Young readers' skill in learning spellings and meanings of words during independent reading.

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Abstract

Independent reading offers children opportunities to learn the spellings and meanings of words. Evidence to date shows that older children take advantage of these orthographic and semantic learning opportunities. We provide a much-needed test of whether young readers can acquire spellings and meanings of novel words through independent reading, as well as of the possibility that each of these skills explain individual differences in word reading and reading comprehension. To test theory stringently, we assess whether these effects are separable from those of decoding. A sample of 66 Grade 1 and 2 English-speaking children independently read stories containing novel words referring to new inventions (e.g., a veap, used to clean fish tanks). We scored accuracy in reading the novel words in the stories to assess target decoding. Children completed choice measures evaluating learning of the novel words' spellings and meanings, along with word reading and reading comprehension and controls for age, short-term memory, vocabulary and phonological awareness. Scores for both the orthographic and semantic learning measures were higher with successful decoding than without. At both grade levels, children were above chance in choosing correct spellings and meanings even when they had not accurately decoded the target a single time. In terms of individual differences, after accounting for controls including target decoding, orthographic learning was related to word reading and semantic learning was related to reading comprehension. Young children have powerful skill in learning spellings and meanings through their independent reading, with highly specific impacts of such learning on reading outcomes.

Keywords: self-teaching, orthographic learning, semantic learning, word reading, reading comprehension

Skilled reading relies on having a large store of well-specified representations for individual words (Ehri, 1992; 2005; Perfetti, 1992). The Self-Teaching Hypothesis (Share, 1999; 2011) is a prominent theory put forward to explain how children acquire this bank of words. According to this theory, children acquire representations of words through their independent reading of natural texts. Further, phonological decoding, or skill in sounding out words letter-by-letter, is argued to be necessary for the creation of these representations (Share, 1995). This theory has focused most strongly on the learning of orthographic forms of word-representations. Other theories, such as the Lexical Quality Hypothesis (Perfetti & Hart, 2002), emphasise that word-specific representations need to include semantic along with orthographic and phonological information. Intriguingly, although self-teaching is advocated as operating from the outset of children's reading development (e.g., Share, 1995), most studies have tested self-teaching with more accomplished readers, who have established decoding skills (i.e., Grades 2 and up). The few studies to date with young readers provide only "glimmerings" of evidence of self-teaching (Share, 2004, page 288; see also Cunningham, 2006). We report here on a study investigating whether young readers can simultaneously learn orthographic and semantic representations of novel words through their independent reading, as well as the role of decoding in this learning. We also test the broader implications of the Self-Teaching Hypothesis for individual differences in children's reading skills; we evaluate whether children's skill in acquiring orthographic and semantic representations for new words explains variability in children's word reading and reading comprehension skills. Testing whether these effects emerge beyond decoding provides empirical impetus to examine just what goes into the "black box" that is orthographic learning (Share, 2011, p. 53).

Self-Teaching of Orthographic Representations

In the self-teaching paradigm, children independently read stories containing new words, such as *veap* (Share, 1999). Children are not given feedback on the accuracy of their reading of the stories or of the novel words within them, offering a clean test of their unsupervised learning. The extent to which children acquire representations of the spellings for the novel words encountered through this experience is termed orthographic learning (e.g., Bowey & Miller, 2007; Share, 1999). Evidence of orthographic learning has emerged in this paradigm in multiple studies of English-speaking children in Grades 2 to 5 (e.g., Bowey & Miller, 2007; Bowey & Muller, 2005; Cunningham, Perry, & Stanovich, 2001; Mimeau et al., 2018; Ouellette, 2010; Ricketts et al., 2011; Share, 1999; Tucker, Castles, Laroche, & Deacon, 2016; Wang, Castles, Nickels, & Nation, 2011). In these studies, children substantially are above chance in selecting the spelling (such as *veap*) that they had read from amongst a set of distractors (e.g., *veap*-*veep*-*yeap*-*yeep*) and at generating accurate spellings for these new words.

To our knowledge, three studies to date have used a self-teaching paradigm with children below Grade 2, each reporting very little evidence of self-teaching. These studies were all conducted at the end of children's first year of formal education (i.e., Grade 1), when the children were 7 years of age. Share (2004) reported on two separate studies with Grade 1 Hebrew-speaking children. In these studies, children read texts independently that contain novel words. Following on this reading, there was little evidence of orthographic learning. On the spelling task, children were at chance in both studies and, on orthographic choice, they were marginally above chance in one study and at chance in another. A similar pattern emerged when the stimuli were real words that the children would be expected to know orally, but not in writing. Similar results emerged in Cunningham's (2006) study with English-speaking children. In this study, children independently read texts containing words for which they were expected to know the meaning, but not the spelling (e.g., *prince*). Children selected the spelling that they had read 48% of the time, and its homophonic alternative 32% of the time (e.g., *prince-prinse*). No statistical tests against the chance level of 25% were reported. In terms of spelling, the children produced non-target spellings more often than target spellings, providing little evidence for detailed orthographic representations. This evidence of limited orthographic learning in young children directly contrasts with the prediction that "beginning reading is beginning self-teaching" (Share, 1999, p. 97).

Share (2004) described these studies as showing only young readers had "negligible" memory for orthographic detail (p. 289). He went on to suggest that young readers of Hebrew are reading in a relatively surface fashion, with little attention to orthographic detail. As such, Share suggested that young readers in Grade 1 might be processing print in a very different manner during self-teaching than even slightly older readers, such as children in Grade 2 (but see Share, 2011). Given that studies of both English and Hebrew-speaking children who little evidence of orthographic learning, this might be the case for young readers generally.

The studies described above cannot fully evaluate the possibility of age-related differences in orthographic learning. Slight differences in the instantiation of self-teaching for different age groups make results difficult to compare across available studies. As an example, Cunningham (2004) used real word stimuli, which is not standard in studies with older English-speaking children (e.g., Cunningham, Perry, & Stanovich, 2001). We report here on a study in which we contrast the extent to which children in Grades 1 and 2 can learn the orthographic forms of novel words through their self-teaching.

Self-Teaching of Semantic Representations.

In his suggestions as to the nature of young readers' learning, Share (2004) speculated there might be a trade-off, with young readers focusing on meaning to the detriment of attention to orthographic detail. The studies that we described above cannot address this possibility. They evaluated children's learning of the orthographic forms, but not the meanings of the novel words following self-teaching.

A separate body of research has demonstrated that children can learn the meanings of words through their reading (e.g., Nagy, Herman & Anderson, 1985); a small set of these studies with older readers has done so in the context of independent reading akin to the self-teaching paradigm. These studies with children in grades 2 and up show that children can learn the meanings of novel words through their independent reading (e.g., Cain et al., 2003; Cain et al., 2004; Swanborn & de Glopper, 2002). These studies assessed semantic learning, or the extent to which children acquire meaning for novel words through their self-teaching, by asking children to produce a definition or recognize a word's meaning in a multiple-choice task. Two newer studies show that children in Grades 3 can acquire both the meanings and spellings of novel words at the same time, at least in somewhat independent reading (Ricketts et al., 2011; Mimeau, Ricketts & Deacon, 2018). In the study that we report on here, we explore the extent to which young readers can learn the meanings and spellings of novel words in fully independent reading scenarios akin to the self-teaching paradigm. We contrast children in Grades 1 and 2 to determine if learning of both orthographic and semantic features might occur in parallel, or if there might be a developmental shift from initial attention to semantic features to later attention to orthographic detail.

The Role of Decoding in the Establishment of Orthographic and Semantic Representations Through Self-Teaching.

A further question lies in whether decoding is required for successful self-teaching of both orthographic and semantic representations. The Self-Teaching Hypothesis predicts that phonological decoding is necessary for children to establish orthographic representations of novel words (Share, 2011); indeed, Share (1995) described phonological decoding as the "sine qua non" of reading acquisition (page 151). Decoding is argued to force the letter-by-letter processing needed to establish these representations. And yet there are remarkably few tests of this theoretically based prediction; the question remains as to whether orthographic learning, and indeed semantic learning, can occur in the absence of successful decoding. Currently, the evidence in support of this is not as clear-cut as one might initially presume, and there is more data available for orthographic than semantic representations.

In terms of orthographic representations, there is mixed evidence as to whether learning of orthographic forms is stronger when decoding has occurred, and also as to whether decoding is required for self-teaching of orthographic forms to occur. On the first front, experimental manipulations show that suppressing decoding during the self-teaching experience substantially reduces subsequent performance on orthographic outcome measures (e.g., Share, 1999; Kyte & Johnson, 2006). Studies taking advantage of natural variation in children's decoding accuracy show correlations between accuracy in decoding target non-words in self-teaching paradigms and success in choosing the correct target spellings in orthographic choice tasks (e.g., Cunningham, 2006; Wang et al., 2013). And yet recent re-analyses of data from the 37 Grade 1 children in Cunningham's (2006) study showed significant relations between decoding and performance on spelling outcome measures, but not on orthographic choice outcome measures (Chen, Irey, & Cunningham, 2018; see also Nation et al., 2007). On the second front, there is very limited exploration as to whether self-teaching occurs in the absence of successful decoding. Tucker et al. (2016) examined performance on the orthographic choice task separately for items that children had accurately decoded the targets at least once and for items that children had never accurately decoded in the self-teaching experience. In this study, children in Grades 3 and 5 were statistically above chance in choosing the correct spelling for target non-words even for items for which they had not successfully decoding the target a single time in the self-teaching task (see also Share, 1999). These findings raise the possibility that children who cannot decode the novel words in the self-teaching experience might still acquire some degree of orthographic representations. This possibility needs to be tested with young readers, for whom this experience might be even more common.

The necessity and the role of decoding for the establishment of semantic representations also needs to be explored. The answer is not clear based on prior studies assessing semantic learning following on self-teaching paradigms. In some of these studies, children were provided with the pronunciation of the new word if they could not decode it on their own (Ricketts et al., 2008; 2011; Mimeau et al., 2018; Steele & Watkins, 2010); this limits the ability to evaluate the influence of the child's own decoding skill on semantic learning. In other studies, children were not provided with the pronunciations, but there was little reporting of the levels of children's decoding accuracy or the connection between these with learning outcomes (e.g., Tamura et al., 2017; Cain et al., 2003; Cain et al., 2004). In the present study, we test the prediction of the Self-Teaching Hypothesis as to the necessity of accurate decoding for the establishment of orthographic and semantic representations for new words encountered during independent reading. Testing these predictions at Grades 1 and 2 enables us to see if these effects shift over reading development, particularly as decoding becomes more automatic.

Individual Differences in Word Reading and Reading Comprehension.

Finally, like all theories of reading development, the Self-Teaching Hypothesis is effectively a model of how children become skilled readers in general, not just of the words that they encounter in self-teaching paradigms. Decoding is central in the self-teaching hypothesis, and is advocated as explaining the bulk of individual differences in reading outcomes. And yet, at least in terms of orthographic learning, Share (1995; 2011) suggested that the "speed and accuracy with which word-specific and general orthographic knowledge is assimilated" (Share, 2011, page 53) is a secondary source of individual differences in the formation of orthographic representations. It is speculated that effects of orthographic learning extend beyond those of decoding and that they flow through to word reading skill more generally.

Intriguingly, despite a clear theoretical division between decoding and orthographic learning (Share, 1995), only a few studies have teased apart the contributions from orthographic learning separately as from those of phonological decoding (Bowey & Miller, 2007; Cunningham et al., 2001; Ouellette & Fraser, 2009). Cunningham et al.'s (2001) study of 8- and 9-year-old children did so with the greatest precision. These researchers found that individual differences in orthographic learning, as assessed through orthographic choice, were correlated with word reading skill after controls for skill in decoding the target words during self-teaching. This small set of studies with 8- and 9-year-old children points to the possibility that skill in orthographic learning supports children's word reading beyond the role of decoding in setting up these representations.

Semantic learning has also been suggested as a possible source of individual differences in both word reading and reading comprehension (e.g., Ricketts, Bishop, Pimperton, & Nation, 2011). The Lexical Quality Hypothesis (Perfetti & Hart, 2002) has most clearly articulated the necessity of detailed representations across semantic, orthographic and phonological dimensions for reading comprehension. That said, this theory is not clearly developmental, nor has it emphasised individual differences in semantic learning. Building on the Lexical Quality Hypothesis, Ricketts and colleagues (2011) suggested that individual differences in semantic learning might be related to both word reading and reading comprehension. Relations to word reading are theorised to emerge because of the involvement of semantics in word representations. A child who is able to learn the meaning of new words after only a few exposures to the words will have a stronger representation of those words and should thus read them more easily (Perfetti

& Hart, 2002; see also Keenan & Betjemann, 2008). Relations to reading comprehension might emerge because of the centrality of individual word meaning in text comprehension. In other words, being proficient at learning the meaning of new words makes one's semantic store more extensive, which is helpful when trying to understand text (e.g., Ouellette, 2006).

Two studies to date have assessed the relations between individual differences in both orthographic and semantic learning with word reading and reading comprehension (Mimeau et al., 2018; Ricketts et al., 2011). In both studies, 8-year-old children read texts independently, although children were provided with the pronunciation of the target word if they could not read it on their own. In Ricketts et al. (2011), orthographic learning was assessed with orthographic choice and spelling tasks and semantic learning was assessed through a picture choice task. Measures of both orthographic and semantic learning were correlated with children's word reading accuracy and reading comprehension. In the second study (Mimeau et al., 2018), following on their reading, children completed both production and choice measures assessing orthographic and semantic learning. They also completed control measures of non-verbal ability, working memory, vocabulary, and phonological awareness. Structural equation modeling showed that orthographic learning was related to word reading and semantic learning was related to reading comprehension. It is not clear the extent to which these effects are independent from decoding (see e.g., Martin-Chang, Ouellette, & Bond, 2017), particularly given the known correlations between decoding and orthographic learning (Nation et al., 2007). These studies cannot evaluate this question for either orthographic or semantic learning, because children were provided with the decoding of the target word if they could not read it on their own. Clearly empirical inquiry with more traditional self-teaching paradigms is needed to establish whether the contributions of orthographic and semantic learning are distinctive from those of decoding.

The Present Study

In the present study, we use an independent reading scenario to evaluate the extent of young children's orthographic and semantic learning through their reading. We do so in a paradigm in which English-speaking children in Grades 1 and 2 read both texts and target words independently. Including children in both Grades 1 and 2 captures the point at which Share (2004) speculated that there might be a critical shift in the nature and extent of the focus of children's learning.

Our first research question lies in whether young readers simultaneously acquire orthographic and semantic representations for novel words that they encounter in their independent reading. Little research with self-teaching paradigms has been conducted with younger readers (see Cunningham, 2006; Share, 2004 for exceptions), leaving few empirical tests of the suggestion that self-teaching should operate from the outset of children's reading (Share & Stanovich, 1995). This is the case for studies of both the orthographic and semantic outcomes of this learning (e.g., Cain et al., 2003). Our study with children in the first and second years of formal instruction, at an average of 6 and 7 years of age, begins to fill this gap.

Our second question was whether accurate decoding is required for orthographic and semantic learning to occur. Certainly, the Self-Teaching Hypothesis considers decoding to be absolutely required in order for orthographic learning to occur. And yet, for young readers, effortful decoding might subsume attention that might otherwise be allocated to learning the forms and meaning of novel words. We test the influence of decoding on both orthographic and semantic learning, to assess the necessity of accurate decoding in this learning.

Our third research question lies in individual differences in children's skill in orthographic and semantic learning (Share, 1999; Perfetti & Hart, 2002) are related to individual differences in their word reading and reading comprehension skill more generally, beyond the effects of decoding. We predict, similar to Share (2011), that the influence of individual differences in orthographic learning on children's word reading will be separable from the influence of decoding. We expect the influence of decoding on word reading to be substantial, but we do not expect this to subsume the effects of orthographic learning skill entirely. In parallel, we predict that semantic learning will be related specifically to reading comprehension, beyond the effects of decoding; children's skill in creating meaning representations for individual words is likely to support their creation of meaning representations of whole texts.

To test these hypotheses, children completed a self-teaching task in which they were exposed to novel words in an independent reading situation. Following on Wang et al. (2011) and Mimeau et al (2018), the novel words had novel meanings. As in standard self-teaching paradigms (e.g., Share, 1999), children were not provided with feedback on their reading of the stories or of the novel words. Children then completed choice post-tests evaluating their learning of the spellings and meanings of the words. Following on several prior studies (e.g., Ouellette & Fraser, 2009; Tucker et al., 2016; Wang et al., 2011), we asked children to complete the choice post-tests (orthographic choice and semantic choice) once right after the reading of the stories and again a few days later. As such, we measured both short- and long-term retention of the spellings and meanings of words.

Finally, in our evaluations of individual differences, we included control variables selected to reduce the possibility that uncovered effects are spurious on other factors. We included phonological awareness because of its known relation to word reading and reading comprehension outcomes (e.g., NICHD, 2000) and to orthographic learning (e.g., Ouellette & Fraser, 2009). We also included short-term memory as a control to be sure uncovered relations are specific to orthographic and semantic learning skill respectively, rather than memory skill in general. We included vocabulary as a control to isolate effects of semantic learning from those of pre-existing vocabulary knowledge (see also Mimeau et al., 2018). In testing relations to reading comprehension, we include controls for word reading, as a check that detected relations are specific to the understanding of texts. This is particularly important for young readers, with known strong relations between word reading and reading comprehension (e.g., Gough, Hoover, & Peterson, 1996).

Method

Participants

As part of a larger study, a total of 66 typically-developing children in Grades 1 and 2 participated in the current study. All participants were enrolled in standard English programs in one of nine public elementary schools in a large metropolitan region in Canada. All instruction was in English. At the time of testing, there were 39 children in Grade 1 (22 males) with a mean age of 6 years, 10 months (*SD* = 4.48) and 27 children in Grade 2 (11 males) with a mean age of 7 years, 10 months (*SD* = 3.18). As a group, participants were within the normal range for standardised measures of vocabulary, assessed with PPVT (mean standard score = 104.62, *SD* = 12.06; Dunn & Dunn, 2007), and reading comprehension, assessed with Gates-MacGinitie (mean percentile score = 50.76, *SD* = 26.25; MacGinitie, MacGinitie, Maria & Dreyer, 2000); they were slightly above average for word reading (Woodcock, McGrew, & Mather, 2001; mean standard score = 117.09, *SD* = 14.62).

Based on parent report, most participants (55%) spoke English as their first language. As with results for the group as a whole, children who did not speak English as a first language had mean standard scores within or slightly above the normal range for each of vocabulary (mean = 99.50; SD = 10.98), word reading (mean = 119.64; SD = 15.09) and reading comprehension (mean = 51.40; SD = 22.72). Given that these standard scores are for English monolinguals, the average levels of performance are very strong indeed. The results of our analyses were the same for participants whose first language was English versus another language (*p*s $\geq .06$ for the interaction term in the regression analyses).

Materials

We administered all measures in the spring of the children's academic year.

Orthographic learning task. Our self-teaching task was based on the paradigm widely used in the literature (e.g., Bowey & Miller, 2007; Cunningham, 2006; Ricketts et al., 2011; Tucker et al., 2016; Wang et al., 2011). In the exposure phase, children were asked to read stories about inventions. Some of the inventions were taken directly from Wang et al., 2011 and others created for this study (Mimeau et al., 2018). These inventions were referred to with non-words and they were always nouns. Children then completed choice tasks in which they were asked to select the spellings and meanings of these non-words.

Exposure phase. In the exposure phase, participants read 12 short stories out loud, divided into a set of 3 stories (see Appendix A). We adapted the short stories from the study conducted by Mimeau et al. (2018) to make them simpler for young readers. The adaptations consisted of: (1) using present tense; (2) using grade appropriate words from the Dolch sight word list (Dolch, 1948); (3) reducing the overall number of words; and (4) using monosyllabic proper nouns for character names.

Each story contained four occurrences of a non-word (e.g., *veap*) that represented an invention (e.g., a fish tank cleaner). Each story was made up of five sentences in present tense and was constructed with the following structure: (1) the first sentence introduced the character and stated the context and the problem, (2) the second sentence described an initial action between the character and the invention, (3) the third sentence explained the function of the invention, (4) the fourth sentence described the character's action using the invention, and (5) the final sentence included a description of the invention being used. As the children read the stories, the experimenter did not provide any feedback on the accuracy of their reading (e.g., Cunningham, 2006; Share, 2004). This ensured that we assessed the outcomes of children's independent reading, to the extent that they were able to do so.

The non-words were based on those in Mimeau et al. (2018; see Appendix B) and adhered to several criteria. First, the non-words contained regular spellings, such that their expected pronunciation was based on the typical grapheme-phoneme correspondence rules listed in Rastle and Coltheart (1999). Second, the non-words were monosyllabic and consisted of four letters starting and ending with a consonant sound. Third, the non-words contained a target sound (e.g., /i/) that could be spelled in different ways (e.g., *ea* or *ee*). This was done so that we could use the alternative spelling as a distractor in the orthographic choice post-test. To control for any preference for a given spelling, each target sound was present in two non-words and spelled differently in each of them (e.g., /i/ *veap* and *seef*). Additionally, we presented half of the participants with one spelling of the non-word (e.g., *veap*) and the other half with the alternative spelling (e.g., *veep*). Further, we ensured that the non-words were novel to the participants by confirming that none of the non-words were listed in the Children's Printed Word Database (http://www.essex.ac.uk/psychology/cpwd/) or sounded like a real word. Finally, we ensured that each non-word began with a different letter to increase distinctiveness from one another.

Target decoding. Children's independent reading of the stories was audio-recorded and later coded for accuracy. Children's total accuracy in reading the target words was the score for the target word decoding; there were 12 targets each presented four times, leading to a maximum score of 48.

After reading each set of 3 stories in the exposure phase, participants completed 2 post-tests: orthographic learning and semantic learning. The items for the orthographic and semantic learning post-tests were the same as in Mimeau et al.'s (2018) study. These measures are discussed below.

Orthographic choice post-test. After reading each set of 3 stories in the exposure phase, participants completed an orthographic choice task to measure orthographic learning. In this post-test, the experimenter presented four spellings to participants (e.g., *veap*, *veep*, *feep*, *feap*) and asked them to identify the spelling of the invention they read about (e.g., "Choose the spelling that matches the invention that you read about."). These four options were presented in a 2 by 2 grid on one page. The order of the items and that of the choices were pre-randomised. The correct answer was the spelling of the target non-word encountered in the story (e.g., *veap*). One of the distractors corresponded to the alternative spelling of the target non-word (e.g., *veep*). The two other distractors were identical to the correct and alternative spellings of the target non-word except for the first or last letter (e.g., *feap* and *feep*).

We administered the orthographic choice post-test on two occasions: immediately after the exposure phase to measure immediate recall and a few days after the exposure phase to measure delayed retention (see the Procedure section for more details). In our regression analyses, we combined these scores to create a comprehensive measure of orthographic learning. Scores were out of a maximum of 24, with a maximum possible score of 12 at each test point. The intraclass coefficient for this post-test, calculated based on a mean-rating, absolute-agreement, two-way mixed-effects model, was .69, indicating moderate test-retest reliability (Koo & Li, 2016).

Semantic choice post-tests. Following orthographic choice, participants completed a semantic choice post-test. In the semantic choice post-test (see Appendix C), the experimenter showed four pictures to participants and asked them to identify the picture of the invention they read about (e.g., "Choose the picture that matches the invention that you read about."). The children were not provided with the name of the invention to remove the influence of any pronunciation provided on later completion of orthographic choice post-tests. It also ensured that measurement was specific to the acquisition of semantic representations. Like the orthographic choice post-test, a 2 by 2 grid containing each of the four choices was presented on one page. The order of the items and that of the choices were pre-randomised. The correct answer was a drawing of the invention presented in the story (e.g., a fish tank cleaner). One of the distractors corresponded to an invention related to the same object as that of the target non-word (e.g., a fish tank painter). The two other distractors were related to the same new object (e.g., a sock matcher and a sock fixer).

We administered the semantic choice post-test on two occasions: immediately following the orthographic choice task and a few days after the exposure phase to measure delayed retention. In our linear regression analyses, we combined these two scores to create a comprehensive measure of semantic learning. Scores were out of a maximum of 24, with a maximum possible score of 12 at each test point. The intraclass coefficient for this post-test, calculated based on a mean-rating, absolute-agreement, two-way mixed-effects model, was .92, indicating excellent test-retest reliability (Koo & Li, 2016).

Word reading. To measure word reading, we used the letter-word identification subtest of the Woodcock-Johnson Test of Achievement III (Woodcock, McGrew, & Mather, 2001) to assess sight word reading accuracy. The test was administered following the standardized procedure. The subtest contains 76 test items and scores represented the total number of letters and words read correctly. Testing stopped when the student responded incorrectly to six consecutive items. In both grades, the reliability was very good (Cronbach's alpha = .98).

Reading comprehension. To measure reading comprehension, we used the Comprehension subtest of the Gates-MacGinitie Reading Tests (GMRT; Form S, MacGinitie,

MacGinitie, Maria, & Dreyer, 2000), following standardized protocol. The Grades 1 and 2 received Level 1 and 2 versions, respectively. In this task, participants were given 35 minutes to read short texts silently and answer multiple-choice questions. Prior to the administration of test items, two practice items with feedback were administered to ensure that the children had understood the task. In both grades, there were 39 test items. We used the extended scale scores in our analyses as these are equivalent across grades. We confirmed that the results are the same when completed with the raw scores. Reliability was very good for both grades (Cronbach's alpha was .91 in Grade 1 and .92 in Grade 2).

Short-term memory. To measure short-term memory, we used the Digit Span subtest of the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999), following standardized protocol. In this task, participants listened to a series of digits of increasing length from an audio recorder, then they were asked to repeat the digits back in the same order. The test was discontinued if the child made 3 consecutive errors. There were 28 test items in this task. In both grades, the reliability was very good (Cronbach's alpha = .98).

Phonological awareness. To measure phonological awareness, we used the Elision subtest of the CTOPP (Wagner et al., 1999), following standardized protocol. Children were asked to delete individual sounds from words and to give the remaining part as their response (e.g., "Say *popcorn* without saying *pop.*"). The test was discontinued if the child made 3 consecutive errors. There were 34 test items in this task. Reliability was very good for both grades (Cronbach's alpha was .96 in Grade 1 and .97 in Grade 2).

Receptive vocabulary. Finally, to measure receptive vocabulary knowledge, we used the Peabody Picture Vocabulary Test-IV (PPVT-IV, Form A; Dunn & Dunn, 2007). There are 228 test items of increasing difficulty. For each item, the child was asked to select one of four pictures that depicted the stimulus word presented orally by the experimenter. The test was terminated on the last item of a set in which the child made eight or more errors. The test was administered according to standardized procedures and the total score represented the number of correct responses. The manual reports high reliability for this test (alpha = .97).

Procedure

Testing took place in the spring semester of the academic year in three sessions of about 30 to 40 minutes each. There were two individual sessions, followed by one group session. All testing sessions were conducted by trained research assistants during school hours at the school site. The orthographic learning task was administered in the first individual session and was audio recorded. Following a set of three stories in orthographic learning, we administered two measures of immediate post-tests (orthographic choice, semantic choice). Measures of word reading and phonological awareness were then administered, followed by measures of short-term memory and vocabulary. The second individual testing session took place between five to nine days after the first one for all children. In this session, we administered two delayed post-tests measures: orthographic choice and semantic choice. Following the two individual testing sessions, we administered reading comprehension in a small group setting (around 4 to 8 children).

Results

All analyses were conducted in IBM SPSS Statistics 23 (IBM Corp., 2015). Our data contained no univariate or multivariate outliers. Two participants did not complete one item of one of the post-tests; their score for this single item was replaced by their mean performance on the remaining 23 items. Four participants did not complete the reading comprehension task. These participants did not differ from the rest of the sample on word reading or on their scores on the learning task post-tests (ps > .42), suggesting that data were missing at random. As such, we used the mean score of the rest of our sample at that grade to replace those missing values. We also conducted our regression analyses without the replaced values for reading comprehension and our results remained the same.

Research Question 1: The Extent of Young Readers' Orthographic and Semantic Learning Through Self-Teaching.

During the exposure phase of the learning task, children were quite accurate in their reading of the stories. Grade 1 and 2 children read an average of 89% (*SD* = 15%) and 95% (*SD* = 7%) of the words accurately, respectively. Accuracy of reading of the target nonwords was more variable, with mean accuracy at 44% (*SD* = 31%) and 59% (*SD* = 26%) for the Grade 1 and 2 children, respectively. Descriptive statistics of the other measures are presented in Table 1.

[insert Table 1 here]

Table 1 reports on mean levels of performance on post-test measures of orthographic and semantic learning, both assessed through a choice task with four options. On average, in the orthographic choice post-tests, children chose the correct spelling (e.g., *veap*) 66% of the time, the alternative spelling (e.g., *veep*) 18% of the time, and another distractor (e.g., *feap* or *feep*) 16% of the time. In the semantic choice post-tests, children chose the correct picture (e.g., a fish tank cleaner) 63% of the time, the picture with the same object (e.g., a fish tank painter) 21% of the time, and another distractor (e.g., a sock matcher or a sock fixer) 16% of the time. See Table 2 for an item by item presentation of children's answer types.

We examined these scores to address our first research question. We conducted a repeated-measures ANOVA with the between-subjects variable of Grade (1 versus 2) and the within-subjects measures of Learning Type (Orthographic and Semantic) and Time (immediate and delayed). The main effect of grade was significant, such that Grade 2 children performed better than Grade 1 children, $F(1, 64) = 12.00$, $p = .001$. The main effect of time was also significant, such that children's immediate learning was higher than their delayed learning, *F*(1,

64) = 21.03, $p < .001$. The main effect of learning type was not significant, $F(1, 64) = 0.46$, $p = .50$. There was also an interaction between learning type and time, $F(1, 64) = 14.67$, $p < .001$. Pairwise comparisons with a Bonferroni adjustment indicated that levels of learning in the immediate testing were higher on the orthographic than semantic tasks ($p = .03$) and levels of learning of orthographic and semantic learning were similar in the delayed testing ($p = .19$). Importantly, there was no significant interaction with grade (ps $\geq .13$).

We followed up on this by contrasting mean levels of performance on the orthographic and semantic choice tasks against chance using one-sample *t*-tests with a test value of 3. At each grade level and on each task at each time point, scores were above chance level, ts(38) > 7.84, ps < .001, ds > 1.26. These analyses show significant amounts of learning of both the spellings and meanings of words in a self-teaching paradigm requiring independent reading in Grade 1 and 2 children.

Research Question 2: The Role of Decoding in Young Readers' Orthographic and Semantic Learning Through Their Self-Teaching.

We then explored whether this evidence of significant learning of both orthographic and semantic forms was dependent on accurate decoding in the self-teaching paradigm. To do so, we tested children's mean levels of performance against chance separately for two types of target non-words: those decoded correctly at least once during the exposure phase and those decoded incorrectly on all four trials. Children's mean scores on the orthographic and semantic choice measures are presented separately for the two types of target non-words in Table 1 (see Table 2 for an item by item presentation of children's answers). We calculated new chance levels separately for the non-words decoded correctly at least once during the exposure phase and those decoded incorrectly on all four trials[1]. For the non-words decoded correctly at least once during the exposure phase, scores were above chance level at each grade and on each of orthographic and semantic learning, *t*s(38) > 4.32, *p*s < .001, *d*s > 0.69. The results were the same for the non-words decoded incorrectly on all four trials, *t*s(38) > 5.38, *p*s < .001, *d*s > 0.86. These results indicate that children can learn the spellings and meanings of new words presented in stories, whether they can decode them or not.

Using data from Table 2, we conducted two chi-square analyses (one for orthographic learning and one for semantic learning) to evaluate if the extent of learning was different whether the non-words were decoded or not. We found differences for both orthographic learning, $\chi 2$ (2) = 25.08, $p < .01$, and semantic learning, $\chi 2$ (2) = 16.52, $p < .01$. In both the orthographic and the

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[1] Children gave 24 responses in each of the orthographic and semantic choice tasks (12 immediate and 12 delayed), and this total is divided across non-words that they decoded accurately at least once and those that they did not ever decode accurately. For Grade 1 children, 11.74 responses on average were for non-words decoded correctly at least once during the exposure phase and 12.26 were for non-words decoded incorrectly on all four trials. For Grade 2 children, 14.81 responses on average were for non-words decoded correctly at least once during the exposure phase and 9.19 were for non-words decoded incorrectly on all four trials. We divided each of these averages by four (i.e., the number of choices in the post-tests) to calculate separate chance levels for the two types of target non-words. For Grade 1, the new chance levels were thus 2.94 for the non-words decoded correctly at least once during the exposure phase and 3.07 for the non-words decoded incorrectly on all four trials. For Grade 2, the new chance levels were 3.70 for the non-words decoded correctly at least once during the exposure phase and 0.77 for the non-words decoded incorrectly on all four trials.

semantic learning post-tests, we found that children chose the correct answer (e.g., *veap* or a fish tank cleaner) more often for the non-words they had decoded correctly at least once during the exposure phase than for those they had decoded incorrectly on all four trials (ps < .05). In the semantic learning post-tests, children chose the picture with the same object (e.g., a fish tank painter) more often for the non-words they had not decoded than for those they had decoded ($p < .05$). Finally, in both the orthographic and the semantic learning post-tests, children chose the other distractors (e.g., *feap*/*feep* or a sock matcher/fixer) more for the non-words they had not decoded than for those they had decoded (ps < .05). These results suggest that successful decoding results in higher levels of orthographic and semantic learning.

Research Question 3: The Roles of Decoding, Orthographic and Semantic Learning in Individual Differences in Word Reading and Reading Comprehension

Correlations between measures are presented in Table 2. As expected, correlations between the orthographic choice post-test, the semantic choice post-test, and the reading measures were significant, and they ranged from moderate to strong. Most control measures were significantly correlated with the learning task and all were correlated with the reading measures, indicating their relevance as control variables.

[insert Table 2 here]

We then examined whether individual differences in performance on measures of orthographic and semantic learning relate to children's word reading and reading comprehension, after controlling for children's accuracy in decoding the items in the self-teaching task. To answer this question, we conducted two hierarchical linear regressions, one with word reading and another with reading comprehension as the dependent variable. We entered age, short-term memory, vocabulary, and phonological awareness as controls (Step 1). Target decoding was entered at Step 2; this was the number of times that the child read the target words correctly (with a maximum possible score of 48). The independent variable (Step 3) was score on the orthographic choice post-test or score on the semantic choice post-test. When reading comprehension was the outcome variable, we conducted an additional set of analyses with word reading as a control, to isolate unique effects on text comprehension. Finally, we included an interaction term for grade to check whether the relations between our variables were similar for Grade 1 and Grade 2 children. We used the macro PROCESS (Hayes, 2016) to conduct our analyses.

[insert Table 3 here]

The results are summarised in Table 3. Results for word reading are presented on the left and reading comprehension on the right. In all models, the control variables accounted for 50 to 55% of variance (*p*s < .001). The addition of target decoding accounted for 12 to 13% of variance (*p*s < .001). When the outcome was word reading, beyond the control of target decoding, orthographic learning still made a significant unique contribution (2%), but semantic learning did not (< 1%). When the outcome was reading comprehension, semantic learning made a significant unique contribution (6%), but orthographic learning did not (1%). The results remained the same when adding word reading as a control in the analyses of predictors of reading comprehension (semantic learning: 5%; orthographic learning: 1%).

The interaction term for grade was not significant in the first three models we tested (*p*s < .43), indicating that the results were similar for Grade 1 and Grade 2 children. In the last model, the interaction term reached significance ($p = .047$). The relation between semantic learning and reading comprehension was significant in both grades ($p = .03$ in Grade 1 and $p < .001$ in Grade 2), with a stronger relation at Grade 2 ($B = 5.42$) than at Grade 1 ($B = 2.37$).

Discussion

In this study of 6- and 7-year-old English-speaking children, we tested key predictions from the Self-Teaching Hypothesis (Share, 2011), integrating the importance of semantic representations as suggested by the Lexical Quality Hypothesis (Perfetti & Hart, 2002). Children independently read texts containing novel words with novel meanings; we tracked the accuracy of their decoding during this reading. Children then completed choice tasks assessing their learning of the spellings and meanings of these new words; these were our metrics of orthographic and semantic learning, respectively. Children also completed measures of word reading and multiple control variables. We found that children in both Grades 1 and 2 can acquire orthographic and semantic information about novel words at the same time through their self-teaching. The extent of learning increased between Grades 1 and 2, but there was no evidence of a substantive shift in the nature of this learning between these grades. These findings provide novel empirical support for the idea that early reading is early self-teaching (e.g., Share, 1999; but see Share, 2004), extending the limited such evidence in prior studies. Contrary to theoretical predictions (Share, 1995), we also found that decoding is beneficial, but not required for orthographic and semantic learning to occur. Finally, in terms of individual differences, we found that, beyond the effects of decoding, skill in orthographic learning was associated with word reading and that skill in semantic learning was associated with reading comprehension. As such, our work offered a strict test of multiple aspects of the Self-Teaching Hypothesis (Share, 2011) within the context of the orthographic and semantic representations that young readers can establish through their self-teaching.

Our evidence that young readers can learn the spellings and meanings of words at the same time through their independent reading shifts our current understanding of young readers' learning capacities. In our study, children's performance on the choice tasks assessing the orthographic and semantic representations established through self-teaching was above chance levels for the children in both Grades 1 and 2. It is a small, but substantial step to show that these effects are statistically significant, as has been demonstrated in studies of older readers (Mimeau et al., 2018; Ricketts et al., 2011). The few studies to date with 7-year-old children have reported a mix of marginal and non-significant evidence of learning during independent reading (Cunningham, 2006; Share, 2004). We extend these bodies of work by demonstrating that children in both Grades 1 and 2 (6 and 7 years) can learn the orthographic and semantic forms of novel words at the same time during their independent reading. As such, we offer much-needed empirical evidence that early reading is indeed early self-teaching (e.g., Share, 1999).

In terms of our second research question, we uncovered that Grade 1 and 2 children can learn spellings and meanings of novel words through self-teaching, even in the absence of accurate decoding. This conclusion is supported by our findings that children were above chance in their performance on the orthographic and semantic choice tasks even when they had not accurately decoded the novel words a single time during the self-teaching experience. These results are surprising in the face of repeated suggestions that decoding is the "sine qua non" of orthographic learning (Share, 1995, page 151). Our study provides empirical evidence that accurate decoding may not be necessary for orthographic learning to occur for children in Grades 1 and 2, nor might it be required for semantic learning either. These findings are consistent with other possibilities raised in the literature. Share (1999) wrote that "some rudimentary self-teaching skills, perhaps sufficient to establish primitive orthographic representations of the kind discussed by Perfetti (1992), may exist at the very earliest stages of learning to read even before a child possesses any decoding skill in the conventional sense" (page 97). Our findings confirm self-teaching is possible for young readers even when they cannot decode words. Our findings are also consistent with evidence of orthographic learning even in the face of reduced decoding or absent decoding with older readers (Share, 1999; Tucker et al., 2016). We do not contend that there is no role for decoding; certainly, our study and several others have shown stronger orthographic learning when phonological decoding does occur, either because of natural variation or experimental manipulation (Share, 1999; Tucker et al., 2016). The same effects also appear for semantic learning. Clearly, there is room for empirical investigation into the nature of early self-teaching, including the necessity of decoding in supporting this learning.

In terms of our third question about individual differences, our results point to highly specific relations between each of orthographic and semantic learning and outcomes of word reading and reading comprehension. Following on controls for target decoding and other reading-related skills, orthographic, but not semantic learning was related to word reading. In tandem, semantic, but not orthographic learning was related to reading comprehension. These unique contributions were relatively small (in the range of 2 to 6%). In our view, they are important because they emerged after accounting for over 60% of variance, including decoding of the target item itself; as such these are highly specific effects. These findings build on two prior studies contrasting the roles of orthographic and semantic learning at the same time in 8-year-old children (Ricketts et al., 2011; Mimeau et al., 2018). Our findings build on this work by exploring relations in younger children and in isolating effects from the influence of target decoding (see also Cunningham et al., 2001). We also include a suite of reading-relevant variables (such as phonological awareness and vocabulary; see also Ouellette & Fraser, 2009). Our results are strikingly similar to those of Mimeau et al. (2018): orthographic learning is specifically related to word reading and semantic learning is specifically related to reading comprehension. Our evidence shows that orthographic and semantic learning have targeted influences on reading outcomes that extend beyond the role of phonological decoding during the learning experience, at least for our young readers.

As a first point of theoretical impact, our findings point clearly to the idea that early reading is indeed early self-teaching. Our evidence of similar learning in our two age groups counters ideas of differences in orthographic learning between younger and older readers (Share, 2004). Both younger and older readers can learn semantic and orthographic features in their independent reading when they are assessed in the same paradigm.

These findings also confirm the prediction from the Self-Teaching Hypothesis that individual differences in the ability to learn word spellings during independent reading, or skill in orthographic learning, is a source of variance in children's word reading outcomes (Share, 2011). This is a small, but clear role and it is one that is specific to word reading and not reading comprehension. We think that these findings push the field to consider the nature of individual differences in orthographic learning; these continue to be a "black box for reading researchers" (Share, 2011, p. 53; see also Castles & Nation, 2017). We encourage further investigation into precisely what goes into the toolbox that is orthographic learning skill.

Our work also extends the classic focus of tests of the Self-Teaching Hypothesis on orthographic learning to semantic learning. The ability to acquire meanings during reading, or semantic learning, is specifically relevant to individual differences in reading comprehension (see also Ricketts et al., 2011; Mimeau et al., 2018) and not in word reading. In terms of mechanisms, we think that our measures of semantic learning might index more closely the ability to infer meaning rather than the semantic representations themselves; this speculation is supported by the fact that relations survived controls for existing vocabulary knowledge. These findings extend classic views of the centrality of word meaning in text comprehension (e.g., Ouellette, 2006); we think that skill in learning word meanings is also important to children's success in understanding texts (see also Ricketts et al., 2011; Mimeau et al., 2018). We think that both orthographic and semantic learning capacities need to be incorporated along with decoding into theoretical models of both word reading and reading comprehension.

As with all studies, our results need to be interpreted in line with the methodology from which they emerged. In our study and in others before us, orthographic learning skill is operationalised as performance on the orthographic outcome measures following on the self-teaching experience itself (e.g., Bowey & Miller, 2007; Cunningham et al., 2001; Ouellette & Fraser, 2009; Cunningham, 2006). And as a result of pragmatic constraints, we used a single measure to capture each skill. The use of multiple measures would be stronger, as would the development of standardised measures for orthographic and semantic learning. Further, even though we evaluate both orthographic and semantic dimensions, we do not look at their intersection. For example, prior research has shown the presence of meaning can support the learning of word spellings (Ouellette & Fraser, 2009; Wang, Nickels, Nation, & Castles, 2013), just as the presence of spellings can support the learning of word meanings (Ehri, 2014). Examining the mechanisms by which semantics supports orthographic learning and vice versa would be important. In terms of participants, we had a relatively small sample size, reducing power. That said, our results are generalizable to diverse classrooms. Our sample included children who speak English as a first language and those that do not, with similar effects for the two groups. Further, our results can only speak to effects at a single point in time; we think that longitudinal studies are much needed in this line of work, particularly to specify the directions of relations (see e.g., Deacon, Pasquarella, Marinus, Tims, & Castles, in press). Developmental studies will be particularly important in exploring potential shifts in the importance of orthographic and semantic learning over time. Such studies need to be wary of methodological differences. As an example, our results cannot be directly contrasted with those of prior studies with older children that have provided decoding to the child (e.g., Mimeau et al., 2018). Finally, it would be useful to contrast orthographic learning through reading with that through spelling, given that both can be useful contexts for learning (Conrad, 2008; Shahar-Yames, & Share, 2008). These are all open questions worthy of further investigation.

In conclusion, our findings point to the capacity of young readers to learn the spellings and meanings of novel words at the same time through their self-teaching. In our study with English-speaking children in Grades 1 and 2, both orthographic and semantic learning occurred during independent reading regardless of whether the children had accurately decoded the target words or not, although learning was better when decoding was successful. Further, orthographic learning was related to individual differences in word reading and semantic learning was related to individual differences in reading comprehension; both these relations were unique from the role of decoding during the learning experience and other known predictors of reading outcomes. These findings push us to consider the importance of semantic and orthographic learning capacity, alongside decoding in gaining a full picture of reading development from its outset.

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Table 1

Descriptive Statistics (Raw scores) for the Learning Task Measures, the Reading Measures, and the Control Measures as a Function of Grade Level

Measure (maximum score)	Grade 1			Grade 2		
	M	*SD*	Range	*M*	*SD*	Range
Learning task						
Word reading in stories (364)	325.18	53.56	145-363	346.48	25.17	243-364
Target decoding in stories (48)	21.21	14.72	0-48	28.22	12.72	2-48
Orthographic choice (24)						
All non-words	14.79	5.20	2-22	17.26	3.88	7-23
Non-words decoded correctly at least once	8.13	6.14	0-22	10.56	5.19	1-19
Non-words decoded incorrectly on all trials	6.67	4.18	0-16	6.70	4.58	0-16
Semantic choice (24)						
All non-words	13.28	5.49	3-23	17.85	4.31	6-24
Non-words decoded correctly at least once	7.00	5.87	0-23	11.37	5.90	0-20
Non-words decoded incorrectly on all trials	6.28	3.68	0-15	6.48	4.34	0-16
Reading						
Word reading (76)	40.00	10.75	20-61	46.67	8.12	28-65

Reading comprehension (39)	25.81	7.85	8-36	28.58	8.62	4-39
Control						
Short-term memory (28)	15.00	2.93	7-21	15.48	2.64	12-21
Vocabulary (228)	118.23	17.01	80-149	119.63	16.04	72-147
Phonological awareness (34)	18.77	6.69	6-31	23.70	5.95	10-32

Table 2

Frequencies (and Percentages) of Answer Types for Each Item of the Orthographic and Semantic Choice Post-Tests as a Function of Target Decoding

	Orthographic learning		Semantic learning	
	Decoded	Not decoded	Decoded	Not decoded
Item 1: *veap*/*veep* (fish tank cleaner)				
Correct	66 (75)	34 (77)	51 (58)	13 (30)
Alternative spelling/Same object	18 (20)	5 (11)	18 (20)	23 (52)
Other	4 (5)	5 (11)	19 (22)	8 (18)
Item 2: *crig*/*krig* (bread toaster)				
Correct	59 (76)	33 (61)	39 (50)	22 (41)
Alternative spelling/Same object	9 (12)	9 (17)	20 (26)	17 (31)
Other	10 (13)	12 (22)	19 (24)	15 (28)
Item 3: *zabe*/*zaib* (card mixer)				
Correct	53 (85)	44 (63)	50 (81)	49 (70)
Alternative spelling/Same object	4 (6)	11 (16)	3 (5)	8 (11)
Other	5 (8)	15 (21)	9 (15)	13 (19)
Item 4: *turg*/*terg* (paper reader)				
Correct	47 (60)	35 (65)	43 (55)	19 (35)
Alternative spelling/Same object	21 (27)	7 (13)	24 (31)	15 (28)
Other	10 (13)	12 (22)	11 (14)	20 (37)
Item 5: *kleb*/*cleb* (orange juicer)				
Correct	49 (66)	31 (53)	35 (47)	33 (57)
Alternative spelling/Same object	20 (27)	12 (21)	29 (39)	17 (29)
Other	5 (7)	15 (26)	10 (14)	8 (14)
Item 6: *fude*/*fewd* (person namer)				
Correct	39 (89)	62 (70)	37 (84)	60 (68)
Alternative spelling/Same object	1 (2)	15 (17)	1 (2)	14 (16)
Other	4 (9)	11 (13)	6 (14)	14 (16)
Item 7: *yaif*/*yafe* (ball thrower)				
Correct	30 (79)	55 (59)	34 (89)	74 (79)
Alternative spelling/Same object	2 (5)	18 (19)	3 (8)	17 (18)
Other	6 (16)	21 (22)	1 (3)	3 (3)
Item 8: *bope*/*boap* (body cleaner)				
Correct	61 (80)	33 (59)	53 (70)	37 (66)
Alternative spelling/Same object	11 (14)	11 (20)	15 (20)	10 (18)
Other	4 (5)	12 (21)	8 (11)	9 (16)
Item 9: *hewl*/*hule* (flower brightener)				
Correct	37 (69)	48 (62)	41 (76)	50 (64)
Alternative spelling/Same object	4 (7)	10 (13)	5 (9)	16 (21)
Other	13 (24)	20 (26)	8 (15)	12 (15)
Item 10: *loak*/*loke* (food sorter)				
Correct	55 (61)	23 (55)	64 (71)	21 (50)

Alternative spelling/Same object	20 (22)	12 (29)	20 (22)	12 (29)
Other	15 (17)	7 (17)	6 (7)	9 (21)
Item 11: *merl*/*murl* (hat drier)				
Correct	49 (60)	22 (44)	55 (67)	26 (52)
Alternative spelling/Same object	14 (17)	12 (24)	21 (26)	17 (34)
Other	18 (22)	16 (32)	6 (7)	7 (14)
Item 12: *seef*/*seaf* (garbage sorter)				
Correct	56 (60)	21 (55)	78 (83)	16 (42)
Alternative spelling/Same object	27 (29)	8 (21)	5 (5)	6 (16)
Other	11 (12)	9 (24)	11 (12)	16 (42)

Note. Decoded = decoded correctly on at least one trial; Not decoded = decoded incorrectly on all four trials.

Table 3

Correlations Between the Learning Task Measures, the Reading Measures, and the Control Measures

	Learning task		Reading		Control			
Measure	1	2	3	4	5	6	7	8
Learning task								
1. Orthographic choice	–							
2. Semantic choice	.44*	–						
Reading								
3. Word reading	.51*	.62*	–					
4. Reading comprehension	.47*	.75*	.66*	–				
Control								
5. Short-term memory	.16	.18	.35*	.30*	–			
6. Vocabulary	.16	.52*	.44*	.56*	.37*	–		
7. Phonological awareness	.36*	.56*	.72*	.49*	.36*	.43*	–	
8. Target decoding in stories	.45*	.64*	.75*	.63*	.25*	.29*	.67*	–

Note. $*p < .05$

Table 4

Hierarchical Linear Regression Analyses Predicting Word Reading and Reading Comprehension From Orthographic Learning and Semantic Learning after Controlling for Decoding of Targets in the Stories, Along with Age, Short-Term Memory, Vocabulary, and Phonological Awareness.

		Word reading			Reading comprehension		
Step	Predictor	*B* (*SE*)	*p*	R^2	*B* (*SE*)	*p*	R^2
1	Age	-0.20 (0.23)	.934		-0.81 (1.10)	.468	
	Short-term memory	0.27 (0.36)	.458		1.29 (1.68)	.446	
	Vocabulary	0.09 (0.06)	.146		1.10 (0.30)	< .001	
	Phonological awareness	0.90 (0.16)	< .001	.55	1.39 (0.76)	.071	.50
2	Target decoding in stories	16.62 (3.43)	< .001	.13	71.73 (16.60)	< .001	.12
3	Orthographic learning	0.37 (0.18)	.044	.02	1.41 (0.87)	.111	.01
3	Semantic learning	0.13 (0.24)	.580	.00	3.76 (1.03)	.001	.06
					Adding word reading as a control		
3	Word reading				1.23 (0.61)	.049	.02
4	Orthographic learning				1.02 (0.89)	.256	.01
4	Semantic learning				3.62 (1.00)	.001	.05

Note. Unstandardised coefficients are presented. The values are from each step of the models as the variables were entered.

Appendix A

Example of Story Presented in the Exposure Phase of the Learning Task

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

Appendix B

Non-Words Used in the Learning Task

Target sound	Version A		Version B	
/i/	veap	seef	veep	seaf
/ɜ/	merl	turg	murl	terg
/eɪ/	zabe	yaif	zaib	yafe
/ju/	fude	hewl	fewd	hule
/oʊ/	bope	loak	boap	loke
/k/	kleb	crig	cleb	krig

Note. Half of the participants read the 12 spellings in Version A, and the other half read the 12 spellings in Version B.

Appendix C

Example of Item Presented in the Semantic Choice Post-Test of the Learning Task