, including five orthographic systems: Dutch ($k = 3$), English ($k = 29$), French ($k = 1$), pointed Hebrew ($k = 8$), and Spanish ($k = 1$). Seven of the studies, encompassing nine experiments, were dissertations or theses, the remaining 33 experiments were published in 10 peer-reviewed journals within 29 articles. Table 2.1 summarizes the elements of the self-teaching experiments including manipulations and conditions, target characteristics, and text characteristics. Overwhelmingly, researchers used homophonic

pseudoword pairs ($k = 31$) as targets, often representing nouns. In some studies (e.g., Ginestet et al., 2021) complex pseudoword targets—a pseudoword base with real affixes attached to change the grammatical category (e.g., *-ing*) or the meaning (e.g., *-er*) of the targets—were used. Although evidence is limited, there appears to be significant generalization to related morphological forms when readers encounter base targets while reading (e.g., Tucker et al., 2016). Most studies ($k = 32$) employed an independent reading task consisting of students learning multiple targets ($M = 10.19$; $SD = 8.93$) per self-teaching session by reading several short texts containing an average of 4 exposures ($SD = 2.02$; range = 1–8) of one or two targets. Across experiments, a total of 2,352 readers were included. Most participants were elementary school readers ($n = 1,605$). Unfortunately, demographic data to describe the sample population were often not reported. Table 2.2 summarizes data that were provided.

Table 2.2. *Student Participant Demographics Across Studies*

Variable	<i>n</i>	%
Total Number of Students	2352	100.00
Grade Level Bands		
K–6	1605	68.24
Undergraduate	724	30.78
NR	23	0.98
Gender		
Male	878	37.23
Female	926	39.37
NR	548	23.30
Race and Ethnicity		
White	59	2.51
Black or African American	2	0.08
Hispanic/Latinx	4	0.16
Asian	39	1.66
Native American/American Indian	6	0.26
Other ^a	45	1.91
NR	2242	95.32
Low-SES Status	68	2.89
SES NR	1638	69.64
Bilingual Status	433	18.41
Bilingual Status NR	1662	70.67
Special Education Status	99	4.21
Special Education Status NR	1694	72.02

Note. ^aIncludes multi-racial; NR = Not Reported; SES = socioeconomic status

Notably, only 4% of all readers were reported as having a disability or learning difficulty; this includes students receiving special education and intervention services.

Target Word Decoding Accuracy During Independent Reading

In approximately two-thirds of the 43 experiments ($k = 29$), students were required to engage in oral (overt) reading, and target word decoding was reported by the authors (see Table 2.3). Target word decoding accuracy during the independent reading session varied, ranging from 43% – 96% accuracy. The variability occurred, most often, between student groups (e.g., average readers [0.67] vs. poor readers [0.43]; Share & Shalev, 2004) or complexity of the target (e.g., monosyllabic [0.90] vs. polysyllabic [0.54]; Gebremedhen, 2021). Reliably target word decoding accuracy was reported to be positively associated with orthographic learning outcomes (de Jong et al., 2009; MacEachron, 2008), supporting the self-teaching hypothesis claim that phonological recoding is the *sine qua non* of acquiring lexical representation. Although younger readers demonstrated weaker decoding skills related to target words (e.g., Cunningham et al., 2002; Deacon et al., 2019), they showed evidence of word learning—which may challenge the underlying premises of the self-teaching hypothesis.

Table 2.3. Independent Reading Session Data

Citation	Target Word Decoding Accuracy	Text Reading Speed	Reading Comprehension Accuracy
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Dutch			
de Jong & Share, 2007	0.89 (0.11)	oral = 76.0 (22.4) s silent = 66.2 (20.3) s	
de Jong et al., 2009 ₁	0.86 (0.12)	overt = 83.9 (34.4) s covert = 70.8 (30.1) s	overt = 0.67 (0.15) covert = 0.56 (0.20)
English			
Bowey & Miller, 2007	0.80 (0.03)	1.3 (0.5) wps	0.93 (0.96)
Bowey & Muller, 2005	0.69 (0.32)	0.9 (0.4) wps	0.56 (0.22)
Conrad et al., 2019	readers = 0.79 spellers = 0.45		readers = 0.83 (0.21) spellers = 0.79 (0.25)
Cunningham et al., 2002	0.44 (0.13)		
Cunningham, 2006	0.75 (0.12)		0.955
Deacon et al., 2019	0.52 (0.29)		
Gebremedhen, 2021 ₁	overt (monosyllabic) = 0.90 (0.00) overt (multisyllabic) = 0.60 (0.20)	overt (monosyllabic) = 48.0 (6.4) s overt (multisyllabic) = 50.9 (8.2) s covert (monosyllabic) = 35.7 (9.6) s covert (multisyllabic) = 39.0 (7.9) s	overt (monosyllabic) = 0.90 (0.10) overt (multisyllabic) = 0.90 (0.10) covert (monosyllabic) = 0.90 (0.10) covert (multisyllabic) = 0.90 (0.10)
Gebremedhen, 2021 ₂	overt (monosyllabic) = 0.90 (0.1) overt (multisyllabic) = 0.54 (0.2)	overt (monosyllabic) = 48.5 (5.3) s overt (multisyllabic) = 54.3 (7.0) s covert (monosyllabic) = 36.2 (8.5) s covert (multisyllabic) = 39.5 (7.9) s	overt (monosyllabic) = 0.80 (0.20) overt (multisyllabic) = 0.90 (0.10) covert (monosyllabic) = 0.90 (0.10) covert (multisyllabic) = 0.80 (0.20)
Li et al., 2021	single = 0.45 (0.50)		
Li et al., 2022	0.74 (0.44)		
Lowell, 2012 ₂	0.98 (0.13)		
MacEachron, 2008	0.65(0.14)	237 ms	
Martin-Chang et al., 2017	context = 0.62 list = 0.55		
Nation et al., 2007	0.78 (0.26)		

Citation	Target Word Decoding Accuracy	Text Reading Speed	Reading Comprehension Accuracy
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Schwartz et al., 2014	biliterates = 0.55 (0.19) bilinguals = 0.48 (0.15) monolinguals = 0.45 (0.20)		biliterates = 0.84 (0.21) bilinguals = 0.83 (0.18) monolinguals = 0.84 (0.23)
Tucker et al., 2016	base = 0.64 (0.28) morphologic = 0.59 (0.33) orthographic = 0.53 (0.31)		
Wang et al., 2011 ₁	context = 0.96 (0.10) list = 0.87 (0.18)		
Wang et al., 2011 ₂	0.63 (0.28)		
Wang et al., 2012	regular = 0.79 (0.07) irregular = 0.79 (0.20)		
Wang et al., 2013	regular = 0.84 (0.09) irregular = 0.84 (0.21)		
Wang et al., 2023	monosyllabic = 0.71 (0.28) bisyllabic = 0.66 (0.30)		
Pointed Hebrew			
Ben-Uriel, 2010		list = 58.1 (18.3) wpm natural = 88.2 (19.6) wpm predictive = 90.1 (21.1) wpm	natural = 0.87 (0.14) predictive = 0.87 (0.15)
Share, 1999 ₁	0.84 (0.10)		0.88
Share, 2004 ₁	0.93	46 s	0.76
Share, 2004 ₂	0.77	<i>Mdn</i> = 92 s	0.61
Share, 2004 ₃	0.89	<i>Mdn</i> = 125 s	0.80 (0.29)
Share & Shalev, 2004	average = 0.67 (0.20) poor = 0.43 (0.20)	0.486 (0.153) s	average = 0.78 (0.11) poor readers = 0.77 (0.13)
Shoam, 2015 ₂	0.70 (0.19)	8.25 (1.84) wpm	
Zorea, 2010	0.57 (0.25)	0.96 (0.13) wpm	0.938 (.087)

Note. wpm = words per minute; wps = words per second

Word Learning Outcomes

Self-teaching experiments evaluate the extent of word learning after independent reading. Word learning encompasses orthographic learning (Fig. 2.3) and semantic learning (Fig. 2.4). Of the 43 experiments, most ($k = 35$) assessed word learning using orthographic learning measures (i.e., orthographic choice, spelling, word naming) alone, and two studies solely measured semantic learning (e.g., definition production, semantic choice). Just six experiments used a combination of orthographic and semantic learning tasks to measure the extent of word learning. Word learning outcomes were administered on average 5.52 days ($SD = 5.81$ days; range = 0–30) following the self-teaching session.

Orthographic Learning. Data reporting the outcomes from the 35 studies measuring orthographic learning are reported in Table 2.4. Orthographic learning was commonly measured with orthographic choice, word naming, and spelling tasks. Orthographic choice data across 30 experiments provide strong support for the self-teaching hypothesis. Readers selected the learned targets at probabilities that exceeded chance levels in all but four studies. Evidence of orthographic learning through self-teaching was further corroborated by word naming measures, with results from 77% of studies that administered word naming ($k = 13$) indicating significantly decreased reading speed times between learned homophonic foils and targets. These results—most often conducted with upper elementary students—have been replicated across writing systems and language status (Schwartz et al., 2014) providing evidence to support the self-teaching hypothesis. Supporting evidence, however, is less clear in studies including young children, with non-significant differences often being observed in participants' reading times between targets and homophonic foils (Nation et al., 2007; Share, 2004).

Table 2.4. Orthographic Learning Outcomes

Citation	Orthographic Choice <i>M (SD)</i>	Orthographic Decision <i>M (SD)</i>	Spelling <i>M (SD)</i>	Word Naming Accuracy <i>M (SD)</i>	Word Naming Speed <i>M (SD)</i>
Dutch					
de Jong & Share, 2007	overt = 0.66 (0.31) covert = 0.64 (0.30)		overt = 0.62 (0.32) covert = 0.54 (0.32)	target = 0.93 foil = 0.96	target = 1.25(0.38) wps foil = 1.24(0.39) wps
de Jong et al., 2009 ₁	overt = 0.585 (0.19) covert = 0.585 (0.19)				target = 1.31(0.41) wps foil = 1.28(0.37) wps
Staels & Van den Broeck, 2015	target = 0.63 (0.13) foil = 0.37 (0.18)		target = 0.57 (0.18) foil = 0.27 (0.13)	target = 0.91 (0.13) foil = 0.90 (0.14)	target = 1.52 (0.39) s foil = 1.6 (0.43) s
English					
Bowey & Miller, 2007	target = 0.60 (0.22) foil = 0.16 (0.18)				
Bowey & Muller, 2005	target = 0.73 (0.20) foil = 0.19 (0.16)				
Conrad et al., 2019	readers = 0.80 spellers = 0.84		readers = 0.41 spellers = 0.45	readers = 0.85 spellers = 0.91	target = 813 ms foil = 854 ms
Cunningham et al., 2002	target = 0.747 foil = 0.13		0.70 (0.21)		
Cunningham, 2006	context = 0.33 (0.20) scrambled = 0.31 (0.16)		0.43 (0.268)		
Gebremedhen, 2021 ₁	overt = 0.45 (0.25) covert = 0.45 (0.20)		overt = 0.60 (0.25) covert = 0.50 (0.25)		
Gebremedhen, 2021 ₂	overt = 0.65 (0.25) covert = 0.50 (0.25)		overt = 0.65 (0.25) covert = 0.55 (0.20)		
Ginestet et al., 2021	ortho. = 0.67 (0.20) morph. = 0.74 (0.20)		ortho. = 0.26 morph. = 0.41		
Li et al., 2021		story = 0.34 (0.48) scrambled = 0.34 (0.46)	story = 0.31 (0.46) scrambled = 0.07 (0.22)		
Li et al., 2022	story = 0.23 (0.42) scrambled = 0.15 (0.37)		story = 0.40 (0.43) scrambled = 0.47 (0.48)		

Citation	Orthographic Choice <i>M (SD)</i>	Orthographic Decision <i>M (SD)</i>	Spelling <i>M (SD)</i>	Word Naming Accuracy <i>M (SD)</i>	Word Naming Speed <i>M (SD)</i>
MacEachron, 2008	0.651 (0.183)		target = 0.47 (0.23) foil = 0.15 (0.11)	0.77 (0.219)	182 (53) ms
Martin-Chang et al., 2017			context = 0.28 (0.16) isolation = 0.31 (0.15)		
Nation et al., 2007	context (exp.1) = 0.37 (0.36) list (exp.1) = 0.46 (0.26) context (exp.2) = 0.51 (0.30) list (exp.2) = 0.39 (0.27) context (exp.4) = 0.62 (0.33) list (exp.4) = 0.56 (0.41)				
Schwartz et al., 2014			biliterates = 76.9 (0.15) bi = 61.5 (0.04) mono = 64.1 (0.25)	target = 0.70 (0.17) foil = 0.69 (0.18) target = 0.59 (0.15) foil = 0.58 (0.14) target = 0.53 (0.22) foil = 0.56 (0.20)	target = 16 (5.82) s foil = 18.1 (6.42) s target = 20.7 (0.14) s foil = 21.1 (7.25) s target = 20.4 (8.3) s foil = 22.6 (8.66) s
Tucker et al., 2016	base = 0.84 (0.42) morph. = 0.86 (0.35) ortho. = 0.86 (0.37)				
Wang et al., 2011 ₁	0.73 (0.18)	0.79 (0.16)	0.53 (0.21)		
Wang et al., 2011 ₂	context = 0.53 list = 0.51		context = 0.16 list = 0.14		
Wang et al., 2012		regular = 0.38 (0.29) irregular = 0.25 (0.25)	regular = 0.40 (0.30) irregular = 0.16 (0.17)		
Wang et al., 2013		regular = 0.42 (0.29) irregular = 0.28 (0.24)	regular = 0.43 (0.30) irregular = 0.21 (0.19)		
Wang et al., 2023	mono = 0.71 (0.22) bi = 0.68 (0.24)		mono = 0.38 (0.23) bi = 0.32 (0.24)		
Wegener et al., 2022	mass = 0.59 spaced = 0.75		mass = 0.46 spaced = 0.48		

Citation	Orthographic Choice <i>M (SD)</i>	Orthographic Decision <i>M (SD)</i>	Spelling <i>M (SD)</i>	Word Naming Accuracy <i>M (SD)</i>	Word Naming Speed <i>M (SD)</i>
Wegener et al., 2023	mass = 0.63 (0.03) space = 0.84 (0.02)		mass = 0.44 (0.03) space = 0.62 (0.03)		
French					
Sabatier et al., 2023	DHH = 0.58 (0.49) TH = 0.45 (0.50)		DHH = 10.9 TH = 13.4		
Pointed Hebrew					
Ben-Uriel, 2010	no context = 0.61 (0.16) natural = 0.56 (0.18) predictive = 0.59 (0.20)		no context = 0.64 (0.19) natural = 0.58 (0.18) predictive = 0.56 (0.17)		
Share & Shalev, 2004	average = 0.66 poor readers = 0.64		average = 0.58 poor readers = 0.57		
Share & Shalev, 2004	average = 0.66 poor readers = 0.64				
Share, 1999 ₁	target = 0.68 foil = 0.19		target = 0.51 foil = 0.18	target = 0.68 foil = 0.69	target = 816 (338) ms foil = 874 (408) ms
Share, 2004 ₃	real = 0.57 foil = 0.55		real = 0.48 foil = 0.52	real = 0.62 foil = 0.75	
Share, 2004 ₂	0.52		0.46		
Share, 2004 ₁	exp. 1 = 0.72		exp. 1 = 0.61	exp. 1 = 0.77 (0.37)	target = 784 (219) ms foil = 814 (216) ms
	exp. 3 = 0.74		exp. 3 = 0.63	exp. 3 = 0.77 (0.37)	target = 779 (202) ms foil = 781 (235) ms
	exp. 4 = 0.73		exp. 4 = 0.58	exp. 4 = 0.75 (0.40)	target = 787 (219) ms foil = 800 (218) ms
Shoam, 2015 ₁	read = 0.65 (0.18) write = 0.45 (0.25) overall = 0.55 (0.24)		read = 0.54		
Zorea, 2010	0.752 (0.146)	target = 0.54 (0.23) foil = 0.32 (0.22)			

Note. DHH = deaf or hard of hearing; TH = typical hearing; exp. = exposures; mono = monolingual; bi = bilingual

A growing trend within the self-teaching studies is to include an orthographic decision task, with the first published study to include this measure being Wang et al., (2011). Orthographic decision tasks combine traditional orthographic choice and lexical decision tasks—where the target and three foils are presented separately on a screen and the participant must decide if the lexical item was learned during the independent reading task or not. The orthographic decision task is a more stringent measure of orthographic knowledge as the probability of a correct response (correct responses for each of the four items) is 0.0625 rather than 0.25, as is in the traditional orthographic choice task. The initial evidence of orthographic learning provided by an orthographic decision task appears robust (Wang et al., 2011, 2013), with scores significantly greater than chance alone, for typical readers in Grades 2 and 3.

Data collected using student spelling as an outcome measure provides the least support for the self-teaching hypothesis. The questionable support from these data may partially be due to the challenge associated with scoring spelling data, the difficulty of quantifying word learning from the task, or the way outcomes are scored. Some researchers (e.g., Share, 1999, 2004) compared student productions to the likelihood of producing a correct response at the symbol or letter level, whereas others relied on whole word spelling scoring (e.g., Share & Shalev, 2004) or target letter spelling (e.g., Geremedhen, 2021). It could also be the case that students do not acquire sufficiently high-quality lexical representations from independent reading alone.

Spelling is more difficult than word naming as it requires more precision. Therefore, spelling is hypothesized to be the *mechanism* for developing high-quality lexical representations (Bahr et al., 2009). Indeed, when students write—or spell—the

targets during the self-teaching task, outcomes improve (e.g., Conrad et al., 2019; Shoam, 2015). Spelling as a mechanism of word learning may be attributable to the motor integration or increased attentional processes required to complete spelling tasks (Andrews, 2008; Andrews et al., 2020). A parallel line of research aims to examine how spelling induces orthographic learning with typically developing students (Conrad et al., 2019; Ouellette, 2010; Shahar-Yames & Share, 2008). Results across these studies indicate that relative to reading practice alone, spelling practice results in significantly greater accuracy on measures of orthographic choice and spelling production. Most importantly, Conrad et al. (2019) found that lexical representations established during spelling extended to reading that same word. The results from these studies underscore the notion that spelling may help students develop higher-quality lexical representations over reading. However, there is only limited evidence for this hypothesis, and no studies have investigated the relative effects of independent spelling versus independent reading on the word learning outcomes of students with dyslexia.

Semantic Learning. Only two studies (Kivrak, 2019; Pulido, 2003) exclusively examined semantic learning outcomes via a self-teaching paradigm. Data reporting the outcomes from these studies are reported in Table 2.5. These studies focused on novel vocabulary learning following limited exposures. Results indicated that phonological information significantly influenced semantic learning outcomes following reading—a clear extension of the self-teaching hypothesis.

Table 2.5. *Semantic Learning Outcomes*

Citation	Expressive Vocabulary	Receptive Vocabulary
	<i>M (SD)</i>	<i>M (SD)</i>
Kivrak, 2019	upper = 0.00 lower = 0.63	upper = 0.06 lower = 0.25
Pulido, 2003	0.35 (0.44)	0.23 (0.35)

Coordinated Word Learning. Only six experiments across four studies sought to examine both aspects of word learning—orthographic and semantic learning—following independent reading (see Table 2.6 for outcomes). Lowell (2012) found evidence that skilled, adult readers acquired orthographic and semantic information of novel words from just a single exposure in context. However, Adlof et al. (2016) reported differences in word learning between young readers and adults with respect to contextual facilitation. Young readers learned orthographic forms better in isolation than in context. While adults derived more semantic information from context than young readers, as evidenced by better performance on semantic posttests between conditions. Furthermore, number of exposures affected orthographic learning, but quality of exposures influenced semantic learning, suggesting different underlying mechanisms for orthographic and semantic learning. Interestingly, similar findings were observed by Wang et al. (2012) when they measured students learning of regular and irregular words (Wang et al., 2012). In this study, vocabulary knowledge significantly predicted Grade 3 readers' success in orthographic learning of irregular words.

In one of the few self-teaching studies to assess coordinated word learning, Deacon et al. (2019) expanded the scope of the self-teaching hypothesis to examine the extent to which readers in Grades 1 and 2 acquire spellings and meanings of novel words during independent reading. The authors examined orthographic and semantic learning in 66 typically developing students learning to read English using the orthographic-learning paradigms (see Wang et al., 2011). Students read 12 short stories out loud in sets of three, each containing four exposures of the target words. In addition to traditional measures of orthographic learning (i.e., orthographic choice, target decoding), semantic learning was

measured using a semantic choice task. The semantic choice task, modeled after the orthographic choice task, requires students to select the correct picture, among four pictures, that illustrated a target from the reading task. Results indicated that scores on both the orthographic and semantic choice measures were above chance for each task at each time point, providing evidence of both orthographic and semantic learning via self-teaching.

Table 2.6. *Combined Word Learning Outcomes*

Citation	Orthographic Choice	Spelling	Expressive Vocabulary	Receptive Vocabulary
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Adlof et al., 2016 ₁		child = 0.61 (0.04) adult = 0.80 (0.04)	child = 0.43 (0.09) adult = 1.29 (0.20)	child = 0.34 (0.03) adult = 0.74 (0.06)
Adlof et al., 2016 ₂		0.58 (0.05)	0.11 (0.13)	0.11 (0.13)
Brusnighan et al., 2014 ₂		NH = 0.38 NN = 0.25		NH = 0.56 NN = 0.59
Deacon et al., 2019	G1 = 0.62 (0.22) G2 = 0.72 (0.16)			G1 = 0.55 (0.23) G2 = 0.74 (0.18)
Lowell, 2012 ₁	strong = 0.52 moderate = 0.50			strong = 0.41 moderate = 0.37
Lowell, 2012 ₂	high = 0.51 low = 0.53			high = 0.42 low = 0.42

Note. Subscript indicates experiment number detailed in article
exp. = exposures; NH = novel homophone; NN = novel non-word; G = grade;
strong = strong constraint;; moderate = moderate constraint; high = high motor
context; low = low motor context

Limitations and Future Directions

A key limitation to this corpus of studies stems from the outcome measures selected. The acquisition of lexical representations develops episodically over a continuum that ranges from recognition to retrieval. Researchers (e.g., Nation, 2017;

Perfetti & Hart, 2002; Reichle & Perfetti, 2003; Share, 1995) suggest that word learning progresses gradually, from initially recognizing the word (simply knowing you have seen it before) to retrieving it quickly and automatically from memory. It would, therefore, be inappropriate to determine if students acquire lexical representations after reading a short text with few exposures to target words without measuring the degree—or quality—of those representations. Yet, no self-experiments have measured word learning outcomes through the lens of a continuum of learning. Commonly, choice tasks are used. These tasks may inflate the degree to which lexical representations have been acquired as they only measure recognition, an initial entry point on the continuum of learning.

Spelling and word naming outcomes are also commonly used in research. These measures only measure orthographic learning and inherently cannot provide insight into other aspects of word learning, namely semantic learning (Taylor et al., 2011). Thus, orthographic learning outcomes alone cannot provide reliable information about the development of lexical representations needed for efficient word identification. Since only six experiments examined word learning through both orthographic *and* semantic measures, there is still much to discover about self-teaching mechanisms underlying word learning.

Another limitation of research examining the self-teaching hypothesis stems from the narrow population of readers from which the studies have sampled. Much of the orthographic learning and semantic learning research includes typically developing elementary school readers or skilled adult readers as participants. These findings shed light on how skilled readers learn words and whether their orthographic learning can be explained by the self-teaching hypothesis. If the self-teaching hypothesis accurately

captures the fundamental mechanism of word learning—specifically, phonological recoding—then students with dyslexia are likely to encounter significant challenges in developing stable and high-quality lexical representations. This difficulty arises because phonological recoding relies on the ability to generate, store, and retrieve phonological forms of words in episodic memory, a foundational step in word learning (Perfetti et al., 2005). Since students with dyslexia frequently exhibit deficits in phonological processing (Alt et al., 2017; Snowling, 1998), they may struggle to effectively encode phonological word forms. As a result, these initial disruptions in phonological storage could impair their ability to form high-quality lexical representations, ultimately hindering their ability to develop word reading efficiency over time.

Relying on one mechanism, such as phonological recoding, for word learning is problematic within the context of the English language, where mappings between graphemes and phonemes deviate at the individual sound level (Treiman et al., 1995). Share (1995, 2008) identified orthographic knowledge as a secondary mechanism of word learning. However, students with dyslexia often also have deficits in orthographic knowledge (Georgiou et al., 2021; Harm & Seidenberg, 2001). When phonological and orthographic knowledge skills are impaired, as with students with dyslexia, other mechanisms may explain word learning. Examination of these other mechanisms has yet to be investigated. It is imperative that we work to understand the contexts and experiences students with dyslexia need to acquire high-quality lexical representations needed for word reading efficiency.

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CHAPTER 3

WORD LEARNING OF READERS WITH DYSLEXIA: A TEST OF THE SELF-TEACHING HYPOTHESIS

It is indisputable that reading is about words (cf. Perfetti, 2017; Seidenberg et al., 2022). The ability to identify printed words efficiently—accurately and rapidly—is the most important acquisition in reading development (Ehri, 1980; Perfetti, 1985, 2007). Successful reading requires processing written words both individually and within the context of sentences in which they are situated (Perfetti & Stafura, 2014). Readers who retrieve lexical representations (i.e., words) efficiently have a higher probability of successful comprehension (Perfetti, 1985, 1992).

Given a string of letters, readers must retrieve information stored in memory (i.e., lexical representation) instantaneously to (a) identify the specific word that string of letters represents and (b) situate the identified word within the text to create a coherent understanding of what they are reading (Perfetti & Stafura, 2014). A determinant of lexical retrieval (i.e., word identification)—or the automaticity of word identification—is asserted to be the quality of the representations in long-term memory (*lexical quality hypothesis*; Perfetti & Hart, 2001, 2002) because efficiency only transpires when the orthographic form of a word (i.e., spelling) triggers its complete identification, in that all representations of its identity—phonological, syntactic, and semantic—are activated concurrently by its spelling (Perfetti & Hart, 2001, 2002). Therefore, to form a lexical representation, readers must acquire knowledge of a word’s identity.

A word's identity is composed of defining variables or constituents, depicted in Figure 3.1. The orthographic form (i.e., spelling) is an invariant sequence of letters that connects to linguistic specification (i.e., pronunciation and grammatical features) and connects to semantic (i.e., meaning) and pragmatic features (Ehri, 2005; Perfetti, 1985, 1992, 2017). It is hypothesized that successful readers efficiently activate all constituents of a word's identity synchronously when presented with any single form (Perfetti, 1985; Perfetti & Hart, 2001, 2002).

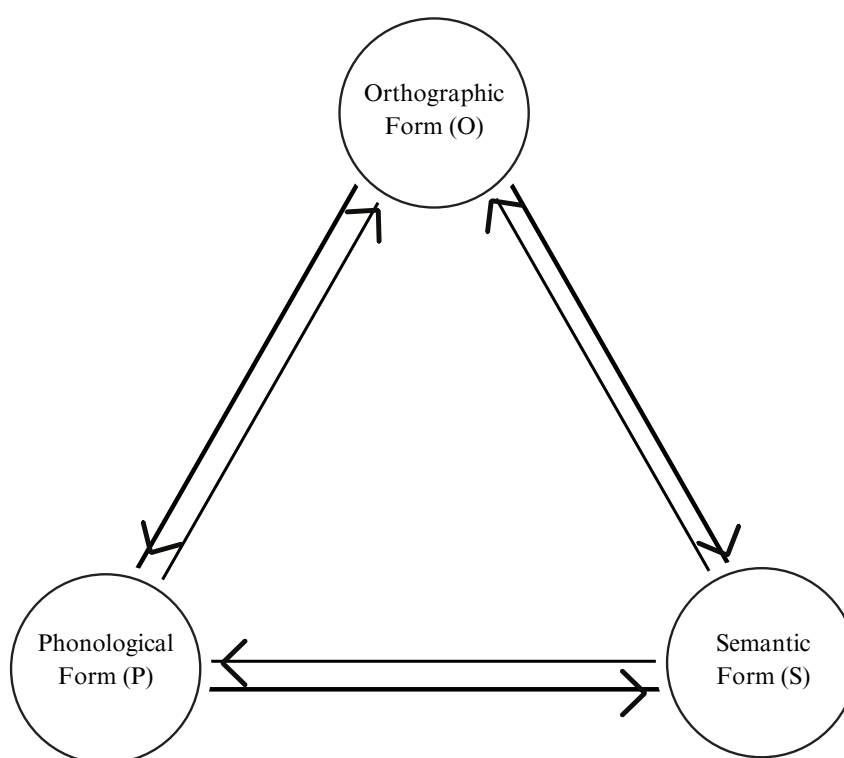


Figure 3.1. *Word Identity (Adapted from Perfetti, 2017)*

Efficient word reading is dependent on stored high-quality lexical representations in long-term memory (Cunningham & Stanovich, 1997). These representations are constructed from knowledge of the specific constituents of word identity, including its orthographic, phonological, and semantic forms (Perfetti, 1992, 2017) *and* strong bindings between those constituents. The bindings are bidirectional and exist between all

three constituents. A stored high-quality lexical representation enables a reader to automatically produce a constituent form in response to another constituent form. For example, when given the phonological form of a word (i.e., pronunciation), readers with a high-quality lexical representation can accurately and quickly produce the orthographic form (i.e., spelling). This pathway represents the phonological-orthographic (P–O) connection. Conversely, when given the written word (i.e., the spelling visually), readers with high-quality lexical representations can produce the correct phonological form (i.e., pronunciation) efficiently. This example illustrates the orthographic-phonological (O–P) connection. When readers have developed a high-quality lexical representation—all six pathways tightly secured together—efficient word reading can transpire (Cunningham & Stanovich, 1997; Perfetti, 1985, 2017). The bindings between constituent forms illustrate the necessary learning required to develop a high-quality lexical representation (viz., word learning).

Word learning can be conceptualized as the amalgamation of orthographic learning and semantic learning (Steady et al., 2017). Orthographic learning describes the transition from laboriously sounding out a new word to the automatic recognition of the word (Castles & Nation, 2006). It stems from the mappings of phonological forms with orthographic forms (e.g., /ɪn vɛn ʃən/ – *invention*). Semantic learning, in its earliest form, can be labeled vocabulary learning (Ouellette, 2006). It stems from the mapping of phonological forms or orthographic forms with semantic forms (e.g., /ɪn vɛn ʃən/ – novel creation that solves a problem; *invention* – novel creation that solves a problem). Thus, word learning refers to the complete integration of *all* constituents of a word’s identity—sound, spelling, and meaning.

High-quality lexical representations are stored in long-term memory. The lexicon—the brain’s library of words—houses words (i.e., lexical representations), the by-product of word learning *and* word parts, or the knowledge of bindings between constituent forms at a sublexical level. For example, the suffix *–ed* has three O–P connections: /t/, /d/, /ɪd/. The correct pronunciation of the affix in a given word depends on the spelling of the base word. Readers also store knowledge of semantic bindings. the suffix *–ed* indicates past tense when added to base words.

Word knowledge can be acquired explicitly or implicitly (Share, 1995, 2008). Explicit word learning occurs when the phonological, orthographic, and semantic forms are first taught to students, and the connections between the forms are practiced with feedback (e.g., Baron et al., 2018; Ricketts et al., 2021). This transpires at the lexical and sublexical levels. Explicit instruction solely at the lexical level is not feasible. That is, it is impractical to teach students all of the words needed for proficient reading, particularly given a typically developing reader—one who does not experience difficulties in decoding, fluency, or comprehension—in Grade 8 has approximately 10,000 word-specific representations stored in the lexicon (Brysbaert et al., 2016; Castles & Nation, 2022; Compton et al., 2023). Consequently, reading researchers (see Boucher et al., 2024; Hall et al., 2022 for reviews) have developed interventions to target sublexical knowledge while others (e.g., Share, 1995; Steacy et al., 2019) have theorized and tested the mechanisms undergirding implicit word learning—independently acquiring lexical representations from connected text without corrective feedback or support.

Dyslexia

Dyslexia—a specific learning disability characterized by difficulties with word-level reading—is the most common disability affecting school-aged children in the United States (Wagner et al., 2020). The neurological and cognitive influences on dyslexia are multifactorial (Compton, 2021), and the manifestation of dyslexia occurs on a continuum (see Catts & Petscher, 2022; Pennington, 2006). However, a core deficit in phonological processing is experienced by most students (Snowling, 1998; Stanovich, 1998). This disruption to the phonological system interferes with the ability to attend to and manipulate individual linguistic sounds, which is critical to deciphering the alphabetic principle, developing decoding skills, and acquiring a robust lexicon (Compton, 2021; Harm & Seidenberg, 2001).

A fully developed lexicon is essential for proficient reading comprehension. As readers become skilled, the lexicon transitions from a functional system—comprising both sublexical knowledge (e.g., letter-sound patterns) and burgeoning lexical representations—to a stable, autonomous lexicon (Perfetti, 1992). Readers must increase the number of lexical representations acquired and increase the quality of those representations to establish a context-free autonomous lexicon full of high-quality lexical representations. Current evidence suggests that readers with dyslexia may have difficulty establishing high-quality lexical representations (Perfetti, 2007). However, the cause of this difficulty is not yet defined.

When the functional lexicon is underdeveloped, students may experience *lexical asymmetry* (Compton et al., 2014). Compton et al. (2023) hypothesize that lexical asymmetry results from limited sublexical knowledge, predominantly O–P connections,

and impedes readers decoding skills, thus weakening their ability to engage in lexical learning. In the early stages of word learning, weak phonological processing skills often translates to weaker or less stable word forms stored in episodic memory (Perfetti et al., 2005), affecting both spoken and written forms (Di Betta & Romani, 2006). Efficient word identification depends on forming strong connections between all forms of a word (Hulme et al., 2007). Yet, students with dyslexia often experience challenges in forming these cross-modal verbal associations (Messbauer & de Jong, 2003). This pattern suggests that dyslexia may involve a specific impairment in linking phonological and orthographic forms when learning new words, which may directly hinder the attainment of high-quality lexical representations during independent reading.

Understanding how students with dyslexia acquire the coherent and stable lexical representations fundamental to skilled reading comprehension (Perfetti & Hart, 2001, 2002) is central to developing robust interventions. The self-teaching hypothesis is one theoretical framework that offers insight into this acquisition process (Share, 1995). The central claim is that individuals acquire lexical representations of new words through exposure to written word forms during independent reading via phonological recoding. However, the extent to which students with dyslexia engage in word learning via self-teaching is unclear.

The Self-Teaching Hypothesis

The self-teaching hypothesis (Jorm & Share, 1983; Share, 1995) proposes that children acquire lexical representations during independent reading. Coined the *sine qua non* (or absolutely necessary skill) for word learning, the self-teaching hypothesis suggests that the process of translating print to speech, the act of phonological

recoding¹—without feedback—provides rich opportunities for readers to acquire lexical representations (Share, 1995, 2008). It is hypothesized that successful phonological recoding, paired with orthographic knowledge as a secondary factor, enables readers to acquire lexical representations in an item-by-item manner (Castles & Nation, 2006; Share, 2008). Further, collective ongoing experiences with many new words allows the reader to accumulate a lexicon of lexical representations in long-term memory.

Researchers have tested the self-teaching hypothesis with typically developing readers in Hebrew (e.g., Share, 1999, 2004), Dutch (de Jong & Share, 2007), Chinese (e.g., Li et al., 2020), and English (e.g., Cunningham et al., 2002), providing general evidence that orthographic learning occurs during independent reading through a self-teaching mechanism. In his seminal study, Share (1999) examined the orthographic learning following independent reading of 40 Grade 2 readers learning Hebrew. Ten homophonic target pseudowords were embedded four or six times in short texts. Three days following students' independent reading of the texts, results from three orthographic learning tasks (i.e., orthographic choice, naming, spelling) provided evidence of orthographic learning of the targets. That is, students recognized, named, and spelled the targets correctly significantly more than they recognized, named, or spelled the corresponding homophonic foils.

As an extension of Share (1999), Cunningham et al. (2002) examined the orthographic learning of 34 typically developing Grade 2 students learning English. Results pointed to robust orthographic learning via self-teaching as measured by all orthographic learning outcomes (i.e., orthographic choice, spelling, word naming), thus

¹Phonological recoding is the process of converting letters to sounds and then blending those sounds together to form words. It is a specific skill encompassed in decoding—transfer of the written code to the language code (Perfetti & Hogaboam, 1975). In this paper, phonological recoding and decoding will be used interchangeably.

replicating Share. Cunningham et al. further extended Share by examining which variables related to orthographic learning (i.e., non-verbal IQ, vocabulary, working memory, rapid automatized naming [RAN], and orthographic knowledge) predicted the degree of orthographic learning. Results indicated that target word decoding accuracy and orthographic knowledge significantly predicted unique variance in orthographic learning, whereas general cognitive ability and RAN did not reach significance in the models when target decoding accuracy was included. These findings support the self-teaching hypothesis assertion that orthographic learning occurs primarily due to phonological recoding, but also that orthographic knowledge maintains a secondary role (Share, 1995).

The number of times a reader must encounter a word to acquire a secure lexical representation of the word is believed to vary as a function of person and word characteristics (Nation & Castles, 2017; Share, 2008). There is evidence to suggest that typically developing readers develop a robust representation from as few as three exposures to a word (Hogaboam & Perfetti, 1978; Nation et al., 2007; Share, 1999). However, it is unclear how many exposures to a word students with dyslexia might need to develop an equally robust representation. Hoagboam and Perfetti (1978) found that Grade 3 students with weak reading comprehension needed at least six exposures to show evidence of a burgeoning representation determined by word naming speed. These results align with He and Tong (2017), who found that Chinese children with dyslexia showed impaired statistical learning—a hypothesized essential mechanism in orthographic learning (e.g., Apel et al., 2006)—with a small but not large number of exposures. Thus, students with dyslexia may need more target exposures during independent reading than typically developing readers to develop robust lexical representations. However, to date, I

am unaware of any published study that has examined the number of exposures needed by students with dyslexia to acquire lexical representations during independent reading.

Instance-Based Framework for Learning Word Meanings

The instance-based framework for learning word meanings (Reichle & Perfetti, 2003) parallels the self-teaching hypothesis and posits that semantic learning from discourse happens incrementally through the gradual refinement of meaning gained from the amalgamation of multiple exposures to words in context. Much of the semantic learning research (e.g., Brusinghan et al., 2012; Kivrak, 2019; Smejkalova & Chetail, 2023) includes skilled adult readers as participants, which sheds light on how skilled readers learn words. Studies including developing readers and readers experiencing reading difficulties are, however, necessary to examine these processes across readers.

Several factors are influential to semantic learning (see Nagy et al., 1987; Swanborn & Glopper, 1999). For instance, exposure frequency has emerged as a robust predictor of semantic learning following independent reading of sentences (e.g., de Long & Folk, 2022), paragraphs (e.g., Hulme et al., 2022), and novels (e.g., Pellicer-Sánchez, 2015). In some instances, researchers have provided evidence to suggest that skilled readers acquire semantic learning with as few as one exposure, with evidence of stronger representations after six and eight exposures (Godfroid et al., 2018; Webb, 2007).

Another identified factor that affects the semantic learning outcomes following independent reading is the type of exposure. Evidence suggests greater acquisition of word meaning when new words are presented across multiple contexts versus an equal number of exposures within the same context. For example, Smejkalova and Chetail (2023) found that the semantic learning of pseudowords in adult readers improved when

the varied contexts included both informative and uninformative contexts, corroborating the results of previous research (e.g., Balass, 2011; Eskenazi et al., 2018). An informative context includes semantic information about the target word, whereas an uninformative context only includes orthographic information about the target in a context-neutral sentence. However, Lowell (2012) found that while differences in context quality affected word reading behaviors measured by eye-tracking, there were no significant differences in recognition and meaning accuracy on posttests. Thus, a variety of exposures, regardless of contextual information, may improve semantic learning—this could potentially be associated with a spacing effect, which can significantly impact orthographic learning (Wegener et al., 2022). However, to date, I am unaware of any published study examining the number of exposures or contexts needed by students with dyslexia to acquire lexical representations during independent reading.

Word Learning

Some factors that affect semantic learning, such as context and exposures, are reported to have null effects on orthographic learning. Target decoding accuracy during independent reading tends to be better when initial orthographic exposure transpires in context rather than isolation (Ben-Uriel, 2010); however, the opposite is found with orthographic learning outcomes (Nation et al., 2007). These conflicting findings suggest that context aids in identifying unknown words but may reduce orthographic learning efficiency (Ben-Uriel, 2010). The interplay between phonological recoding, context, and exposures in word learning is complex and reciprocal. Phonological recoding may provide the foundation for recognizing and processing words, whereas context may offer the semantic framework for meaning acquisition—both necessary for word learning.

Repeated exposures may strengthen both phonological and semantic representations, creating robust memory traces that support the acquisition of high-quality lexical representations (Leach & Samuel, 2007; Salasoo et al., 1985). However, the extent to which each factor affects word learning is not yet determined. There is still much to learn about how readers acquire the impressive lexicon needed for skilled reading. Thus, it is important to continue exploring interactions and the balancing act between orthographic and semantic learning when securing robust lexical representations characterized by strong mappings between all constituents of word identity. Unfortunately, the coordination of both orthographic and semantic learning following independent reading is understudied (Compton et al., 2014). In fact, to date, no study has been conducted examining what readers with dyslexia learn about words following independent reading using a self-teaching paradigm.

In one of the few self-teaching studies examining coordinated word learning (i.e., orthographic and semantic learning), Deacon et al. (2019) expanded the scope of the self-teaching hypothesis to examine the extent to which young readers acquire meanings of novel words during independent reading. Grounded in the lexical quality hypothesis (Perfetti & Hart, 2001, 2002), which emphasizes the importance of semantic information in acquiring high-quality lexical representations (Perfetti, 2017), Deacon et al. aimed to integrate findings from previous self-teaching (e.g., Cunningham et al., 2002) and vocabulary (e.g., Cain et al., 2004) experiments. The authors examined orthographic and semantic learning in typically developing students learning to read English. The procedures resembled that of other self-teaching paradigms (e.g., Cunningham, 2006; Mimeau et al., 2018; Wang et al., 2011). Grade 1 and 2 students read 12 short stories out

loud in sets of three, each containing four exposures of the target words. In addition to traditional measures of orthographic learning (i.e., orthographic choice, target word decoding), semantic learning was measured using a semantic choice task. The semantic choice task, modeled after the orthographic choice task, required students to select the correct picture among four that illustrated a target from the reading task. Results indicated that scores were above chance for each task at each time point, providing evidence of both orthographic and semantic learning via self-teaching. Unfortunately, our understanding of coordinated word learning has not been robustly explored; thus, generalized claims cannot yet be drawn.

Word Learning by Students with Dyslexia

The self-teaching mechanism for word learning is theoretically applicable to readers at all levels, from beginners to experts (Share, 1995). However, students with dyslexia often have deficits in phonological skills (Alt et al., 2017; Snowling, 1998) and orthographic knowledge (Georgiou et al., 2021; Harm & Seidenberg, 2001), impeding their experience with print (Stanovich et al., 1986), thus resulting in fewer opportunities for self-teaching during independent reading (Compton et al., 2023; Share, 1995).

To date, the evidence of self-teaching as a mechanism for word learning in students with dyslexia and other learning disabilities is mixed (e.g., Martinez-Garcia et al., 2019; Share & Shalev, 2004). Recently, Li and Wang (2023) conducted a systematic review of orthographic learning outcomes from self-teaching studies. They found that readers with reduced decoding skills acquired less robust learning from self-teaching compared to typically developing students. That is, readers with dyslexia may only acquire low-quality representations from independent reading, which may be one cause

of sustained difficulties. However, these claims stem from only five studies (Bar-Kochva et al., 2016; Martínez-García et al., 2019; Share & Shalev, 2004; Staels & van den Broeck, 2015; Suárez-Coalla et al., 2014), none of which included participants whose first language was English. The limited evidence indicates some level of orthographic learning in students in spite of phonological impairments. This evidence, paired with Deacon et al.'s (2019) findings of orthographic and semantic learning following mediocre target decoding, suggests that phonological decoding may not be necessary for orthographic and semantic learning to occur. The previous studies involving students with reading difficulties were comparative and not designed to examine the extent of word learning via self-teaching of students with dyslexia, nor did they include students learning to read English. This study aims to address those gaps.

Current Study

The current study employed the seminal self-teaching paradigm (Share, 1999) with a within-participant (exposure level) design to examine the extent to which students with dyslexia learn new words via self-teaching. Grade 3 students with dyslexia read short texts containing four or eight exposures to a homophonic pseudoword target. Researchers (e.g., Nation, 2017; Perfetti & Hart, 2002; Reichle & Perfetti, 2003; Share, 1995) suggest that word learning progresses gradually (see Figure 3.2), from recognition to automatic production and retrieval. Thus, nine word learning tasks meant to assess this continuum of learning were administered immediately following students' independent reading and 3–7 days later. Resulting data were used to answer three research questions:

1. To what extent do students with dyslexia acquire *high-quality* lexical representations of regular words following independent reading?

2. Is the quality of the acquired lexical representation a function of the number of exposures (4 vs 8) of the target word?
3. Does target word decoding accuracy and/or text reading fluency during independent reading predict the quality of lexical representations?

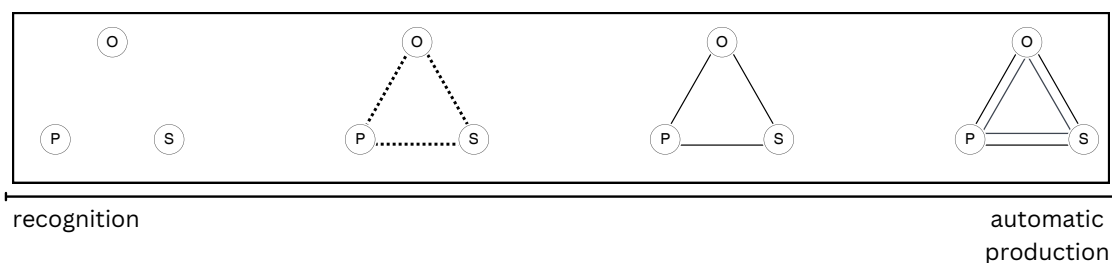


Figure 3.2. *Continuum of Word Learning*

For RQ1, participants' accuracy from each of the nine learning measures were analyzed to examine the extent of word learning. Based on theory and prior research, each of the nine measures employed could be “placed” along the continuum of word learning. We first explored our hypothesized placement of each measure visually to substantiate our claims. From there, each score was aggregated together in such a way that placement on the continuum acted as the weight. This formed a quality composite score unique to each item and participant. This quality composite score was then used as the outcome variable for the explanatory item-response models (EIRMS; de Boeck et al., 2017) used to address RQ2 and RQ3.

Method

Participants and Setting

Students with dyslexia in Grade 3 ($M = 9.8$ years) were recruited to participate in this study from schools in the Southeast and West regions of the United States. Students attended a range of schools, including five specialized private schools serving students

with dyslexia and other language-based learning disabilities, four rural public schools, and two urban public schools. Prior to any data collection, parent permission, approved by the first author's institutional review board, was sent home with students identified by the school. After parent permission was obtained, 60 students were asked to provide verbal assent to participate. Students were screened for inclusion in the study using the *Test of Word Reading Efficiency, Second Edition* (TOWRE; Torgesen et al., 2012) to ensure participants had significant word-level reading difficulties (see description in *Measures* below). The TOWRE measures one's ability to recognize familiar words on sight and sound out words accurately and fluently. The test includes two timed (45 s) subtests where students read as many words (Sight Word Efficiency) or nonwords (Phonemic Decoding Efficiency) as possible out loud from the provided lists. It has excellent reported reliability, .96. A composite standard score was calculated by combining the scale scores of the two subtests and used as an indicator of reading performance. Students who scored at or below the 30th percentile on the TOWRE were included in the study. In total, 57 students participated. See Table 3.1 for demographic data as reported by parents.

Table 3.1. *Student Demographic Data*

School Type	<i>n</i>	Age ^a	Gender		Race					Latinx	TOWRE ^a
			F	M	White	Black	Asian	Multi	Other		
Independent	31	9.3 (0.6)	13	18	26	1	0	3	1	1	78.1 (8.4)
Public (Urban)	14	8.8 (0.5)	6	8	8	0	1	5	0	12	72.7 (6.5)
Public (Rural)	12	8.8 (0.5)	6	6	11	0	1	0	0	3	77.3 (10.5)
<i>N</i>	57	9.8 (0.6)	25	32	45	1	2	8	1	16	76.6 (8.6)
%			43	56.1	79	1.8	3.5	14.0	1.8	28.1	

Note. ^aReported as mean (standard deviation); TOWRE = *Test of Word Reading Efficiency*; F = female; M = male; Multi = multi-racial

Procedure

Students worked individually with a researcher in a separate space in their school for three sessions. Throughout each session, students earned stickers for task completion (see Appendix A) and received small prizes (e.g., slime, bracelet, pens, etc.) at the end of each session. Figure 3.3 provides an overview of the study procedures. Session 1 occurred 1–17 days ($M = 3.25$; $SD = 3.91$) prior to Session 2. Session 2 occurred 3–7 days ($M = 4.23$; $SD = 1.41$) prior to Session 3.

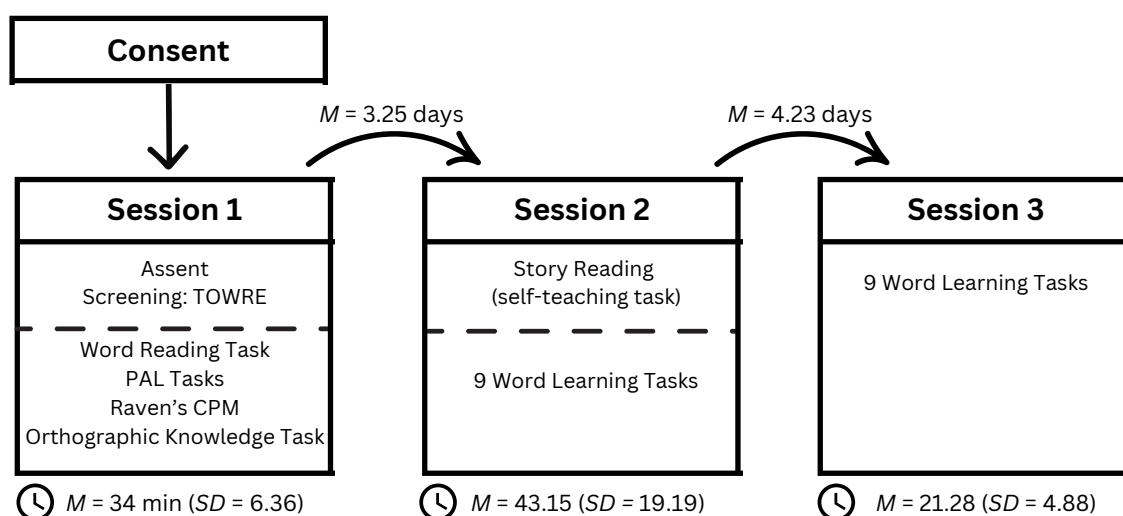


Figure 3.3. *Study Procedures Overview*

Session 1 consisted of screening and descriptive measures and, on average, lasted 34 min ($SD = 6.36$). After providing assent, students were screened using the TOWRE. Students who did not meet the eligibility criteria ($n = 3$) were not included in the remaining study components and were allowed to select a prize and return to class. Students who met the study's eligibility criteria (i.e., ≤ 30 percentile on TOWRE) were individually administered a proximal word reading task, paired-associate learning tasks (Hulme et al., 2007), Raven's Colored Progressive Matrices (Raven, 1998), and an

orthographic knowledge task (Conrad et al., 2013). Data collected using these descriptive measures are being used as part of a larger research project (see Appendix B for full descriptions)

Session 2 began with students reading eight short stories aloud (see Appendix C for all experimental stories). The experimenter presented each story, read the title (Note: no title included an experimental target), and told the student to begin. No corrective feedback was provided at any point. If a student asked for help, the experimenter told them to try their best. All readings were timed and audio recorded for the purpose of measuring students' word reading accuracy and fluency. After reading each story, students were asked two reading comprehension questions to gauge the student's understanding of the story. The comprehension questions could only be answered on the basis of the story, not prior knowledge (see Appendix D for comprehension questions). Students' responses to the questions were scored for accuracy and summed across the eight stories as a measure of reading comprehension. After students completed reading all eight stories, a 2–5 min break was provided. Following the break, students completed the nine word-learning tasks in the order detailed below. On average, Session 2 lasted 43.15 min ($SD = 19.19$).

During Session 3, all nine word-learning tasks were completed again to measure the durability of word learning acquired in the self-teaching session. Once completed, students were asked which invention was their favorite. These social validity data were exploratory in nature and not reported as part of this dissertation. The delayed post-test session lasted approximately 21.28 min ($SD = 4.88$).

Experimental Materials

Targets

Targets were created through a multi-step process (see Appendix E) to systematically create eight homophonic pseudoword pairs (see Table 3.2).

Table 3.2. *Target Homophonic Pseudoword Pairs*

Target Phoneme	Pseudoword Pairs			
/eɪ/	taid	tade	zail	zale
/i/	jeat	jeet	vean	veen
/oʊ/	goak	goke	foat	fote
/ə/	mern	murn	sert	surt

To control for any preference for one spelling over the other (e.g., spelling /zeɪl/ as *zail* rather than *zale*), the pseudowords were counterbalanced such that half of the students read one spelling and the remaining students read the alternative spelling. The pseudowords were also counterbalanced across four and eight exposures so that all targets appeared in both conditions. All students were exposed to half of the target pseudowords four times and the remaining half of the target pseudowords eight times.

Consistent with previous self-teaching experiments (see Share, 1999, 2004), an engaging context for learning was created to represent a natural setting. Therefore, each target homophonic pseudoword pair represented a new invention created by a fictitious character—Professor Parsnip—with a knack for making up clever inventions (Mimeau et al., 2018; Murray et al., 2022; Wang et al., 2011). Each target homophonic pseudoword pair was assigned a picture representing the invention and a definition describing the target's form and function. For example, the target *zail/zale* was presented as the invention shown in Figure 3.4. A *zail/zale* is used to clean your bedroom for you. It is a

robot with lots of arms. A complete list of targets paired with each picture representation and associated definition can be found in Appendix F.

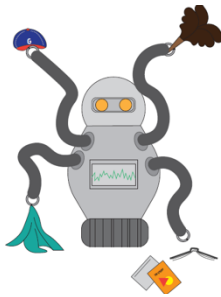


Figure 3.4. *Example Invention²* (Mimeau et al., 2018; Wang et al., 2011)

Experimental Stories

Eight short base stories, each with four versions (2 exposure levels x 2 target word spellings), were adapted from previous orthographic learning studies ($n = 3$; Mimeau et al., 2018; Wang et al., 2011) or created for this study ($n = 5$). Each of the eight base stories was associated with one target pronunciation (e.g., /zeɪl/) and had two versions with one target spelling (i.e., <zail>) at each of the exposure levels (4 and 8), and two with the other spelling (i.e., <zale>) at each of the exposure levels ($2 + 2 = 4$ versions). To decrease the number of exposures from eight to four, the target pseudoword was replaced with the pronoun *it*, sentences were combined, and prepositional phrases were deleted. Overall, the eight base stories with eight exposures of the target pseudowords ranged in length from 77–94 words ($M = 87.5$, $SD = 6.82$) and contained 9–11 sentences ($M = 10.25$, $SD = 1.16$). The eight stories with four exposures of the targets

²Many thanks to Drs. Catherine Mimeau and Hua-Chen Wang for sharing research materials and insights.

ranged in length from 72–89 words ($M = 82.25$, $SD = 6.69$) and contained 9–11 sentences ($M = 10.13$, $SD = 1.25$).

All eight base stories followed the same structure and included parallel information about the inventions, including the intervention's function and form. Half of the target pseudoword exposures (i.e., 2 or 4) were embedded in an informative context, thereby including both orthographic and semantic information, and half of the exposures were in an uninformative context, which only included orthographic information in a neutral context. Each story began with the character(s) and a problem (e.g., *Lin had a messy bedroom, and her mom told her to clean it.*), followed by a sentence containing the first orthographic exposure of the target (e.g., *So, Lin got the zail.*). Next, the invention's function and form were introduced (e.g., *The zail is used to clean your bedroom for you. The zail is a robot. The zail has lots of arms, so it can clean fast.*). The remaining text of each story delineates the main character using the invention to solve the initial problem. All stories contain one sentence with an interjection (e.g., *Wow!*) and a picture of the associated invention to add interest and resemble materials commonly used in Grade 3 classrooms.

To ensure the stories were similar and readable for students with dyslexia, the *Coh-Metrix Common Core Text Ease and Readability Assessor* (Jackson et al., 2016) was used to extract several text characteristic variables, including length, readability features (see Appendix G), and a Flesch-Kincaid grade level estimate (Kincaid et al., 1975). To gain close estimates of the readability features, the target pseudoword was replaced with the word *tool* in each text. A MANOVA was conducted to examine the differences in the seven text characteristic variables across the two exposure versions of the eight base

stories. There were no statistically significant differences found across stories, Pillai's Trace = 0.72, $F(7, 8) = 2.93$, $p = .08$, suggesting that all stories were similar in terms of readability features and length. However, randomization occurred at the vowel level; therefore, it was important to look at text characteristics across the stories in each vowel group. The texts ranged in estimated difficulty from kindergarten to second-grade level, with a distribution across target texts. The two exposure texts within a single target had the same grade-level difficulty, although difficulties differed within the vowel group (e.g., /i/ had a set of Grade 1 stories and a set of Grade 2 stories). An ANOVA was conducted to compare the readability features of each story within a vowel group (see Table 3.3). No significant differences were observed between the four stories within each vowel group regarding average weights of the readability features.

Table 3.3. *Comparison of Stories Within Vowel Group*

Vowel	Pair 1				Pair 2				$F(3, 16)$	p
	8 Exposures		4 Exposures		8 Exposures		4 Exposures			
	M	SD	M	SD	M	SD	M	SD		
/eɪ/	0.89	0.13	0.86	0.11	0.89	.02	0.86	0.07	0.16	0.92
/i/	0.92	0.06	0.91	0.06	0.91	0.08	0.84	0.10	1.07	0.39
/oo/	0.93	0.14	0.92	0.12	0.91	0.07	0.83	0.18	0.59	0.63
/ə/	0.89	0.08	0.85	0.14	0.91	0.08	0.88	0.10	0.35	0.79

Word Learning Tasks

The acquisition of lexical representations occurs gradually and episodically along a continuum that ranges from recognition to retrieval. Researchers (e.g., Nation, 2017; Perfetti & Hart, 2002; Reichle & Perfetti, 2003; Share, 1995) suggest that word learning is a progressive process—beginning with the initial recognition (simply knowing you've seen it before) and advancing toward automatic retrieval from memory. Therefore, it

would be insufficient to determine if students with dyslexia acquire lexical representations following the reading of a short text with up to eight exposures to target words without measuring the degree or quality of those representations.

Therefore, nine word-learning tasks across this continuum were administered immediately following the self-teaching task (Session 2) and after a 3–7-day delay (Session 3) to measure the quality and durability of word learning (see Figure 3.5). The word-learning tasks were all administered in a fixed order. The directions associated with each word-learning task are available in Appendix G. The description, measure construct, and reliability data of each word-learning task are described below.

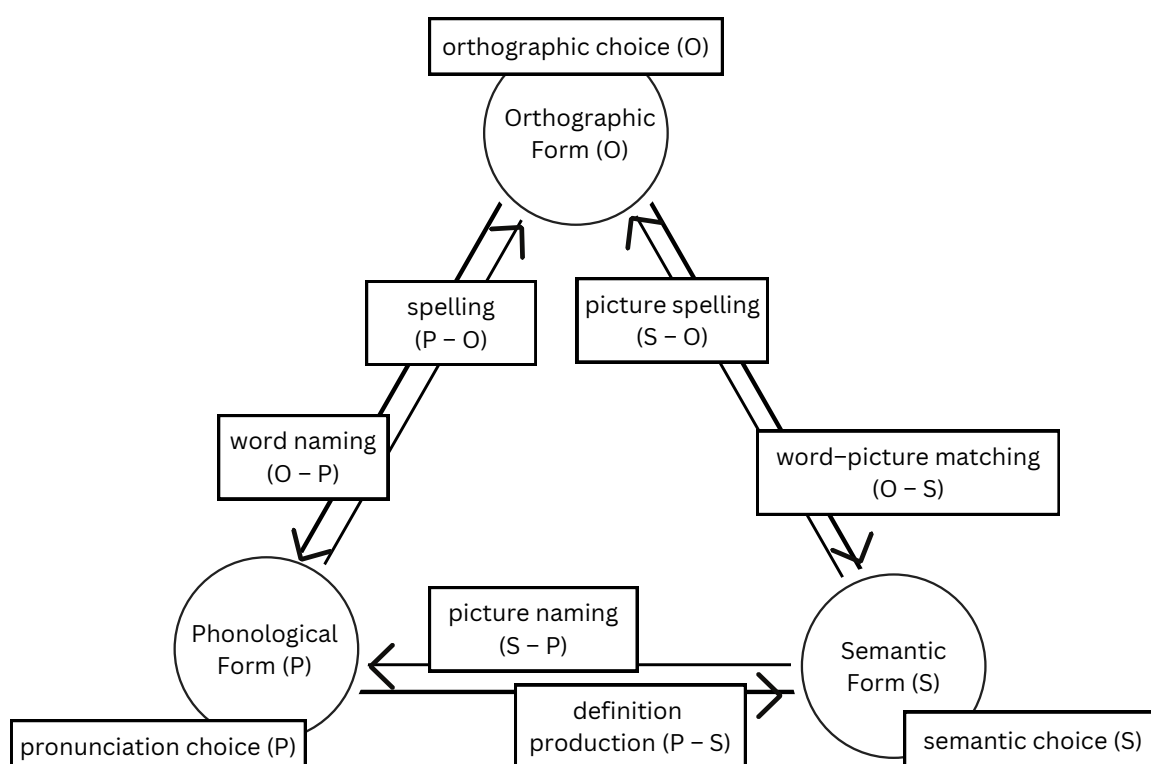


Figure 3.5. *Tasks Used to Measure Word Learning*

As Staels and van den Broeck (2015) purport in experimental research, construct validity is often prioritized over reliability, leading to the omission of reliability reporting

for dependent measures. This trend is evident in studies examining word learning within the self-teaching paradigm. However, reliability data can provide insight into the consistency of word learning measurement across participants. Therefore, we report McDonald's Omega (McDonald, 1999) for each word-learning task to assess its reliability and sensitivity in capturing the effects of word learning. McDonald's Omega was selected over Cronbach's Alpha (Cronbach, 1951) as it accounts for different item contributions (in this case, target words) rather than assuming equal weighting.

Constituent Knowledge. Recognition choice tasks (i.e., orthographic choice, semantic choice, pronunciation choice) were used to measure participants' knowledge of the constituents of word identity. In a recognition choice task, students are given a stimulus aligned to the constituent being measured along with three foil stimuli and asked to choose the correct stimulus corresponding to a learned target. Unlike choice tasks used in previous experiments, no other directive or information was provided; therefore, students were reliant only on their own knowledge of the eight target pseudowords experienced in the self-teaching phase.

Orthographic Choice. Students were presented with four spellings of each target pseudoword and asked to identify the correct spellings of Professor Parsnips' inventions. The four spellings included (a) the target spelling, (b) its homophonic alternative, (c) a letter substitution alternative where a letter of the target pseudoword was replaced by a visually similar letter, and (d) a letter transposition alternative where two adjacent letters were transposed (e.g., *zail*, *zale*, *zoil*, *zial*). The orthographic choice task was used to capture the depth of word-specific orthographic knowledge of the targets. A score of two was allocated for a correct response, one for selecting a homophonic foil, and zero if any

other foil was selected. For this measure, the maximum score was 16. Reliability was calculated at immediate ($\omega_t = .59$) and delay ($\omega_t = .61$). These low estimates indicate that orthographic choice may not be a reliable measure of the underlying construct.

Semantic Choice. Students were presented with four pictures and asked to identify the picture of one of Professor Parsnip's inventions. The four pictures corresponded to (a) the target invention (e.g., robot cleaner), (b) an invention related to the form of the target (e.g., robot cooker), (c) a foil unrelated to the target (e.g., sock matcher), and (d) a foil unrelated to the target but related to the form of the other unrelated foil (e.g., sock fixer). The semantic choice task was used to capture the depth of semantic knowledge of the target pseudowords. A score of two was allocated for a correct response, one for selecting the related foil, and zero for an unrelated foil. For this measure, the maximum score was 16. Reliability was calculated for immediate ($\omega_t = .71$) and was acceptable. For the delay task, reliability was excellent ($\omega_t = .92$) after removing one item (i.e., *vean/veen*) that reached ceiling effects where all participants answered correctly.

Pronunciation Choice. Students were presented with four pronunciations and asked to identify the correct pronunciation of one of Professor Parsnips' inventions. The four pronunciations included (a) the target pronunciation (e.g., /zeɪl/), (b) a pronunciation with a related vowel (e.g., /zæɪl/), (c) a substitution of the initial consonant with a similar phoneme (e.g., /seɪl/), and (d) a random phoneme substitution of the final consonant (e.g., /zeɪm/). The pronunciation choice task was used to capture the depth of phonological knowledge of the target pseudowords. A score of two was allocated for a correct response, one for selecting the vowel substitution foil, and zero if either foil with a

substituted consonant phoneme was selected. The maximum score was 16. Reliability was calculated and acceptable for immediate ($\omega_t = .74$) and delay ($\omega_t = .75$).

Bindings between Constituents. Six production word-learning tasks were used to measure the accuracy and stability of mappings between the constituents. Mappings between orthography and phonology were measured through word naming (i.e., O–P) and spelling (i.e., P–O). Mappings between orthography and semantics were measured through picture spelling (i.e., S–O) and word–picture matching (i.e., O–S). Mappings between phonology and semantics were measured through picture naming (i.e., S–P) and definition production (i.e., P–S). The six word-learning production tasks described below measured these bidirectional mappings between the three constituent forms.

Spelling. From dictation, students were asked to spell the eight target pseudowords from the self-teaching session. Each trial consisted of a target pseudoword presented vocally, in a random order, and the student spelled the pseudoword on a response sheet. The spelling task was used to capture the depth of the P–O binding of target pseudowords. Item responses were scored using a Levenshtein distance measure to index the number of single-letter changes (e.g., deletions, insertions, substitutions) needed for an attempt to match the target orthographic form (Ricketts et al., 2021; Themistocleous et al., 2020). This score gives credit for partially correct responses as well as correct responses. The maximum score is 0, with higher scores indicating less accurate responses. Additionally, whole word accuracy was calculated, where two points were given for a correct target spelling and one point for an orthographically plausible, correct homophonic spelling, and zero points for an implausible spelling. A total of 16

was possible. Reliability was calculated for the whole word accuracy scores and was good for immediate ($\omega_t = .84$) and delay ($\omega_t = .87$).

Definition Production. A dynamic definition production assessment was administered to measure semantic knowledge and capture partial knowledge acquired for all eight target pseudowords presented in self-teaching. Dynamic assessments use a cueing hierarchy (Ricketts et al., 2021). First, students were asked to provide a definition for a target pseudoword (e.g., *What is a zail used for?*) If students could not produce a definition independently, they were given a semantic cue using a set format that included the form in the target's definition (e.g., *It is a robot.*) and again, asked to provide the definition. If students still could not provide a definition, then the students were given two definitions to choose between (*Does the zail clean your room for you or make meals for you?*) The foil was the definition used as the foil in the semantic choice task.

The dynamic definition production task was used to capture the depth of the P–S binding of the targets. A score of three was allocated for a correct response in the definition task, two for a correct response in the cued-definition task, one for a correct response in the recognition (i.e., choice) task, and zero if the item was not correctly defined or recognized. For this measure, the maximum score was 24. Reliability was calculated for a binary score (1 = definition or cued definition, 0 = otherwise) and was excellent for immediate ($\omega_t = .92$) and delay ($\omega_t = .89$).

Picture Naming. When presented with a picture of an invention, students were asked to name the associated target. When students could not produce the name of the target, the initial sound of the target was provided as a cue (e.g., *It starts with /z/*; Wang et al., 2011). If students could not provide the correct answer, they were asked to choose

between the target and a foil containing the same consonant sounds but a different, yet similar vowel (e.g., *Is this /zeɪl/ or /zæɪl/*?). Pictures were shuffled prior to beginning the task. A score of three was given for an independent correct response, two for a cued-correct response, one for a correct choice, and zero for never providing the correct response. For this measure, the maximum score was 24. Reliability was calculated for immediate ($\omega_t = .67$) and delay ($\omega_t = .73$).

Word Naming. Students were asked to read individually presented words twice. The word naming task included both spellings of the target pseudowords and eight filler real words (see Table 3.4). The filler words were high-frequency nouns containing three sounds and were 3–4 letters long ($M = 3.5$, $SD = 0.53$)—similar to the pseudoword targets. The nouns were all common objects with a defined use. Items were selected from the *Children’s Picture Books Lexicon* database (Green et al., 2023) based on rank order of frequency to ensure all fillers were high in frequency. Additionally, all filler words have an age-of-acquisition of two years based on norms derived from children’s behavioral data (Brysbaert & Biemiller, 2017), thus ensuring students would be highly familiar with the filler nouns.

Table 3.4. *Filler Nouns*

Noun	Definition	Length	Frequency per Million
bed	to sleep on	3	756.62
book	to read	4	571.92
cup	to drink from	3	113.31
game	to play	4	268.56
home	to live in	4	1243.78
map	to find how to get somewhere	3	59.78
pot	to cook with	3	257.86
ship	to travel on water	3	122.24

Each word was presented twice, resulting in 48 trials ([8 target pseudowords + 8 homophone pseudoword foils + 8 filler real nouns] * 2 = 48). For each trial, words were presented randomly in the middle of a screen in 50-point Palatino Linotype font. The word remained visible until the student produced a vocal response. The intertrial interval (i.e., blank screen) was 2500 ms (Cunningham et al., 2002). The word naming task was used to capture the depth of the O–P binding of target words. The experimenter coded the accuracy of each response (0 = incorrect, 1 = correct). The maximum accuracy score was 48; however, only the 16 target pseudowords were used in the main analyses; thus, the total score possible was 32. In addition, word naming time was calculated by subtracting the reaction time, measured by a voice-activation key, from the total time required to read the word completely. Reliability was calculated for accuracy and was excellent at immediate ($\omega_t = .95$) and delay ($\omega_t = .96$).

Picture Spelling. Students were presented with a picture of an invention and asked to spell its name. All eight target pictures were presented in a random order. The picture spelling task was used to capture the depth of the S–O binding of target pseudowords. Responses were scored in the same fashion as the spelling task using a Levenshtein distance measure (Ricketts et al., 2021; Themistocleous et al., 2020). Additionally, whole pseudoword spelling accuracy, where two points were given for a correct target spelling and one point for an orthographically plausible, correct homophonic spelling was scored. Reliability was calculated with accuracy scores and was acceptable for immediate ($\omega_t = .80$) and delay ($\omega_t = .74$).

Word–Picture Matching. Students were presented with two pictures (the target invention and another invention from the experiment) and given the associated

orthographic form for the target (i.e., spelling). The students were asked to select the picture that matched the word presented. All eight targets were included, as well as two filler nouns used in the word naming task. The word–picture matching task was used to capture the depth of the O–S binding of targets. The experimenter coded the accuracy of each response (0 = incorrect, 1 = correct). For this measure, the maximum score was 8. Reliability was calculated and good for immediate ($\omega_t = .75$) and delay ($\omega_t = .75$).

Quality Composite. As stated previously, word learning transpires across a continuum ranging from recognition to instantaneous retrieval and production. Unfortunately, many self-teaching experiments do not measure word learning outcomes through the lens of a continuum of learning. Commonly, choice tasks are used. These measures may inflate the degree to which lexical representations have been acquired as these tasks only measure recognition, an initial entry point on the continuum of word learning. Spelling and word naming outcomes are also commonly used in self-teaching research. It is important to remember that these tasks only measure orthographic learning. Orthographic learning outcomes inherently cannot provide insight into other aspects of word learning, namely semantic learning. Thus, orthographic learning outcomes alone cannot provide reliable information about the development of high-quality lexical representations needed for efficient word identification. To address this seeming measurement imbalance, the quality of target lexical representations was calculated at an item level for each student. For RQ2 and RQ3, the quality composite was used as the outcome in the EIRMs.

Results

All analyses were conducted in *R*. First, student performance during the independent reading task was analyzed to provide an understanding of how the students read in relation to the texts and targets. During Session 2, errors and text reading time were scored and independently verified by a trained graduate researcher, resulting in a .998 agreement for errors and a .999 agreement for text reading time. These data were used to calculate reading performance metrics: target pseudoword decoding accuracy, text reading accuracy, and words correct per minute. Target word decoding accuracy was calculated by dividing target pseudowords read correct per passage by the number of exposures to the target pseudoword (4 or 8). Text reading accuracy was calculated: $(\text{total words} - \text{errors}) / \text{total words} * 100$. To calculate word correct per minute, a measure of text reading fluency, text reading accuracy was divided by $(\text{total time [s]}/60)$. Means and standard deviations of all reading metrics were calculated using *dplyr* (Wickham et al., 2023).

Independent Reading Task

Overall, students performed well during the independent reading task. Table 3.5 depicts the average performance across passages for key reading measures. Based on the passages' readability, high accuracy was expected despite students' persistent reading difficulties. In alignment with this expectation, students read the texts with 91.46% accuracy with an average reading fluency of 74.48 words correct per minute ($SD = 36.73$; range = 13.09–233.33). After reading each passage, students were asked two text-dependent questions and averaged 1.72 correct responses per passage, or 85.83% accuracy across all passage questions.

Table 3.5. *Descriptive Metrics for Independent Reading Task*

Metric	<i>M</i>	<i>SD</i>	Range
Text Level			
Text reading accuracy (%)	91.73	6.71	66.67 – 100
Text reading speed (s)	81.07	45.55	18 – 298
Text reading fluency (wcpm)	74.44	36.73	13.09 – 233.33
Comprehension accuracy per passage (%)	85.83	54.01	0 – 2
Total comprehension (16)	13.73	1.61	9 – 16
Target Level			
Target decoding in stories (48)	26.21	14.07	0 – 48
Target decoding accuracy (%)	57.01	45.90	0 – 100

Note. wcpm = words read correctly per minute

Although text-level metrics are globally relevant, the primary interest was at the individual target pseudoword level. The average target pseudoword decoding accuracy across participants varied widely. Students read the targets with an average of 57.01% accuracy ($SD = 46.19$; range = 0–100). Each student was exposed to two different spelling patterns within the four target vowel phonemes. The average decoding target pseudoword accuracy is represented in Table 3.6.

Table 3.6. *Proportion of Correctly Decoded Targets as a Function of Vowel Spelling*

Target	Exposure								Overall
	1	2	3	4	5	6	7	8	
/ei/	53.51	53.51	53.51	56.14	50.00	51.17	50.00	50.00	52.91
ai	49.12	50.88	49.12	47.37	44.83	48.28	44.88	44.83	47.97
a_e	57.89	56.14	57.89	64.91	55.17	55.17	55.17	55.17	57.85
/i:/	49.12	54.39	51.75	52.63	64.44	62.71	57.63	61.02	55.20
ea	45.61	50.88	47.37	43.86	48.15	48.15	40.74	48.15	46.73
ee	52.63	57.89	56.14	61.40	78.13	75.00	71.88	71.88	63.20
/ou/	62.28	62.28	70.18	56.14	54.55	50.91	50.91	59.09	59.02
oa	58.93	57.14	67.86	50.00	55.17	51.72	51.72	41.38	55.59
o_e	65.52	67.24	72.41	62.07	53.85	50.00	50.00	57.69	62.50
/ə/	71.05	59.65	57.89	53.51	54.55	58.18	60.00	54.55	59.32
er	64.91	61.40	61.40	56.14	58.62	62.07	68.97	58.62	61.34
ur	77.19	57.89	54.39	50.88	50.00	53.85	50.00	50.00	57.23

Note. $N = 228$ observations per vowel; $n = 114$ observations per vowel spelling

Normality of the data was assessed using skewness and the Shapiro-Wilk test (Shapiro & Wilk, 1965). Data were not skewed (-0.17); however, the Shapiro-Wilk test was significant, $W = 0.79$, $p < .001$. Given this violation, a non-parametric test (Kruskal & Wallis, 1952) was conducted to determine if target pseudoword decoding accuracy differed based on vowel spelling patterns. The results were not statistically significant, $H(7) = 9.58$, $p = .214$, suggesting that target pseudoword decoding accuracy did not differ significantly as a function of vowel spelling pattern.

To what extent do students with dyslexia acquire lexical representations of regular words following independent reading?

Multiple analyses were conducted to address RQ1. Each word-learning task was analyzed individually. Then, performance across measures is reported as a function of target pseudoword to address the item-by-item nature of the self-teaching hypothesis. Normality was assessed using the Shapiro-Wilk test (see Table 3.7 for p -values; Shapiro & Wilk, 1965).

Table 3.7. *Shapiro-Wilk Results per Word-Learning Task*

Task	Immediate	Delay
OC	.084	.243
SC	< .001*	< .001*
PC	.224	.100
Spell	.110	.067
WN		
Accuracy	< .001*	< .001*
Speed	< .001*	< .001*
Def	< .001*	< .001*
PN	.002*	.067*
PS	< .001*	.010
WPM	< .001*	< .001*

Note. *Significant p -value indicates a non-normal data distribution; OC = orthographic choice, SC = semantic choice, PC = pronunciation choice, WN = word naming, Def = definition production, PN = picture naming, PS = picture spelling, WPM = word-picture match

Based on these results, data associated with the orthographic choice, pronunciation choice, and spelling tasks were normally distributed at both immediate and delayed sessions ($p > .05$). Therefore, paired samples t -tests were conducted to assess whether performance significantly differed as a function of test session (see Table 3.8). There was one significant finding from these tests indicating a significant increase in spelling accuracy from the immediate ($M = 7.70$, $SD = 4.08$) to the delay session ($M = 8.74$, $SD = 4.27$), $t(52) = 2.58$, $p = .013$, $d = 0.35$, suggesting moderate improvement in spelling of target pseudowords over time.

Table 3.8. *Paired t -tests for Word-Learning Tasks with Normal Data*

Task	M	SD	SE	Paired t -test				
				M difference	t	df	p	d
Orthographic Choice (16)				−0.21	−0.49	52	.628	−0.07
Immediate	10.30	2.76	0.60					
Delay	10.20	0.78	0.38					
Pronunciation Choice (16)				1.08	1.82	52	.074	0.25
Immediate	8.79	3.26	0.43					
Delay	10.10	3.53	0.49					
Spelling from Dictation (16)				1.11	2.58	52	.013	0.35
Immediate	7.70	4.08	0.54					
Delay	8.74	4.27	0.59					

Outcomes from the remaining word-learning tasks (i.e., semantic choice, definition production, picture naming, word naming accuracy, word naming speed, picture spelling, and word-picture match) violated the test of normality ($p < .05$) for at least one testing session. Therefore, a Wilcoxon signed-rank test (Wilcoxon, 1945) was used to determine if differences in *median* performance were a function of test session (see Table 3.9). Analyses revealed two significant findings. A significant increase in picture naming accuracy was observed from the immediate session ($Mdn = 9$, $IQR = 4$) to

the delay session ($Mdn = 12$, $IQR = 5$), $W = 888$, $p < .001$, $z = 3.74$, suggesting a significant improvement in target pseudoword naming over time. Similarly, a significant increase was observed in picture spelling accuracy from the immediate session ($Mdn = 2$, $IQR = 3$) to the delay session ($Mdn = 6$, $IQR = 4$), $W = 862$, $p < .001$, $z = 3.90$, suggesting a significant improvement in target pseudoword spelling when given its semantic form, over time. Overall, the reported results above summarize findings at the aggregate level based on the sum of participant responses. To further explore these findings, each word-learning task was analyzed.

Table 3.9. *Wilcoxon Signed-Rank Tests for Word-Learning Tasks with Non-Normal Data*

Task	<i>Mdn</i>	<i>IQR</i>	Wilcoxon Signed-Rank Tests			
			<i>Mdn difference</i>	<i>W</i>	<i>p</i>	<i>d</i>
Semantic Choice (16)			0	53.5	.727	0.35
Immediate	16	1				
Delay	16	0				
Word Naming (32)			2	193	.001	3.53
Immediate	23	15				
Delay	26	11				
Definition Production (24)			0	350	.137	1.49
Immediate	17	3				
Delay	17	4				
Picture Naming (24)			3	156	< .001	4.45
Immediate	9	4				
Delay	12	5				
Picture Spelling (16)			2	110	< .001	4.72
Immediate	2	3				
Delay	6	4				
Word-Picture Match (8)			0	413	.336	0.96
Immediate	6	3				
Delay	7	2				

Constituent Knowledge

Three recognition choice tasks were used to measure participants' knowledge of the three constituents of word identity: the orthographic, phonological, and semantic

forms. A correct response was scored if the student selected the exact constituent form of the target pseudoword between four options. A χ^2 test compared student performance to chance performance levels (i.e., 25% correct response vs. 75% any other response). A significant test provides evidence of robust constituent-level learning.

Orthographic Choice. As presented in Table 3.10, most choices on the orthographic choice task matched the correct target pseudoword orthographic form at the immediate (48%) and delay (46%) tests. Results were aggregated across measure time points because there were no significant differences ($p = .628$) between immediate and delay outcomes. Overall, choosing *target* over any other response significantly differed from chance performance (25% vs. 75%), $\chi^2 (7, N = 880) = 18.38, p = .01$. Thus, as measured by the orthographic choice task, students showed significant learning of the orthographic form of the target pseudowords.

Table 3.10. *Post-Test Orthographic Choices as a Function of Exposures and Time*

Time	Target	Homophone	Substitution	Transposition
Immediate				
Four Exposures ($n = 228$)	.46 (105)	.34 (77)	.08 (18)	.12 (28)
Eight Exposures ($n = 228$)	.51 (115)	.31 (71)	.07 (15)	.12 (27)
Overall ($N = 456$)	.48 (220)	.33 (148)	.07 (32)	.12 (55)
Delay				
Four Exposures ($n = 212$)	.41 (87)	.39 (84)	.13 (27)	.07 (14)
Eight Exposures ($n = 212$)	.51 (106)	.34 (72)	.11 (22)	.06 (12)
Overall ($N = 424$)	.46 (193)	.37 (155)	.12 (49)	.06 (26)

Semantic Choice. As presented in Table 3.11, a clear ceiling effect was observed in the semantic choice task, with 74.5% of participants earning perfect scores. This limited variability indicates the measure may be too easy, a finding that directly opposes Mimeau et al. (2018), where the semantic choice task was more sensitive than definition

and matching tasks. Thus, researchers need to continue to improve methods for measuring students' semantic knowledge in the absence of phonological or orthographic forms.

Table 3.11. *Post-Test Semantic Choices as a Function of Exposures and Time*

Time	Target	Related	Unrelated
Immediate			
Four Exposures ($n = 228$)	.96 (219)	.03 (7)	.01 (2)
Eight Exposures ($n = 228$)	.95 (215)	.04 (9)	.02 (4)
Overall ($N = 456$)	.95 (434)	.04 (16)	.02 (6)
Delay			
Four Exposures ($n = 212$)	.96 (204)	.02 (5)	.01 (3)
Eight Exposures ($n = 212$)	.94 (200)	.03 (6)	.03 (6)
Overall ($N = 424$)	.95 (404)	.03 (11)	.02 (9)

Pronunciation Choice. Most choices on the pronunciation choice task matched the correct target pseudoword at the immediate (43%) and delay (53%) tests (see Table 3.12). Although there appeared to be a difference between immediate and delay accuracy, no significant differences existed between immediate and delay ($p = .074$); therefore, results were aggregated across measure time points. At the vowel level, choosing the *target* pronunciation over any other response did not significantly differ from chance, $\chi^2(3, N = 880) = 4.06, p = .26$. Students had not formed secure knowledge of the word-specific phonological forms to a strong enough degree. Students selected either the correct vowel pronunciation (e.g., /vi:n/) or the phonological form containing the related vowel foil (e.g., /vɜ:n/) for the target pseudoword. The related phonological forms to the target pseudoword were selected above chance levels, $\chi^2(7, N = 880) = 22.95, p = .002$. These results provide evidence of developing, but weak, phonological representations.

Table 3.12. *Post-Test Pronunciation Choices as a Function of Exposures and Time*

Time	Target	Alternate Vowel	Initial Substitution	Final Substitution
Immediate				
Four Exposures ($n = 228$)	.40 (92)	.23 (52)	.16 (37)	.21 (47)
Eight Exposures ($n = 228$)	.46 (105)	.24 (55)	.17 (38)	.13 (30)
Overall ($N = 456$)	.43 (197)	.24 (107)	.16 (75)	.10 (77)
Delay				
Four Exposures ($n = 212$)	.52 (111)	.21 (45)	.17 (35)	.10 (21)
Eight Exposures ($n = 212$)	.53 (113)	.19 (40)	.18 (38)	.10 (21)
Overall ($N = 424$)	.53 (224)	.20 (85)	.17 (73)	.10 (42)

Differences Between Constituent Knowledge. Comparison analyses were conducted to explore the differences between the constituent choice tasks. A Kruskal-Wallis test revealed significant differences in performance across choice tasks, $\chi^2(2) = 735.65, p < .001$. Post-hoc Dunn's tests with Bonferroni correction were performed with the *FSA* package (Ogle et al., 2025) to determine which pairs of tasks differed significantly. Differences between orthographic and pronunciation choice indicated a small statistically significant difference between the knowledge students learned of the orthographic form compared to the phonological form of the target pseudowords, $Z = -5.53, p < .001, \epsilon^2 = 0.04$. The semantic choice task was also significantly different from orthographic choice ($Z = -25.75, p < .001, \epsilon^2 = 0.76$) and pronunciation choice ($Z = -20.23, p < .001, \epsilon^2 = 0.53$). However, the large effect sizes should be interpreted cautiously due to the ceiling effects on the semantic choice task.

Orthographic Learning

Two word-learning tasks, spelling and word naming, were used to measure the strength of the bindings linking the orthographic form with its phonological form and vice versa—or orthographic learning. Accuracy and distance measures—as described in the methods—were used to describe the spelling data. The word naming task was the

only outcome to directly measure performance on target pseudowords and the target pseudoword homophones; therefore, the accuracy and speed data of the target pseudoword homophonic spellings were compared.

Spelling. Given the significant differences between the two test sessions, precise orthographic spellings of the target pseudowords were analyzed separately. On the immediate post-test, 33% of spellings matched the target pseudoword (e.g., *taid*), while 31% of responses were phonologically correct with an incorrect orthographic form (e.g., *tade*). Given that over 60% of spellings were phonologically correct, it is unclear if word-specific learning transpired or if students relied on sublexical P–O connections already stored in memory. Table 3.13 displays the proportion of responses in each category.

Table 3.13. *Post-Test Spelling from Dictation as a Function of Exposures and Time*

Time	Target	Homophone	Vowel Error	Other
Immediate				
Four Exposures ($n = 228$)	.35 (80)	.29 (67)	.18 (42)	.17 (39)
Eight Exposures ($n = 228$)	.30 (69)	.33 (74)	.25 (56)	.13 (29)
Overall ($N = 456$)	.33 (149)	.31 (141)	.22 (98)	.15 (68)
Delay				
Four Exposures ($n = 212$)	.39 (82)	.34 (72)	.16 (33)	.19 (41)
Eight Exposures ($n = 212$)	.39 (82)	.30 (63)	.19 (41)	.20 (42)
Overall ($N = 424$)	.39 (164)	.39 (135)	.16 (74)	.18 (83)

The Levenshtein distance captures partial spelling knowledge that may indicate a developing lexical representation. Average distances for each target pseudoword are reported in Table 3.14. A score of 0 means the attempt is an exact match to the orthographic form of the target pseudoword. Spelling attempts from the immediate session obtained an average score of 1.12, suggesting that spelling attempts needed more

than one single-letter change to match the target pseudoword orthographic forms correctly. Attempts from the delay session scored an average of 0.95, suggesting attempts were more closely matched to target pseudoword orthographic forms. These data, paired with the significant paired t-test, $t(52) = 2.58, p = .013, d = 0.35$, suggest that students' orthographic representations of target pseudowords were strengthened over time.

Table 3.14. *Edit Distances by Target Spelling on Spelling from Dictation Task*

Target	Immediate			Delay		
	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range
<i>/eɪ/</i>						
taid	1.31	0.82	0–2	1.14	0.89	0–2
tade	0.88	0.88	0–2	0.76	0.78	0–3
zail	1.44	1.08	0–4	1.00	0.96	0–3
zale	1.22	1.07	0–3	1.43	0.96	0–3
<i>/i:/</i>						
jeat	1.44	1.08	0–4	1.28	0.88	0–3
jeet	1.23	1.11	0–3	1.00	0.89	0–2
vean	1.00	0.96	0–3	0.76	0.88	0–3
veen	1.00	0.98	0–4	0.71	0.81	0–2
<i>/oʊ/</i>						
goak	1.28	0.98	0–3	0.87	0.92	0–2
goke	1.19	1.06	0–3	1.00	0.95	0–2
foat	1.16	0.78	0–2	0.93	0.84	0–2
fote	1.00	0.98	0–3	1.12	1.11	0–2
<i>/ə/</i>						
mern	0.73	1.01	0–4	0.62	0.73	0–2
murn	1.00	0.83	0–3	0.88	0.80	0–3
sert	1.00	0.96	0–3	0.76	1.01	0–2
surt	1.00	0.54	0–3	0.89	0.50	0–2

Word Naming. On the immediate word naming task, each student read a total of 16 target pseudowords (8 targets twice) and 16 homophone pseudoword foils (8 homophones twice), as well as 16 high-frequency filler real words (8 real words twice). Only fully specified pronunciations ($n = 2,567$) of the target pseudoword were accepted as correct (see Table 3.15). Overall, there was no significant difference in the

pronunciation accuracy of either the original or alternative spelling at immediate (target pseudowords = 67%; homophone pseudowords = 68%) or delay (target pseudowords = 76%; homophone pseudowords = 75%) test sessions, $W = 1502238$, $p = .72$. These findings were expected and align with previous experiments (e.g., Share, 1999).

Table 3.15. *Post-Test Word Naming Accuracy as a Function of Target Type and Time*

Vowel	Target				Homophone			
	Immediate		Delay		Immediate		Delay	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
/eɪ/								
ai	0.59	0.47	0.74	0.44	0.69	0.47	0.71	0.46
a_e	0.66	0.48	0.76	0.43	0.73	0.45	0.84	0.37
/i:/								
ea	0.60	0.49	0.73	0.45	0.65	0.48	0.67	0.48
ee	0.74	0.44	0.77	0.43	0.65	0.48	0.74	0.44
/oo/								
oa	0.69	0.47	0.82	0.38	0.72	0.45	0.74	0.44
o_e	0.70	0.46	0.78	0.42	0.76	0.43	0.86	0.35
/ə/								
er	0.66	0.48	0.76	0.43	0.71	0.46	0.75	0.44
ur	0.64	0.48	0.72	0.45	0.62	0.49	0.73	0.45

One would expect a difference in mean pronunciation time between target pseudowords and homophone pseudoword foils if students acquired a lexical representation (Cunningham et al., 2002). During the immediate session, the average naming time for correctly named target pseudowords was 661 ms ($SD = 848$), and the mean pronunciation time for the homophone pseudowords was 648 ms ($SD = 656$). Overall, there was no significant difference in the naming time of either the target or homophonic pseudoword spelling at immediate or delay test sessions, $W = 767467$, $p = .70$. These data were further analyzed to examine if there were potential differences between target and homophone pseudowords as a function of vowel spellings; however, there were no significant differences observed for any vowel spelling (Table 3.16). These

results indicate that students did not acquire the strong orthographic–phonological mappings needed for efficient word naming to transpire. Overall, the data do not support evidence of robust orthographic learning as a function of self-teaching for students with dyslexia.

Table 3.16. *Post-Test Word Naming Speed (ms) as a Function of Target Type, Vowel, and Time*

Vowel	Target				Homophone			
	Immediate		Delay		Immediate		Delay	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
/eɪ/								
ai	625	755	704	723	764	948	665	630
a_e	773	968	685	710	632	619	644	569
/i:/								
ea	658	753	635	634	597	737	612	688
ee	548	630	573	639	592	650	563	472
/oo/								
oa	607	916	595	590	607	729	603	606
o_e	622	746	580	547	584	703	651	692
/ɜ:/								
er	776	1150	739	623	683	698	749	803
ur	682	741	672	643	727	719	727	730

Semantic Learning

Four word-learning tasks were administered to measure the strength of the bindings associated with semantic learning that students developed. Definition production and picture naming measured the link between the phonological and semantic forms and vice versa. These measures were given using a hierarchical cuing system; thus, probabilities were calculated, plotted, and compared for each response score (i.e., 3 = independent correct, 2 = cued definition, 1 = recognition between two choices, 0 = incorrect). Picture spelling and word-picture match measured the bi-directional link

between the orthographic and semantic forms. Accuracy and distance measures—as described in the methods—were used to describe the spelling data. Word-picture match is a choice task, so correct responses were compared to chance levels (50%).

Definition Production. To visualize definition production outcomes across responses, the probabilities were calculated and plotted as a function of time (immediate vs. delay), in Figure 3.6. Most responses reflected cued definitions or recognition of the definition (choice) of the target pseudoword. For responses to the final cue—the choice—correct recognition of the definition was statistically different than chance levels, $\chi^2(1, N = 197) = 131.58, p < .001$, indicating effective learning of semantic forms. Students produced an independent correct definition of target pseudowords for 36.93% of the occurrences. The number of independent correct definition productions increased between the immediate (21.9%) and delay (32.3%) sessions, but the difference between probabilities was not statistically significant. It is important to note that the probability of a cued definition decreased from immediate to delay as the independent response probability increased. This, paired with the fact that it was unlikely that students would produce an incorrect definition, suggests that semantic learning of target pseudowords transpired and strengthened to some degree over time.

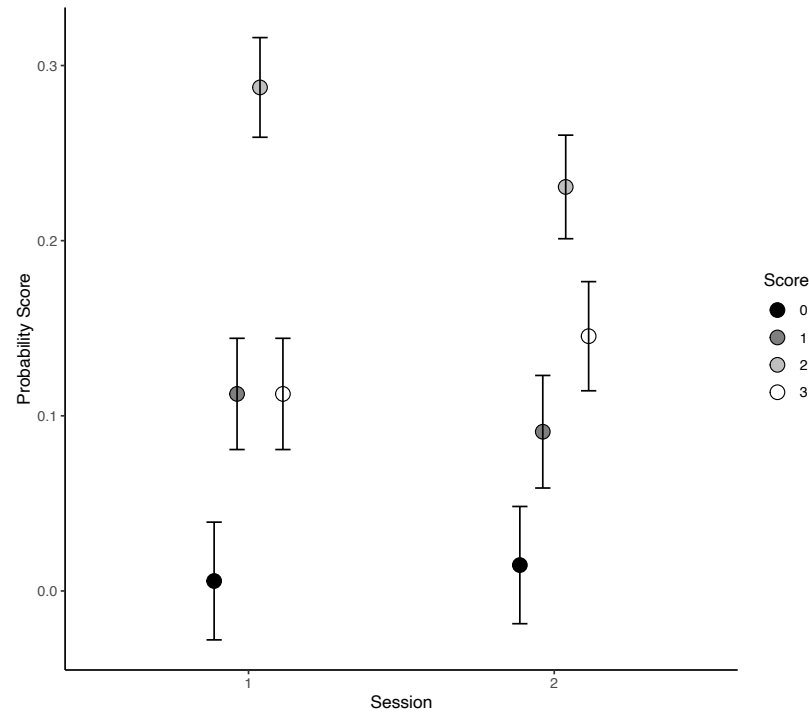


Figure 3.6. *Probability of Definition Production Response as a Function of Time*

Picture Naming. Picture naming was administered identically to definition production, so data were analyzed in the same manner. Figure 3.7 depicts the probabilities of each response as a function of time (immediate vs. delay). At the immediate session, the majority of responses reflected recognition of the target pictures when given a choice at the immediate session ($n = 232$, 50.88%). However, the distribution of responses significantly changed from immediate to delay, $\chi^2(3, N = 880) = 32.22, p < .001$. Post-hoc standardized residuals revealed that independent naming ($z = 4.27, p < .001$) and choice ($z = 2.68, p = .022$) were significantly higher in delay ($z = 4.27, p < .001$), whereas incorrect ($z = -2.23, p = .026$) and cued responses ($z = -3.56, p = .002$) decreased from immediate to delay sessions. These findings suggest a strengthening of the binding between semantic and phonological forms of targets between sessions.

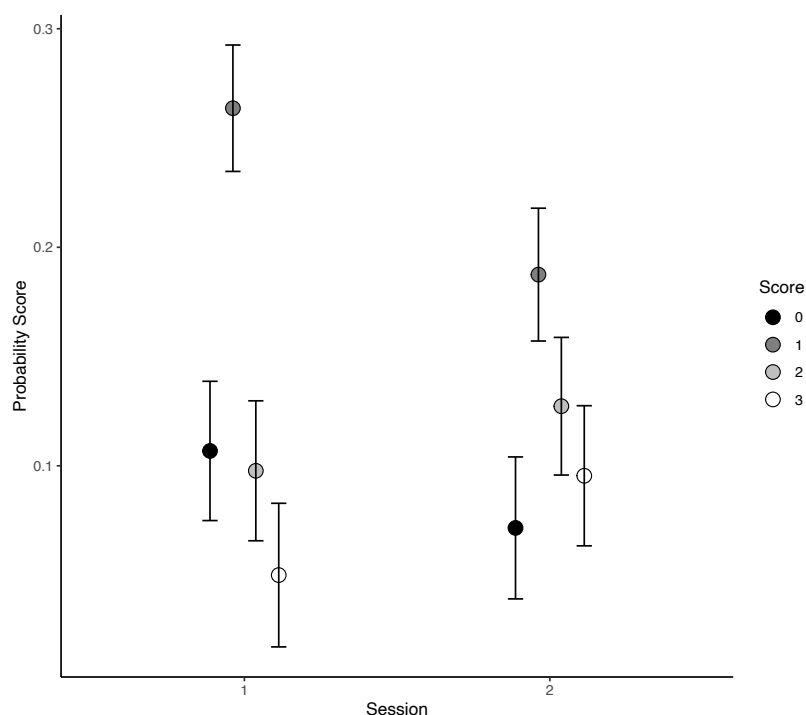


Figure 3.7. *Probability of Picture Naming Response as a Function of Time*

Picture Spelling. The picture spelling task measured the extent to which students could produce the precise orthographic form of target pseudowords when given a picture of the target. Overall, on the immediate post-test, students performed poorly with only 14% of picture spellings precisely matching the target pseudowords. Another 10% matched the target in phonological form but not orthographic. These data do not support a secure mapping of semantic *and* orthographic forms (see Table 3.17).

Table 3.17. *Post-Test Picture Spelling as a Function of Exposures and Time*

Time	Target	Homophone	Vowel Error	Alternative Intervention	Other
Immediate					
Four Exposures ($n = 228$)	.14 (31)	.10 (22)	.15 (34)	.08 (17)	.17 (38)
Eight Exposures ($n = 212$)	.15 (33)	.08 (19)	.15 (33)	.08 (18)	.15 (33)
Overall ($N = 456$)	.14 (64)	.09 (41)	.15 (67)	.08 (35)	.16 (71)
Delay					
Four Exposures ($n = 212$)	.22 (47)	.21 (45)	.09 (20)	.08 (16)	.13 (29)
Eight Exposures ($n = 212$)	.26 (55)	.18 (38)	.12 (26)	.05 (10)	.15 (31)
Overall ($N = 424$)	.24 (102)	.20 (83)	.11 (46)	.07 (26)	.14 (60)

The mean Levenshtein distances for each target pseudoword are reported in Table 3.18. A score of 0 means the attempt is an exact match to the orthographic form of the target pseudoword. Spelling attempts from the immediate session obtained an average score of 2.11, suggesting that spelling attempts needed changes to over 50% of the letters in the word to match the target pseudoword orthographic form correctly. Attempts from the delay session scored an average of 1.71, suggesting delay attempts were more closely matched to target pseudoword orthographic forms. These data, paired with the significant Wilcoxon signed rank test, $W = 862$, $p < .001$, $z = 3.90$, suggest that the mapping between the semantic and orthographic form of target pseudowords was strengthened over time.

Table 3.18. *Edit Distances by Target Spelling on Picture Spelling Task*

Target	Immediate			Delay		
	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range
/ei/						
taid	2.57	1.10	0–4	2.07	1.21	0–4
tade	3.00	1.35	1–5	2.08	1.32	0–4
zail	2.44	1.16	0–5	2.28	1.28	0–5
zale	2.75	0.95	0–4	2.54	0.88	0–4
/i:/						
jeat	1.57	1.19	0–4	1.41	1.12	0–4
jeet	1.30	1.44	0–4	1.08	1.38	0–4
vean	1.75	0.97	0–4	1.08	1.04	0–3
veen	1.59	1.43	0–4	0.89	1.20	0–3
/oo/						
goak	1.88	1.24	0–4	1.74	1.21	0–4
goke	2.29	1.64	0–7	1.52	1.38	0–4
foat	2.00	1.29	0–4	1.76	1.24	0–4
fote	2.26	1.35	0–4	1.83	1.09	0–4
/ə/						
mern	1.93	1.10	0–3	1.55	1.30	0–4
murn	2.15	1.41	0–5	1.50	1.22	0–4
sert	2.14	1.16	0–4	1.88	1.24	0–4
surt	2.11	0.83	1–4	2.18	1.22	0–4

Word-Picture Match. As indicated in Table 3.19, most choices on the word-picture match task correctly matched a picture of the target to the provided orthographic form at the immediate (74%) and delay (81%) tests. Because there were no significant

differences between immediate and delay outcomes ($p = .336$), results were aggregated across measure time points. A proportion test compared the observed proportion of correct responses to chance levels (50%) due to insufficient cell counts for a Chi-square test. For all target pseudowords, the proportion of correct responses significantly differs from chance levels of performance ($ps < .01$). As measured by the word-picture match task, students showed significant learning associating the inventions (semantic form) to the correct target pseudoword orthographic form.

Table 3.19. *Post-Test Word-Picture Match as a Function of Exposures and Time*

Time	Target
Immediate	
Four Exposures ($n = 228$)	.74 (16)
Eight Exposures ($n = 212$)	.79 (181)
Overall ($N = 456$)	.77 (349)
Delay	
Four Exposures ($n = 212$)	.81 (172)
Eight Exposures ($n = 212$)	.81 (171)
Overall ($N = 424$)	.81 (343)

Quality Composite

The nine word-learning tasks were theoretically “placed” along the continuum of word learning (Massaro & Rowe, 2015). The three word-learning choice tasks would be clustered at the recognition level—as the tasks only require one knowledge source, and students are not required to actively produce a response (Spataro et al., 2018). Word-picture match and the naming—word and picture—tasks would fall next as they are also recognition tasks; however, these tasks require the connection between two constituent knowledge sources. Next along the continuum would be the definition production and spelling task. These tasks require a production of constituent knowledge. Finally, the

picture spelling task would fall toward the end of the continuum, as this task, can be argued, requires the coordination of all three constituent knowledge sources (Bonin et al., 2015).

The aggregate participant scores across word-learning tasks were plotted to visualize this hypothesized task placement along the continuum of word learning. If the hypothesized placement correctly categorizes task difficulty, a downward slope from the recognition tasks to the picture-spelling production task would be expected. Figure 3.8 depicts the hypothesized claims. Indeed, an approximate downward slope is evident.

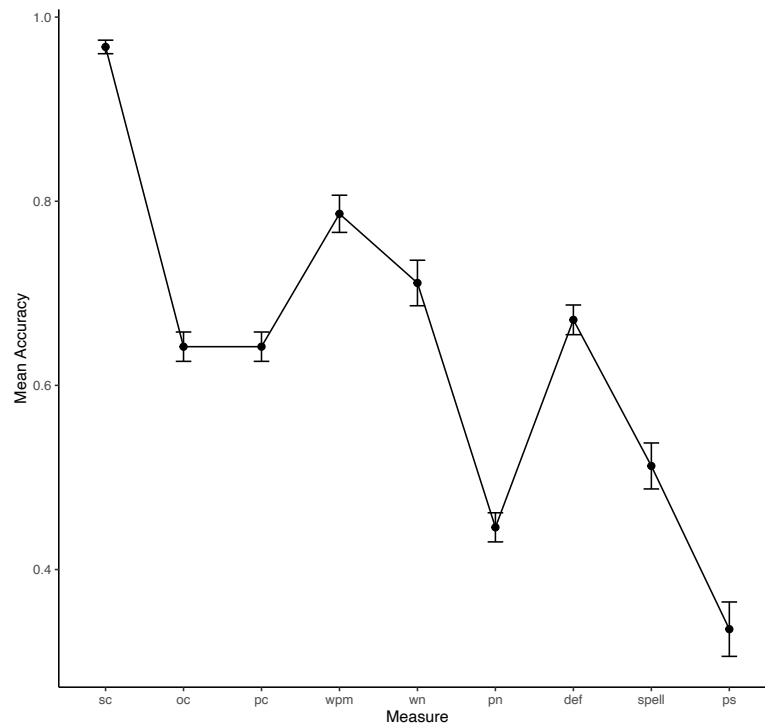


Figure 3.8. *Aggregate Accuracy Score Across Measures*

While not perfectly substantiated, this finding supports using the word-learning task's placement as a weight to calculate the quality composite. Two sub-composite scores—recognition and production—were calculated by aggregating the proportion

correct for each word-learning task. Then, the two sub-composites were aggregated together to create the quality composite. Mathematically, this lowers the weight of each word-learning recognition task to the composite score, giving more weight to tasks that require knowledge and application of more than one constituent binding. The quality of target lexical representations was calculated at the item level resulting in each of the eight target pseudowords having a quality composite score (see Table 3.20).

Table 3.20. *Descriptive Statistics for Quality Scores*

Target	<i>M</i>	<i>SD</i>	<i>Mdn</i>	Target	<i>M</i>	<i>SD</i>	<i>Mdn</i>
taid	0.349	0.098	0.354	zail	0.338	0.092	0.326
tade	0.340	0.097	0.333	zale	0.337	0.089	0.347
jeat	0.343	0.086	0.347	vean	0.354	0.078	0.361
jeet	0.344	0.073	0.361	veen	0.380	0.071	0.375
goak	0.349	0.081	0.361	foat	0.341	0.095	0.361
goke	0.347	0.073	0.333	fote	0.360	0.081	0.389
mern	0.352	0.088	0.361	sert	0.327	0.095	0.319
murn	0.324	0.110	0.319	surt	0.336	0.086	0.326

Since composite scores were derived from proportions, Beta family and Gaussian family EIRMs were run using the *glmmTMB* (Brooks et al., 2017) and *lme4* (Bates et al., 2015) packages and compared to determine which model family provided the best model fit. For RQ2 and RQ3, the Gaussian models provided a better model fit due to lower AIC and BIC, higher log-likelihood, and relatively normal data with very small deviations. Heteroscedasticity was checked by plotting the spread of the residuals, which depicted no clear funnel shapes or extreme outliers. Thus, Gaussian EIRMs were used to answer RQ2 and RQ3.

Is the quality of the acquired lexical representations a function of the number of target exposures during independent reading?

Gaussian EIRMs were fit for an intercept model and exposure model using the *lme4* package (Bates et al., 2015). Results are reported in Table 3.21. The exposure model revealed that number of exposures did not have a significant effect on quality composite scores ($b = 0.0002$, $SE = 0.002$, $p = .91$, 95% CI $[-0.02, 0.02]$). The likelihood ratio test was insignificant ($\Delta\chi^2 = 0.013$, $p = .909$), indicating that including number of exposures did not improve the overall model. In other words, quality composite scores did not vary as a function of whether students were exposed to the targets four or eight times during independent text reading.

Table 3.21. *RQ2 EIRMs Summary*

Predictors	Intercept Model				Exposure Model			
	Estimates	SE	<i>p</i>	95% CI	Estimates	SE	<i>p</i>	95% CI
(Intercept)	0.584	0.017	< .001	[0.55, 0.62]	0.582	0.022	< .001	[0.52, 0.59]
Exposures					0.0002	0.002	.91	$[-0.02, 0.02]$
Random effects								
σ^2	0.13	0.01		[0.12, 0.14]	0.13	0.003		[0.12, 0.14]
$\tau_{\text{stu id}}$	0.11	0.01		[0.09, 0.14]	0.11	0.01		[0.09, 0.14]
τ_{target}	0.03	0.00		[0.02, 0.05]	0.03	0.001		[0.02, 0.05]
ICC	0.44				0.44			
$N_{\text{stu id}}$	57				57			
N_{target}	16				16			
Goodness of fit								
Model R ²	0.000				0.000			
Conditional R ²	0.444				0.443			
Deviance	−946.04				−946.05			
$\Delta\chi^2$					0.013		.909	
Δdf					1			
AIC	−938.04				−938.05			

Does target word decoding accuracy and/or text reading fluency predict the quality of lexical representations?

Three Gaussian EIRMs, using the *lme4* package (Bates et al., 2015), were fit to examine the effect of target decoding and text reading fluency on the quality of lexical

representation. Results are reported in Table 3.23. Each successive model was a better fit than the Intercept Model that did not include any predictors, as measured by a likelihood ratio test. In the Target Model, target pseudoword decoding accuracy was added as a fixed effect, with results indicating that target pseudoword decoding accuracy was a significant predictor of quality of lexical representations acquired from independent reading ($b = 0.029$, $SE = 0.013$, $p = .025$). However, when text reading fluency was added in the model, the effects of target pseudoword decoding accuracy diminished. In this third all-inclusive model, text reading fluency significantly predicted the quality of lexical representations ($b = 0.001$, $SE = 0.0002$, $p = .008$) but target pseudoword decoding accuracy was not a significant predictor ($b = 0.026$, $SE = 0.013$, $p = .064$). These findings suggest that readers who demonstrated more efficient overall text reading learned lexical representations more robustly and that text reading fluency mediated the effect of target decoding accuracy on the quality of lexical representations acquired following independent reading.

Table 3.22. *RQ3 EIRMs Summary*

Predictors	Intercept Model				Target Model				Target and Text Model			
	Estimates	SE	p	95% CI	Estimates	SE	p	95% CI	Estimates	SE	p	95% CI
(Intercept)	0.584	0.017	< .001	[0.50, 0.62]	0.568	0.018	< .001	[0.53, 0.60]	0.515	0.026	< .001	[0.46, 0.57]
Target Decoding					0.029	0.013	.025	[0.00, 0.05]	0.026	0.013	.064	[0.00, 0.05]
Text Fluency									0.001	0.0002	.008	[0.00, 0.01]
Random effects												
σ^2	0.02				0.13				0.13	0.003		[0.12, 0.14]
$\tau_{\text{stu_id}}$	0.01				0.11				0.09	0.01		[0.08, 0.12]
τ_{target}	0.00				0.03				0.03	0.007		[0.12, 0.14]
ICC	0.44				0.42				0.37			
N _{stu_id}	57				57				57			
N _{target}	16				16				16			
Goodness of fit												
Observations	880				880				880			
Model R ²	0.000				0.006				0.04			
Conditional R ²	0.444				0.425				0.399			
Deviance	−946.04				−950.93				−956.91			
$\Delta\chi^2$					4.891		.027		10.873		.004	
Δdf					1				2			
AIC	−938.04				−940.93				−944.91			

Discussion

To become a skilled reader—characterized by effortless extraction of meaning from text—one must be a skilled word reader (Gough & Tunmer, 1986; Perfetti, 1985; Perfetti & Helder, 2022). Skilled word reading is characterized by rapid and effortless retrieval of a word’s identity (pronunciation and meaning) given its visual word form (i.e., spelling, e.g., Ehri, 2005; Perfetti, 1992). The self-teaching hypothesis (Jorm & Share, 1983; Share, 1995) is one theoretical framework that offers insight into the acquisition of lexical representations necessary for efficient word reading. The central claim asserts that individuals build lexical representations of new words through exposure to written forms during independent reading, predominately through accurate phonological recoding. Evidence has shown that phonological recoding is pivotal for word learning in typically developing students (Cunningham et al., 2002; Nation et al., 2007; Share, 1999, 2004), yet the extent to which students with dyslexia acquire word-specific representations via self-teaching is unclear. When phonological skills are impaired—as is the case with many students with dyslexia—other mechanisms must be employed to facilitate word learning. This has yet to be sufficiently explored. To that end, the purpose of the current study was to investigate the word-learning outcomes of Grade 3 students with dyslexia following independent reading.

The current study used the self-teaching paradigm (Share, 1999) with a within-participant (exposure level) design to investigate the extent to which students with dyslexia acquire lexical representations through self-teaching. Elementary students with dyslexia engaged with short texts that included four or eight exposures to a pseudoword target. Researchers (Nation, 2017; Perfetti & Hart, 2002; Reichle & Perfetti, 2003; Share,

1995) assert that word learning occurs gradually (Figure 3.2), progressing from initial recognition to automatic production and retrieval. Accordingly, nine word-learning tasks were administered to evaluate this continuum of learning—or the quality of lexical representations—across all aspects of word learning (Figure 3.5) immediately after students’ independent reading and again 3–7 days later.

This study investigated whether students with dyslexia acquire high-quality lexical representations of regular words following independent reading. Students exhibited strong oral reading accuracy (91.73%), reasonable oral reading fluency (74.4 words correct per minute), and adequate comprehension (85.83%) when reading the experimental texts; however, their ability to accurately decode target pseudowords was relatively weak (57.01%). Notably, target decoding accuracy in the current study is below the average target decoding accuracy reported in self-teaching experiments involving students reading English ($M = 0.6812$, $SD = 0.1585$). This relatively weak target word decoding accuracy did not impede *some* word learning to transpire, although word learning outcome results were mixed.

Word-Learning Outcomes

Figure 3.9 visually summarizes the results of the nine word-learning tasks. Solid lines indicate clear evidence of learning as measured by the word-learning tasks, while dashed lines depict areas where learning was unclear or not established. Similar to typically developing students in previous self-teaching studies (e.g., Cunningham, 2006; Deacon et al., 2019; Share, 1999), students with dyslexia demonstrated gains in orthographic and semantic learning over time, suggesting some ability to form lexical representations. However, unlike typically developing readers, students with dyslexia

struggled with phonological precision and orthographic-phonological mapping, which is consistent with prior research highlighting phonological deficits in dyslexia (Snowling, 2001; Ricketts et al., 2021).

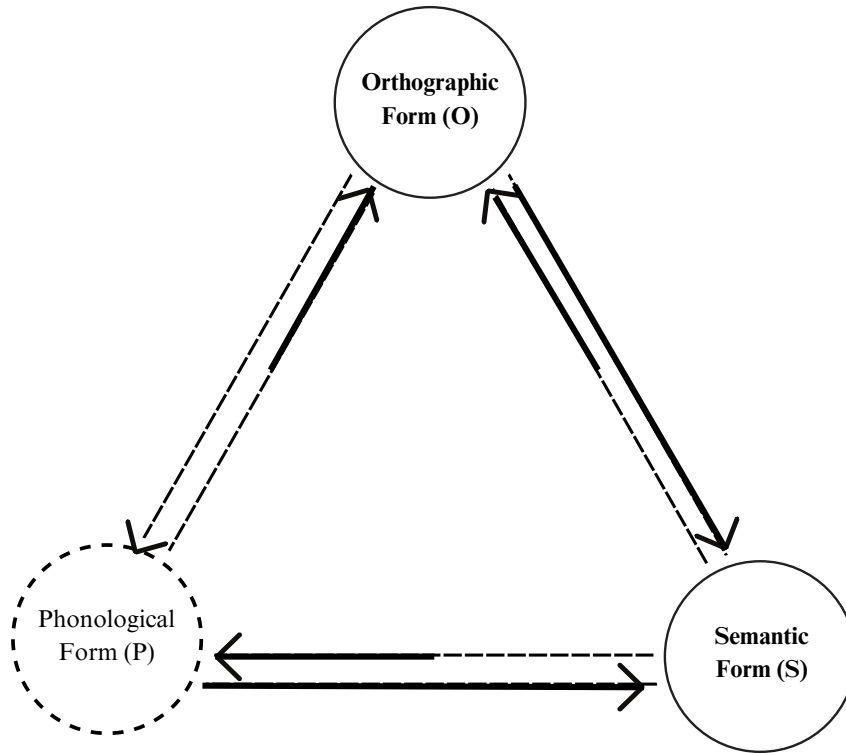


Figure 3.9. *Word Learning Results*

Constituent Knowledge

Readers with dyslexia acquired constituent knowledge as demonstrated by performance on the orthographic and semantic choice tasks. Readers chose the correct orthographic form significantly more than chance levels alone. The semantic choice task revealed a ceiling effect, providing evidence that semantic learning occurred; however, the measure may not have sensitively captured the extent of the learning. The pronunciation choice task told a different story. Pronunciation choice accuracy did not significantly differ from chance levels, implying weaker phonological representations.

These results align with evidence that readers with dyslexia may have difficulty establishing robust lexical representations due to poorly stored phonological forms of words in episodic memory (Di Betta & Romani, 2006; Perfetti, 2007).

There were significant differences in accurate responses between all three constituent choice tasks. Given the ceiling effect, the magnitude of the effect between semantic choice and the other tasks should be interpreted with caution. Despite establishing only weak phonological representations, results from the semantic and orthographic choice tasks provide support for self-teaching as a mechanism for word learning in terms of the spellings and meanings of new words for students with dyslexia.

Knowledge of Constituent Bindings

Correct selections in the word-picture match task were significantly different from random guessing. Responses from the dynamic definition production task indicated students developed semantic knowledge—at least at a recognition level, with responses statistically above the chance level. Three word-learning tasks (i.e., spelling, picture naming, and picture spelling) significantly improved over time, represented by a dotted line morphing into a solid line in Figure 3.9, from immediate to delay sessions, suggesting a gradual strengthening of orthographic and semantic representations. This improvement mirrors the performance of students with reading difficulties found in prior research (Share & Shalev, 2004) and together provide evidence to suggest that students with reading difficulties develop burgeoning lexical representations that are refined over time. One explanation of observed refinements in the lexical representations is that during the administration of the immediate word-learning tasks, students were introduced to the correct phonological forms of the targets (e.g., Spell *taid/tade*.) Perhaps these

exposures led to observational learning, allowing students to refine their burgeoning lexical representations by fixing up their phonological representation. However, if this were the case, we would also expect a significant increase in the pronunciation choice task, which was not observed.

In sum, the findings from the current study support the self-teaching hypothesis, thereby extending the current evidence base. There was clear evidence that students with dyslexia acquired orthographic and semantic knowledge of words following independent reading. However, students with dyslexia did not acquire high-quality lexical representations. Quality was affected by weaker phonological form knowledge, as evidenced by poor performance on the pronunciation choice task and no observed differences between word naming speed between target pseudowords and homophonic pseudowords. These results further support a core phonological impairment in readers with dyslexia (Di Betta & Romani, 2006; Perfetti, 2007). In the future, researchers should further examine the possible underlying mechanisms (e.g., orthographic knowledge, set for variability) responsible for the orthographic and semantic learning that occurred despite the difficulty in forming phonological representations.

Effect of Exposures

The second research question explored if the quality of lexical representations varied as function of number of exposures to the target pseudowords. Although there was evidence of some word learning, students did not acquire high-quality lexical representations. Quality did not vary as a function of whether students were exposed to the targets four or eight times during independent text reading. The absence of a significant effect of exposure frequency on lexical quality diverges from studies

suggesting that repeated exposures enhance orthographic learning (Nation et al., 2007) and semantic learning (Cunningham & Stanovich, 1997). This may be due to the underlying phonological processing difficulties in students with dyslexia, which impede the automatic formation of lexical representations despite multiple encounters with a word. The eight exposures to target pseudowords words presented to students in the current study were seemingly insufficient to allow them to develop a robust lexical representation securely; perhaps, 12 or 18 exposures are necessary, as proffered in Hoagboam and Perfetti (1978) and aligned with He and Tong (2017). Additionally, all exposures to target pseudowords were contained in one experimental text. Word-learning outcomes may improve if the exposures to target pseudowords are spaced across texts, allowing students to retrieve and refine burgeoning lexical representations. Future studies can employ the procedures used by Wegener et al. (2022, 2023) to determine if a spacing effect strengthens the quality of lexical representations developed by students with dyslexia.

Effects of Target Decoding Accuracy and Text Reading Fluency

The final research question examined the effect of target decoding accuracy and text reading fluency on the quality of lexical representations. Target decoding accuracy initially emerged as a significant predictor of higher-quality lexical representations—directly supporting the self-teaching hypothesis. Interestingly, when text reading fluency was added to the model, target decoding accuracy was no longer significant, suggesting that text reading fluency may mediate the effect of target decoding accuracy in students with dyslexia development of high-quality lexical representations. This finding does not support the core premise of the self-teaching hypothesis—that postulates phonological

recoding is the pivotal mechanism in word learning—but rather aligns with research emphasizing the importance of fluent reading in word learning (Ehri, 2005). Further explorations of the magnitude of this effect are needed to understand the fundamental mechanisms that support word learning for students with dyslexia.

Limitations

There are several limitations to consider when interpreting findings from this study. First, the current study used pseudowords as targets. Pseudowords can shed light on how new words are added to the lexicon at the cost of limiting processes that may be at play during word learning. Since students had never heard of the pseudoword targets before, they were unable to detect mispronunciation errors during word reading. Set for variability (Tunmer & Chapman, 2012)—mispronunciation detection—is one mechanism hypothesized to contribute to word learning (Elbro et al., 2012; Steacy et al., 2019). Set for variability describes a reader’s ability to bridge the gap between their phonological recoding attempt (e.g., /k nai h t / for *knight*) and the correct pronunciation of the word (e.g., /nart/). In the future, orthographic learning paradigms (e.g., Wang et al., 2011) should be employed in a series of studies to examine the effect of semantic and phonological knowledge (i.e., vocabulary) on the quality of lexical representations acquired following independent reading. By first teaching students the phonological and semantic forms of target pseudowords prior to independent reading, researchers can ascertain if set for variability—a cognitive fix-up strategy for word reading—plays a causal role in word learning. Additionally, researchers can examine the effect of initial vocabulary training on the quality of lexical representations acquired between different

word types and the extent to which semantic knowledge plays a role in word learning for students with dyslexia (see Wang et al., 2012).

Two limitations pertain to the methods deployed. First, the methods by which reading was observed have inherent limitations. When students read aloud, only some reading processes can be observed. Recently, eye-tracking methodologies have been used (Brusnighan et al., 2014; Ginestet et al., 2021) to observe more covert reading processes. Eye-tracking data provide a deeper understanding of processes students engage in while reading. In the future, eye-tracking studies employing a self-teaching or orthographic learning paradigm with students with dyslexia may provide further insights into the mechanisms underlying word learning. Additionally, due to scheduling conflicts (e.g., field trips, holidays, absences), the number of days between administering the immediate and delay word-learning tasks was not constant. The sessions occurred within 3–7 days; however, this range may have affected the word-learning outcomes. Although the individual word-learning task data cannot easily be adjusted to reflect the variance in the delay, when a fixed effect for the delay was included in the model for RQ3, results did not change.

The final limitation pertains to how the quality composite was calculated. Although theoretically grounded (Massaro & Rowe, 2015; Nation, 2017; Perfetti, 2017), the composite was derived from hypothesized placement along a word-learning continuum. Aggregating word-learning tasks into two sub-composites decreased the weight of recognition tasks—along the initial stages of word learning. More research is needed to validate and refine the word-learning tasks that contribute to a reliable and valid composite to capture the quality of a lexical representation. When the models were

refit with a composite that assumed equal weight of the word-learning tasks, as in prior research (see Cunningham et al., 2002), the findings did not differ; therefore, for the purposes of this study, the quality composite used in RQ2 and RQ3 analyses is sufficient.

Conclusion

Overall, this study partially supports the self-teaching hypothesis in students with dyslexia but highlights the challenges these students face in word learning. Although observed gains in orthographic and semantic knowledge suggest some ability to develop lexical representations, the lack of strong phonological learning, evidenced by weak target decoding accuracy and poor performance on the pronunciation choice task, indicates that the reliance on phonological recoding impairs lexical learning for students with dyslexia. Future research should focus on further exploring contexts that initiate word learning in this population.

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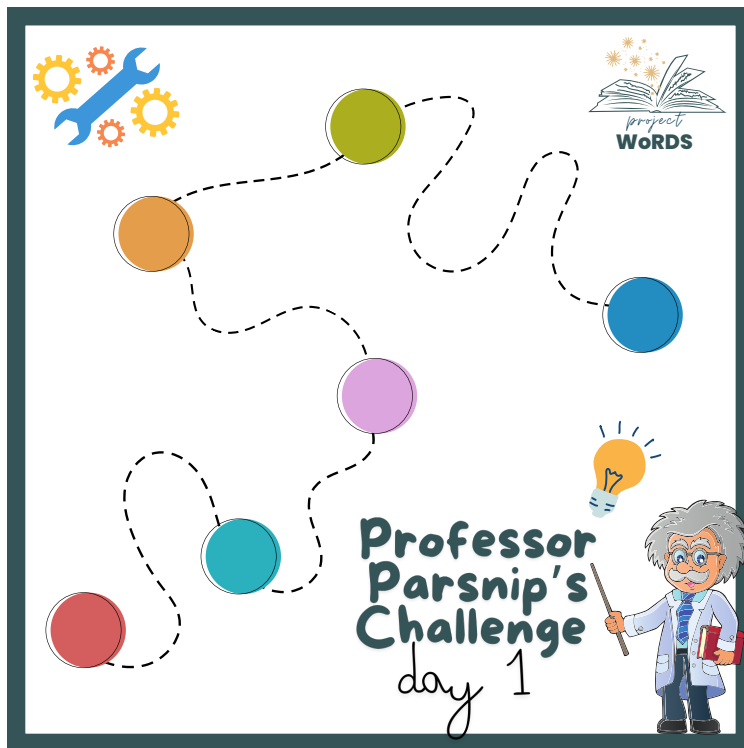
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Appendix A

Session Sticker Chart Example



Appendix B

Descriptive Measures

Baseline measures, including four standardized tasks, were administered in Session 1 in the order found below. The data collected from these measures will be used in the scope of a larger research project. For this study, the data are used to describe the study sample.

Test of Word Reading Efficiency (TOWRE)

The TOWRE (Torgesen et al., 2012) measures one's ability to recognize familiar words on sight and sound out words accurately and fluently. The TOWRE includes two timed (45 s) subtests where students read as many real words (Sight Word Efficiency) or nonwords (Phonemic Decoding Efficiency) as possible out loud from provided lists. It has excellent reported reliability, .96. A composite standard score was calculated by combining the scale scores of the two subtests and used as an indicator of reading performance.

Researcher-Developed Word Reading Task

The researcher-developed word reading tool was used to establish an understanding of the student's current knowledge of the patterns used in the experimental tasks. The tool consisted of a list of 16 real words that shared the rime patterns and initial consonants with the experimental targets (see Table B.1). Students read the list of real words out loud. Accuracy was determined by summing the correct responses, dividing by 16, and multiplying by 100.

Table 3.1. *Researcher-Created Screening Tool*

Target Phoneme	Real Words			
/eɪ/	maid	fade	tail	gale
/i/	neat	meet	lean	seen
/oʊ/	soak	joke	boat	vote
/ə/	fern	burn	pert	curt

Note. No word selected was the *most* frequent word corresponding to the rime pattern.

Verbal PAL Ability

Verbal PAL ability is one's ability to form links between two items—one of which involves verbal material—which has strong correlations with word learning (Wang et al., 2017). This study measured PAL ability within (verbal-verbal) and across (visual-verbal) modalities. Stimuli for the two PAL tasks were originally used by Hulme et al. (2007) and included ten nonwords paired together and five nonwords paired with five 6-sided shapes (Vanderplas & Garvin, 1959), shown in Table B.2. Each task was presented as a game and consisted of a learning phase and test trials. Prior to each task, the student repeated each of the nonwords to ensure correct pronunciation.

Table B.2. *Stimuli for PAL Tasks*

Task	Items				
Verbal-Verbal					
Set 1	huk	fot	jat	zog	raz
Set 2	dof	teg	lum	mab	sep
Visual-Verbal					
Nonwords	kel	gug	nid	bim	vob
Shapes					

Verbal-Verbal PAL Task. During the learning phase, the experimenter said each pair of nonwords twice (e.g., *Huk goes with dof*, [2-s interval], *huk goes with dof*.)

Following the learning phase, 25 test trials (five per pair) ensued. Each nonword was presented in the form of a question (e.g., *What goes with huk?*) The student provided a response, and regardless of performance, the correct response was provided (e.g., *dof*). The number of correct responses was recorded and used to measure verbal-verbal PAL ability.

Visual-Verbal PAL Task. Five nonwords were paired with five shapes. During the learning phase, the experimenter presented one shape at a time and stated the associated nonword twice (e.g., *This shape goes with kel*, [2-s interval], *this shape goes with kel*.) Once all five shape–word pairs had been presented, the 25 test trials (5 per pair) began. In a random order, a shape was presented, and the student was asked, “What word goes with this shape?” Regardless of the response, the correct response was provided (e.g., *kel*). The number of correct responses was recorded and used as a to measure of visual-verbal PAL ability.

Raven’s Colored Progressive Matrices (CPM)

The CPM (Raven, 1998) was administered to measure analogical reasoning. The measure includes 36 items divided into three sets. Each item includes a visual pattern with a missing piece; the student selects the missing piece from four options. The CPM is designed for students ages 6–11 or older individuals with disabilities. The reported internal consistency is .85–.90 (Cotton, 2007). The total number of correct responses was used to derive the standard score. The standard score was used as an indicator of analogical reasoning ability.

Orthographic Knowledge Task

An orthographic knowledge task used in prior research (Conrad et al., 2013) was used to assess students' general orthographic knowledge—defined as the sensitivity to orthographic regularities in a language (Apel, 2011). In the 45-item task, participants select the nonword in a pair of words that looks most like a real word. The reported internal consistency from prior research is .88 (Conrad et al., 2013). The number of correct responses was recorded and used as an indicator of existing orthographic knowledge.

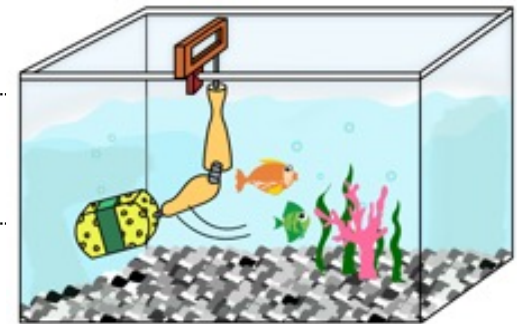
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Appendix C

Cleaning the Dirty Fish Tank

Ben looked at his fish swim, but the tank was dirty. So, he got the taid. The taid is used to clean fish tanks. The taid has an arm that looks like a sponge. Ben put the taid in the tank. Then he turned the taid on. The taid started to clean. Wow! The taid had cleaned the fish tank really fast. Ben looked at his fish.



When he took the taid out of the tank, the fish looked happy.

1.11.08

Figure C.1. 8 Exposure Text <taid>

Cleaning the Dirty Fish Tank

Ben looked at his fish swim, but the tank was dirty. So, he got

the taid. The taid is used to clean fish tanks. It has an arm

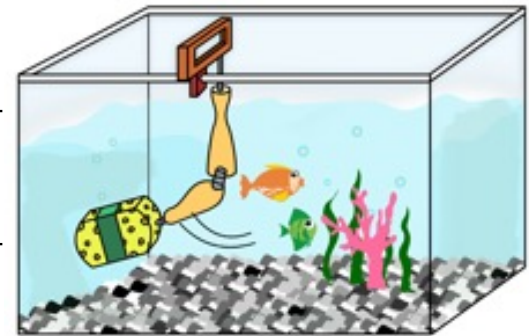
that looks like a sponge. Ben put it in the tank. Then he turned

it on. It started to clean. Wow! The taid

had cleaned the fish tank really fast.

Ben looked at his fish. When he took the

taid out of the tank, the fish looked happy.

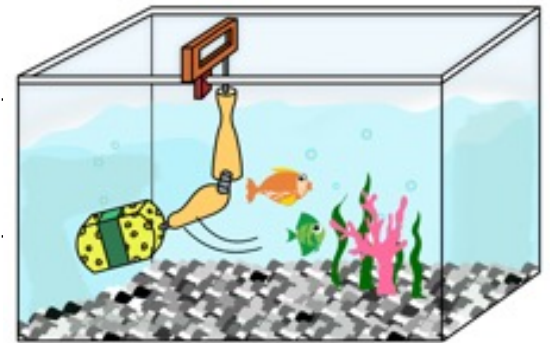


1.11.04

Figure C.2. 4 Exposure Text <taid>

Cleaning the Dirty Fish Tank

Ben looked at his fish swim, but the tank was dirty. So, he got the tade. The tade is used to clean fish tanks. The tade has an arm that looks like a sponge. Ben put the tade in the tank. Then he turned the tade on. The tade started to clean. Wow! The tade had cleaned the fish tank really fast. Ben looked at his fish.



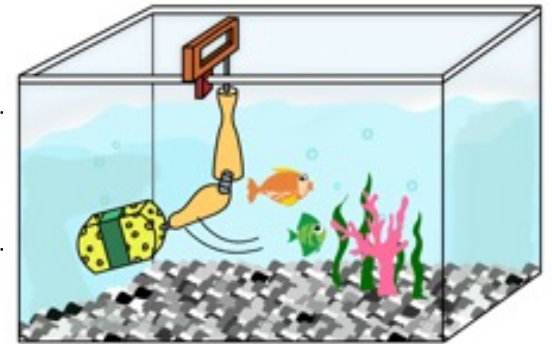
When he took the tade out of the tank, the fish looked happy. 1.12.08

Figure C.3. 8 Exposure Text <tade>

Cleaning the Dirty Fish Tank

Ben looked at his fish swim, but the tank was dirty. So, he got the tade. The tade is used to clean fish tanks. It has an arm that looks like a sponge. Ben put it in the tank, Then he turned it on. It started to clean. Wow! The tade had cleaned the fish tank really fast.

Ben looked at his fish. When he took the tade out of the tank, the fish looked happy.

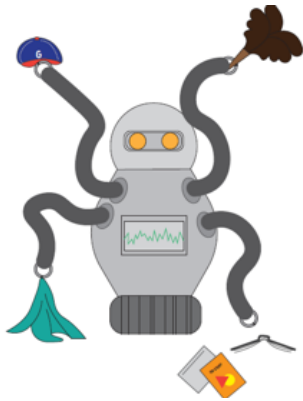


1.11.04

Figure C.4. 4 Exposure Text <tade>

Cleaning the Messy Bedroom

Lin had a messy bedroom, and her mom told her to clean it. So, Lin



got the zail. The zail is used to clean your bedroom for

you. The zail is a robot. The zail has lots of arms, so

it can clean fast. Lin turned the zail on. She sat on her

bed and watched the zail. Wow! The zail cleaned her room in no time.

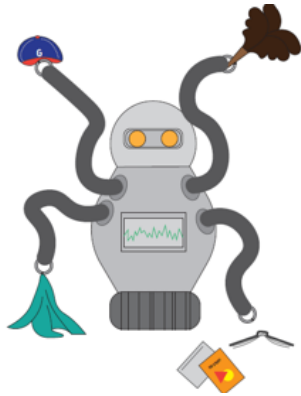
When the job was done, Lin put the zail away.

1.21.08

Figure C.5. 8 Exposure Text <zail>

Cleaning the Messy Bedroom

Lin had a messy bedroom, and her mom told her to clean it. So, Lin



got the zail. The zail is used to clean your bedroom for
you. It is a robot with lots of arms, so it can clean fast.

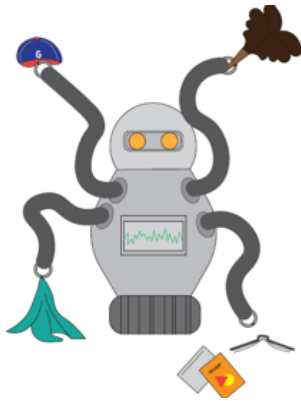
Lin turned it on. She sat on her bed and watched the
zail. Wow! The zail cleaned her room in no time. When the job was
done, Lin put it away.

1.21.04

Figure C.6. 4 Exposure Text <zail>

Cleaning the Messy Bedroom

Lin had a messy bedroom, and her mom told her to clean it. So, Lin



got the zale. The zale is used to clean your bedroom for

you. The zale is a robot. The zale has lots of arms, so

it can clean fast. Lin turned the zale on. She sat on her

bed and watched the zale. Wow! The zale cleaned her room in no

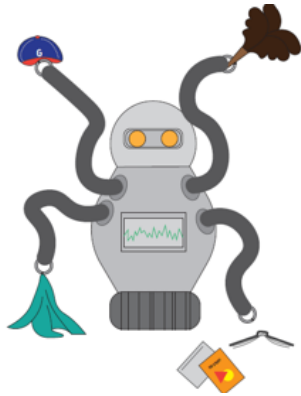
time. When the job was done, Lin put the zale away.

1.22.08

Figure C.7. 8 Exposure Text <zale>

Cleaning the Messy Bedroom

Lin had a messy bedroom, and her mom told her to clean it. So, Lin



got the zale. The zale is used to clean your bedroom for you. It is a robot with lots of arms, so it can clean fast.

Lin turned it on. She sat on her bed and watched the zale. Wow! The zale cleaned her room in no time. When the job was done, Lin put it away.

1.22.04

Figure C.8. 4 Exposure Text <zale>

Homework Helper

Jon played all day, but he had math homework. Now, it was bedtime.

So, Jon got the jeat. The jeat is used to do your homework

while you sleep. The jeat is soft and shaped

like a pillow. Jon put his math homework



into the jeat. The jeat began to work. Jon fell asleep. When Jon woke

up, the jeat had finished his homework. "Yes!" Jon said when he

grabbed his homework out of the jeat. Before going to school, Jon

put the jeat away.

2.11.08

Figure C.9. 8 Exposure Text <jeat>

Homework Helper

Jon played all day, but he had math homework. Now, it was bedtime.

So, Jon got the jeat. The jeat is used to do your homework

while you sleep. It is soft and shaped like a

pillow. Jon put his math homework into it.



It began to work. Jon fell asleep. When Jon woke up, the jeat had

finished his homework. "Yes!" Jon said as he grabbed his homework.

Before going to school, Jon put the jeat away.

2.11.04

Figure C.10. 4 Exposure Text <jeat>

Homework Helper

Jon played all day, but he had math homework. Now, it was bedtime.

So, Jon got the jeet. The jeet is used to do your homework

while you sleep. The jeet is soft and shaped

like a pillow. Jon put his math homework



into the jeet. The jeet began to work. Jon fell asleep. When Jon woke

up, the jeet had finished his homework. “Yes!” Jon said when he

grabbed his homework out of the jeet. Before going to school, Jon

put the jeet away.

2.12.08

Figure C.11. 8 Exposure Text <jeet>

Homework Helper

Jon played all day, but he had math homework. Now, it was bedtime.

So, Jon got the jeet. The jeet is used to do your homework

while you sleep. It is soft and shaped like a

pillow. Jon put his math homework into it.



It began to work. Jon fell asleep. When Jon woke up, the jeet had

finished his homework. "Yes!" Jon said as he grabbed his homework.

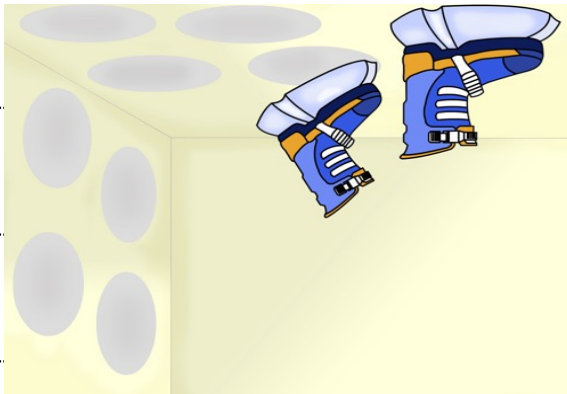
Before going to school, Jon put the jeet away.

2.12.04

Figure C.12. 4 Exposure Text <jeet>

Min and Jen Play Tag

Jen and Min were playing tag. Jen was “it,” but Min was faster than her. So, Jen got the vean. The vean is used to walk up walls. The



vean is blue and looks like big boots. Jen put the vean on her feet. Then she started walking up the wall in the vean. The vean

helped Jen get to the ceiling without falling. Min ran into the room.

She was safe. But Jen came down in the vean quietly. She took off

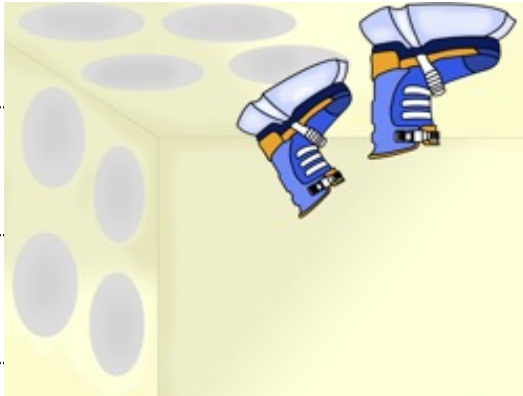
the vean. Then, she snuck up on Jen. Boo! Jen tagged Min.

2.2.1.08

Figure C.13. 8 Exposure Text <vean>

Min and Jen Play Tag

Jen and Min were playing tag. Jen was “it,” but Min was faster than her. So, Jen got the vean. The vean is used to walk up walls. It is



blue and looks like big boots. Jen put it on her feet. Then she started walking up the wall.

The vean helped Jen get to the ceiling without

falling. Min ran into the room. She was safe. But Jen came down

quietly. She took off the vean. Then, she snuck up on Min. Boo! Jen

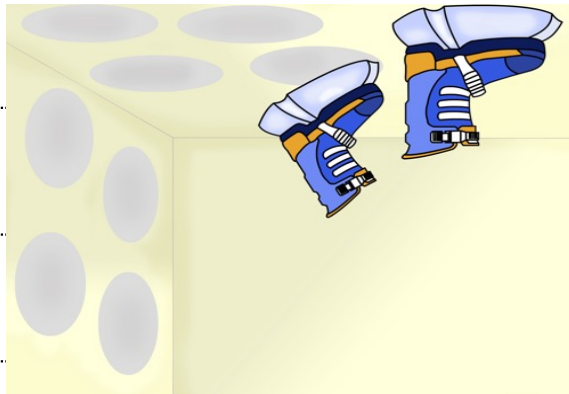
tagged Min.

2.21.04

Figure C.14. 4 Exposure Text <vean>

Min and Jen Play Tag

Jen and Min were playing tag. Jen was “it,” but Min was faster than her. So, Jen got the veen. The veen is used to walk up walls. The



veen is blue and looks like big boots. Jen put

the veen on her feet. Then she started

walking up the wall in the veen. The veen

helped Jen get to the ceiling without falling. Min ran into the room.

She was safe. But Jen came down in the veen quietly. She took off

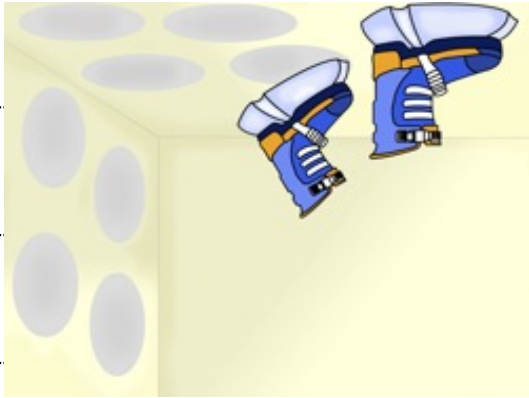
the veen. Then, she snuck up on Jen. Boo! Jen tagged Min.

2.22.08

Figure C.15. 8 Exposure Text <veen>

Min and Jen Play Tag

Jen and Min were playing tag. Jen was “it,” but Min was faster than her. So, Jen got the veen. The veen is used to walk up walls. It is



blue and looks like big boots. Jen put it on her feet. Then she started walking up the wall.

The veen helped Jen get to the ceiling without falling. Min ran into the room. She was safe. But Jen came down quietly. She took off the veen. Then, she snuck up on Min. Boo! Jen tagged Min.

2.22.04

Figure C.16. 4 Exposure Text <veen>

A Day at the Park

Tim and his dog Bud were at the park, but Bud did not stop barking.

So, Tim turned on the foat. The foat is used to translate dog

barks. The foat has an antenna and fits in your hand. The

foat lit up when Bud barked, and the foat said, "BALL!"

So, Tim kicked the ball for Bud a lot. Bud ran after the ball each time.

The foat lit up again. The foat said, "HOME!" So, Tim turned the foat

off. Then, they went home.



Figure C.17. 8 Exposure Text <foat>

A Day at the Park

Tim and his dog Bud were at the park, but Bud did not stop barking.

So, Tim turned on the foat. The foat is used to translate dog

barks. It has an antenna and fits in your hand. The foat

lit up when Bud barked, and said, "BALL!" So, Tim kicked

the ball for Bud a lot. Bud ran after the ball each time. The foat lit

up again. It said, "HOME!" So, Tim turned it off. Then, they went

home.



Figure C.18. 4 Exposure Text <foat>

A Day at the Park

Tim and his dog Bud were at the park, but Bud did not stop barking.

So, Tim turned on the fote. The fote is used to translate dog

barks. The fote has an antenna and fits in your hand. The

fote lit up when Bud barked, and the fote said, "BALL!"

So, Tim kicked the ball for Bud a lot. Bud ran after the ball each time.

The fote lit up again. The fote said, "HOME!" So, Tim turned the fote

off. Then, they went home.



Figure C.19. 8 Exposure Text <fote>

A Day at the Park

Tim and his dog Bud were at the park, but Bud did not stop barking.

So, Tim turned on the fote. The fote is used to translate dog

barks. It has an antenna and fits in your hand. The fote

lit up when Bud barked, and said, “BALL!” So, Tim kicked

the ball for Bud a lot. Bud ran after the ball each time. The fote lit

up again. It said, “HOME!” So, Tim turned it off. Then, they went

home.



Figure C.20. 4 Exposure Text <fote>

Traveling in the Lake

Kat was at the lake, and she wanted to see the fish. So, she asked her mom to get her the goak. The goak is used to travel underwater.



The goak looks like a bike, but the goak has flippers. Kat gets on the goak. She starts to pedal, and the goak moves. Then, the goak makes a bubble around Kat so she can breathe underwater. Wow! Kat sees so many

fish. She rides the goak around the lake until she gets tired. Then,

Kat goes back to her Mom.

3.21..08

Figure C.21. 8 Exposure Text <goak>

Traveling in the Lake

Kat was at the lake, and she wanted to see the fish. So, she asked her mom to get her the goak. The goak is used to travel underwater. It



looks like a bike but it has flippers. Kat gets on the goak.

She starts to pedal, and it moves. Then, the goak makes

a bubble around Kat so she can breathe underwater.

Wow! Kat sees so many fish. She rides it around the lake

until she gets tired. Then, Kat goes back to her mom.

3.21.04

Figure C.22. 4 Exposure Text <goak>

Traveling in the Lake

Kat was at the lake, and she wanted to see the fish. So, she asked her mom to get her the goke. The goke is used to travel underwater.



The goke looks like a bike, but the goke has flippers. Kat gets on the goke. She starts to pedal, and the goke moves. Then, the goke makes a bubble around Kat so she can breathe underwater. Wow! Kat sees so many

fish. She rides the goke around the lake until she gets tired. Then, Kat goes back to her Mom.

3.22..08

Figure C.23. 8 Exposure Text <goke>

Traveling in the Lake

Kat was at the lake, and she wanted to see the fish. So, she asked her mom to get her the goke. The goke is used to travel underwater. It



looks like a bike but it has flippers. Kat gets on the goke.

She starts to pedal, and it moves. Then, the goke makes

a bubble around Kat so she can breathe underwater.

Wow! Kat sees so many fish. She rides it around the lake

until she gets tired. Then, Kat goes back to her mom.

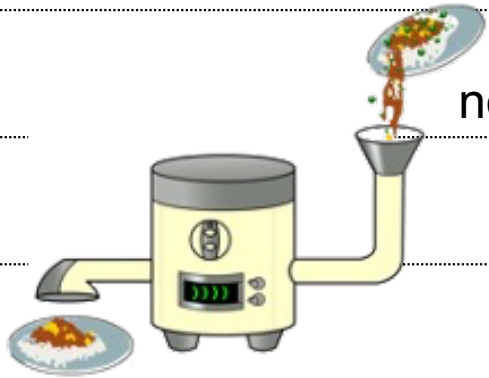
3.22.04

Figure C.24. 4 Exposure Text <goke>

Making a Tasty Lunch

Max was hungry, but there were peas in his lunch. Yuck! Max hates

peas. So, Max got the mern. The mern is used to remove food you do



not like from your meals. The mern has a tube with

two open ends. Max put his lunch into the mern

and he pressed the button. The mern started to

make noises as it got rid of the peas. Then, the mern stopped. The

mern had removed all of the peas. Finally, Max could eat his lunch.

When he was done, he put the mern away.

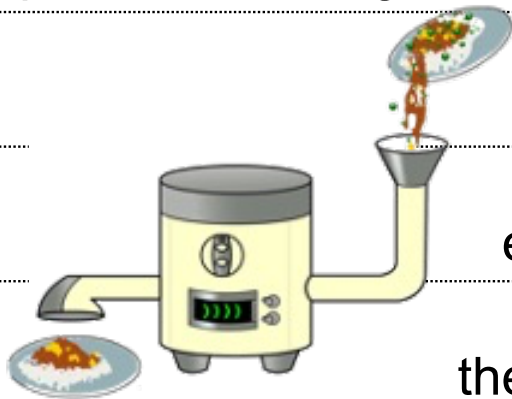
4.11.08

Figure C.25. 8 Exposure Text <mern>

Making a Tasty Lunch

Max was hungry, but there were peas in his lunch. Yuck! Max hates

peas. So, Max got the mern. The mern is used to remove food you do



like from your meals. It has a tube with two open

ends. Max put his lunch into the mern. He pressed

the button. Then, the mern started to make noises

as it got rid of the peas. It stopped. It had removed all of the peas.

Finally, Max could eat his lunch. When he was done, he put it away.

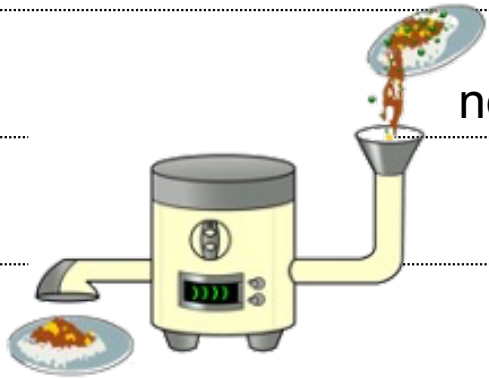
4.11.04

Figure C.26. 4 Exposure Text <mern>

Making a Tasty Lunch

Max was hungry, but there were peas in his lunch. Yuck! Max hates

peas. So, Max got the murn. The murn is used to remove food you do



not like from your meals. The murn has a tube with

two open ends. Max put his lunch into the murn

and he pressed the button. The murn started to

make noises as it got rid of the peas. Then, the murn stopped. The

murn had removed all of the peas. Finally, Max could eat his lunch.

When he was done, he put the murn away.

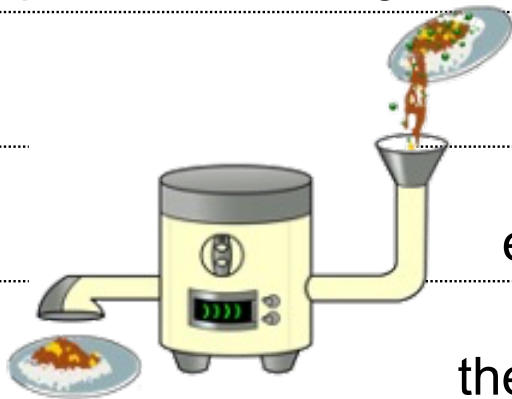
4.12.08

Figure C.27. 8 Exposure Text <murn>

Making a Tasty Lunch

Max was hungry, but there were peas in his lunch. Yuck! Max hates

peas. So, Max got the murn. The murn is used to remove food you do



like from your meals. It has a tube with two open

ends. Max put his lunch into the murn. He pressed

the button. Then, the murn started to make noises

as it got rid of the peas. It stopped. It had removed all of the peas.

Finally, Max could eat his lunch. When he was done, he put it away.

4.12.04

Figure C.28. 4 Exposure Text <murn>

Staying Dry in the Rain

Beth was walking to school when the clouds got dark, and it looked like rain. Beth did not want to get wet, so she needed the sert. The sert is used to keep you dry when it rains. The sert is waterproof and the sert looks like a small umbrella that attaches to your backpack. Beth clicked the button on the sert. Pop! The sert opened up. Then, the rain started, but the sert kept Beth dry. When she got to school Beth put the sert away.



4.21.08

Figure C.29. 8 Exposure Text <sert>

Staying Dry in the Rain

Beth was walking to school when the clouds got dark, and it looked like rain. Beth did not want to get wet, so she needed the sert. The sert is used to keep you dry when it rains. It is waterproof and looks like a small umbrella that attaches to your backpack.

Beth clicked the button on the sert. Pop! It opened up.

Then, the rain started, but the sert kept Beth dry. When she got to school Beth put it away.



4.21.04

Figure C.30. 4 Exposure Text <sert>

Staying Dry in the Rain

Beth was walking to school when the clouds got dark, and it looked like rain. Beth did not want to get wet, so she needed the surt. The surt is used to keep you dry when it rains. The surt is waterproof and the surt looks like a small umbrella that attaches to your backpack. Beth clicked the button on the surt. Pop! The surt opened up. Then, the rain started, but the surt kept Beth dry. When she got to school Beth put the surt away.



4.22.08

Figure C.31. 8 Exposure Text <surt>

Staying Dry in the Rain

Beth was walking to school when the clouds got dark, and it looked like rain. Beth did not want to get wet, so she needed the surt. The surt is used to keep you dry when it rains. It is waterproof and looks like a small umbrella that attaches to your backpack.

Beth clicked the button on the surt. Pop! It opened up.

Then, the rain started, but the surt kept Beth dry. When she got to school Beth put it away.



4.22.04

Figure C.32. 8 Exposure Text <surt>

Appendix D

Cleaning the Fish Tank (*taid/tade*)

1. What was wrong in the beginning?
2. Who was happy at the end?

Cleaning the Messy Bedroom (*zail/zale*)

1. What did her mom ask her to do?
2. Where did she watch from?

Homework Helper (*jeat/jeet*)

1. What did Jon do all day?
2. What kind of homework did he have?

Min and Jen Play Tag (*vean/veen*)

1. Who was “it” or the person tagging?
2. Where did she come from to sneak up on her friend?

A Day at the Park (*foat/fote*)

1. Who is Bud?
2. What did he want first?

Traveling in the Lake (*goak/goke*)

1. What did she see?
2. Who helped her in the beginning?

Making a Tasty Lunch (*mern/murn*)

1. What did he not like?
2. What did he do after he ate lunch?

Staying Dry in the Rain (*sert/surt*)

1. Why did Beth think it was going to rain?
2. Where was she going?

Appendix E

Initially, six common vowel pronunciations (/i/, /eɪ/, /oʊ/, /u:/, /ə/, /aʊ/) served as the primary basis of pseudoword creation. Words that contained the target phonemes were extracted from the *Children's Picture Book Lexicon Database* (CPBLD; Green et al., 2023). From these items, frequent rime patterns were identified for each phoneme. Only frequent rime patterns that had a matching homophonic pattern were selected ($N = 64$). Then, data pertaining to the feedforward and feedback consistency of each rime pattern were retrieved from Chee et al. (2020), using the most frequent item identified in CPBLD to systematically select eligible rime patterns for pseudoword creation.

Feedforward consistency refers to the relationship from spelling to sound (i.e., reading), and feedback consistency refers to the relationship from sound to spelling. Data from token consistency was used as these data are weighted by frequency of occurrence (Treiman et al., 1995). Rime patterns used in this study were to have high feedforward consistency to ensure readers would be familiar with the pronunciations but relatively matched feedback consistencies to ensure a *word-specific* representation could be measured and not attributed to stark differences between rime pattern spelling consistencies. Therefore, any rime pattern with a feedforward consistency $\leq .6$ was excluded along with its homophonic match ($n = 16$). Additionally, any rime pattern with a feedback consistency $\leq .1$ was excluded along with its homophonic match ($n = 20$). From the remaining rime patterns, only one pair remained for /aʊ/ and /u:/; therefore, those two sounds were excluded ($n = 4$). Additionally, only two pairs remained for /eɪ/ and /oʊ/. Thus, those two patterns were selected for pseudoword creation. From the remaining sounds, /i/ and /ə/, patterns were selected based on two factors (a) feedback

consistencies closest to .5 for both homophonic patterns and then (b) the lowest differences in feedback consistency ($n = 6$). Therefore, eaf/eef were excluded since feedback consistencies for both patterns was .2 even though there was no difference between the two. Additionally, ert/urt were excluded because a .2 difference in feedback consistency was higher than the .1 and 0 differences between the other two remaining pairs. Finally, 16 rime patterns, matched into eight pairs, were selected (see Table E.1).

Table E.1. *Target Rime Patterns*

Target Phoneme	Rime	Most Frequent Monosyllabic Word	Consistency	
			Feedforward	Feedback
/eɪ/	aid	laid	.75	.23
/eɪ/	ade	made	.96	.40
/eɪ/	ail	tail	1	.59
/eɪ/	ale	whale	1	.34
/i/	ean	mean	.93	.36
/i/	een	green	.90	.44
/i/	eat	eat	.74	.52
/i/	eet	feet	.99	.41
/oʊ/	oak	oak	1	.20
/oʊ/	oke	woke	1	.62
/oʊ/	oat	goat	1	.56
/oʊ/	ote	wrote	1	.39
/ɜr/	erb	herb	1	.51
/ɜr/	urb	curb	1	.49
/ɜr/	ert	dessert*	.71	.70
/ɜr/	urt	spurt	1	.44

Note. *There are only rare monosyllabic words that end in *ert* so the most frequent bisyllabic word was used.

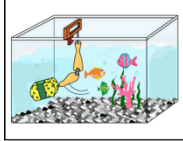
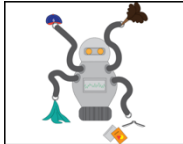
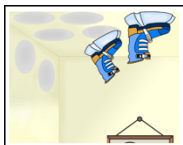
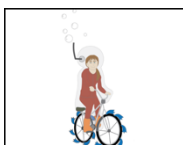
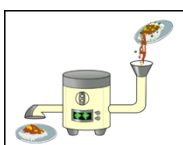
Once all eight homophonic rime patterns were selected, all known English monosyllabic words of four or five letters containing the rime patterns were generated using *Word Finder* (Merriam-Webster, 2024). This list was loaded into the UniPseudo database (Barra et al., under press) to generate four-letter pseudowords containing the

rimes. Pseudowords that would generate a real word with its homophonic pair were excluded (e.g., *rale*). From the 36 remaining pairs, eight were selected in a way that ensured no initial consonant sound was repeated.

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Appendix F

id	target	invention	picture	definition
1.11 1.12	taid tade	fish tank cleaner		The <i>taid/tade</i> is used to clean fish tanks. It has an arm that looks like a sponge.
1.21 1.22	zail zale	room cleaner		The <i>zail/zale</i> is used to clean your bedroom for you. It is a robot and has lots of arms.
2.11 2.12	jeat jeet	homework helper		The <i>jeat/jeet</i> is used to do your homework while you sleep. It is soft and looks like a pillow.
2.21 2.22	vean veen	wall walkers		The <i>vean/veen</i> is used to walk up walls. It is blue and looks like big boots.
3.11 3.12	foat fote	dog translator		The <i>foat/fote</i> is used to translate dog language. It has an antenna and fits in your hand.
3.21 3.22	goak goke	underwater bike		The <i>goak/goke</i> is used to travel underwater. It looks like a bike but has flippers.
4.11 4.12	mern murn	food remover		The <i>mern/murn</i> is used to remove food you do not like from your meals. It has a tube with two open ends.
5.21 5.22	sert surt	backpack umbrella		The <i>sert/surt</i> is used to keep you dry when it rains. It is waterproof and attaches to your backpack.

Appendix G

Text Characteristic Data by Story

Target	Length		Narrativity	Syntax	Concreteness	Cohesion		FK Grade Level ^{a, b}
	Words	Sentences				Referential	Deep	
taid/tade								
8	93	9	.67	.89	.96	.98	.95	1
4	89	9	.72	.94	.90	.77	.97	1
zail/zale								
8	77	10	.88	.88	.93	.88	.88	0
4	72	9	.93	.91	.95	.88	.90	0
jeat/jeet								
8	78	9	.84	.89	.95	1.00	.91	1
4	73	9	.91	.93	.82	.96	.95	1
vean/veen								
8	93	12	.82	.98	.94	.98	.75	2
4	85	12	.85	1.00	.79	.99	1.00	2
foat/fote								
8	86	11	.68	.99	1.00	.99	1.00	0
4	81	11	.74	1.00	1.00	.87	1.00	0
goak/goke								
8	92	11	.81	.96	.90	.89	1.00	2
4	87	11	.87	.98	.74	.57	1.00	2
mern/murn								
8	94	11	.82	.88	.95	.89	.90	1
4	89	11	.87	.93	.82	.52	.93	1
sert/surt								
8	87	9	.78	.92	.98	.97	.90	2
4	82	9	.85	.96	.93	.72	.93	2

Note. ^a Narrativity measures how aligned the form or structure of the text is to a story.

^b Syntax measures the simplicity of the sentences in the text through several indices, including average number of clauses per sentence and number of words per sentence.

^c Concreteness measures the degree to which words in the text represent something that can be perceived by the senses (e.g., peas) as opposed to abstract concepts (e.g., think).

^d Referential Cohesion measures the level of connection between words from one sentence to another by measuring the number of words, stems, and concepts that overlap amongst sentences.

^e Deep Cohesion measures how well the events or ideas of the whole text are tied together by measuring connectives.

^f FK = Flesch-Kincaid Grade Level (Kincaid et al., 1975) refers to the estimate of grade level alignment using a combination of length of sentences and number of letters in words $[(.39 * \text{sentence length}) + (11.8 * \text{word length}) - 15.59]$.

^g 0 = kindergarten, 1 = first grade, 2 = second grade