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EMPIRICAL STUDY

The Effect of Pre-reading Instruction on Vocabulary Learning: An Investigation of L1 and L2 Readers' Eye Movements

Ana Pellicer-Sánchez,[a] Kathy Conklin,[b] and Laura Vilkaitė-Lozdienė[c]

[a]UCL Institute of Education, [b]University of Nottingham, and [c]Vilnius University

Abstract: This study examined the effect of pre-reading vocabulary instruction on learners' attention and vocabulary learning. We randomly assigned participants (L1 = 92; L2 = 88) to one of four conditions: pre-reading instruction, where participants' received explicit instruction on six novel items and read a text with the items repeated eight times; reading-only, where participants simply read the same text with the novel items repeated eight times; reading-baseline, where participants read the same text with the repeated items replaced by known (control) words; and instruction-only, where participants received explicit instruction on the novel items and read an unrelated text. Eye-tracking was used to measure amount of attention to the vocabulary during reading. We assessed knowledge of the target vocabulary in three immediate posttests (form recognition, meaning recall, and meaning recognition). Results showed that pre-reading instruction (plus reading the text) led to both more vocabulary learning and a processing advantage. Cumulative reading times were a significant predictor of meaning recognition scores.

Keywords vocabulary learning; reading; pre-reading instruction; eye-tracking

Introduction

Learners need to know a large number of words to function in a second or foreign language (L2; e.g., Nation, 2006). An effective way to increase learners'

Correspondence concerning this article should be addressed to Ana Pellicer-Sánchez, University College London, 20 Bedford Way, London WC1H 0AL, UK. E-mail: a.pellicer-sanchez@ucl.ac.uk.

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vocabulary knowledge is through exposure to new vocabulary during reading. Empirical evidence for the benefits of reading for incidental vocabulary learning abounds. Previous research has shown that reading is a major source of vocabulary growth in a first language (L1; e.g., Nagy, Herman, & Anderson, 1985; Saragi, Nation, & Meister, 1978) and that, although with smaller gains, L2 learners can also acquire new words incidentally from reading (e.g., Brown, Waring, & Donkaewbua, 2008; Horst, Cobb, & Meara, 1998; Pellicer-Sánchez, 2016; Pellicer-Sánchez & Schmitt, 2010; Pigada & Schmitt, 2006; Waring & Takaki, 2003; Webb, 2005, 2007a, 2007b), helping learners develop the vocabulary knowledge that they need for successful communication.

Successful vocabulary learning from reading depends, among other variables, on learners' degree of involvement in the processing of unknown words (Laufer & Hulstijn, 2001). The degree of attention to and engagement with new vocabulary items predict learning gains (Schmitt, 2008). This argument is supported by the depth of processing hypothesis (Craik & Lockhart, 1972), which asserts that deeper information processing leads to the formation of a stronger memory trace. The importance of depth of processing for incidental vocabulary learning was reflected in Hulstijn and Laufer's (2001) involvement load hypothesis, which claims that learning and retaining new words depend on the involvement load of a task, that is, the amount of need, search, and evaluation that the task entails. The general premise is that successful learning is determined by the depth of learners' initial processing and engagement with target items. However, it has also been claimed that learners do not always notice unknown words in the input (Laufer, 2005), which could explain the often small gains reported in incidental vocabulary learning studies. Thus, an important concern in vocabulary research has been to find ways for making lexical items in the input more salient, thereby increasing learners' attention to those items and encouraging their deeper processing.

Researchers have explored different ways to make the input more salient for learners, with input flood and input enhancement—bolding, underlining, highlighting—being extensively examined in L2 acquisition research. Another way of making target items salient in written input is by explicitly teaching the relevant vocabulary before a reading activity. Vocabulary instruction prior to reading has been suggested as a way of supporting the reading process (e.g., Alessi & Dwyer, 2008) and maximizing its vocabulary learning potential. With pre-reading instruction, learners have the opportunity to learn vocabulary intentionally through explicit exposure and then to further develop and consolidate knowledge of recently learned items through subsequent exposures in context. Pre-reading instruction would therefore be a way to address the reported low rate of success in lexical inferencing during reading (e.g., Nassaji, 2003). Researchers have claimed that pre-reading instruction increases the salience and cognitive processing of target words, resulting in higher incidental vocabulary gains (Paribakht & Wesche, 1993, 1996). However, it has also been suggested that it may discourage guessing strategies, which in turn can reduce the potential learning benefits of further exposures during reading (Nation & Coady, 1988). Despite its widespread use in the language classroom, little is known about the effect of pre-reading instruction on learners' allocation of attention to target vocabulary items during reading and about how that attention is related to learning. Furthermore, the type and amount of lexical learning during reading in pre-reading instruction conditions, above and beyond knowledge accrued from the explicit instruction, have not been explored. The present study addressed these gaps by combining offline vocabulary tests and eye-tracking to examine the effect of pre-reading vocabulary instruction on vocabulary learning (compared to those from reading-only and instruction-only), as well as its effect on processing the newly learned vocabulary by L1 and L2 readers.

Background Literature

Vocabulary Learning From Reading

Research has investigated two main approaches to vocabulary learning: incidental learning and intentional or deliberate learning. Incidental vocabulary learning has been defined as "the picking up of new linguistic features while attention is focused on understanding the input" (Ellis, 2015, p. 147), whereas intentional learning involves a deliberate intention to learn a set of lexical items (Nation, 2001). The distinction between incidental and intentional learning is hard to operationalize because it is difficult to tell whether a learner might be intentionally focusing on lexical items during a meaning-focused activity. However, it is possible to create learning conditions that are not intended to engage learners in deliberate learning (Pellicer-Sánchez & Boers, 2019). In the current study, following Nation and Webb (2011), we considered a learning condition to be incidental when learners were not aware of the existence of post-reading vocabulary tests and the instructions in the main reading task did not ask them to explicitly focus on lexical items. Studies comparing the two methods have generally found an advantage for intentional learning (e.g., Laufer, 2003). However, intentional learning might not benefit all lexical components (i.e., types of knowledge of a word, such as its written form, meaning, or grammatical information) equally because some aspects of vocabulary may be better learned incidentally through repeated exposures in meaning-focused input (Webb & Nation, 2017).

Research into the incidental acquisition of vocabulary from reading has been extensive. Some early studies suggested that amount of reading undertaken accounted for most of the vocabulary growth in a L1 (e.g., Nagy et al., 1985; Saragi et al., 1978). In the L2 context, although with smaller gains, studies have shown that L2 learners can establish the link between new forms and their meanings through reading (e.g., Pitts, White, & Krashen, 1989; Zahar, Cobb, & Spada, 2001). Research has also shown that other components of vocabulary mastery develop through reading, for example, word associations, spelling, grammatical characteristics, and so on (see Pellicer-Sánchez & Schmitt, 2010; Pigada & Schmitt, 2006; Waring & Takaki, 2003; Webb, 2005) but that learners are not equally certain about their knowledge of different components (e.g., Pellicer-Sánchez, 2016; Wesche & Paribakht, 2000).

A robust finding in the vocabulary learning literature is that increased exposures to unknown lexical items leads to more learning of those items (e.g. Waring & Takaki, 2003; Zahar et al., 2001). Estimates of the precise number of exposures needed for incidental vocabulary learning have ranged from six (Rott, 1999) to 10 (e.g., Horst et al., 1998; Pellicer-Sánchez & Schmitt, 2010; Pigada & Schmitt, 2006; Webb, 2007a). In a recent meta-analysis, Uchihara, Webb, and Yanagisawa (2019) confirmed the significant effect of frequency of exposure on incidental vocabulary learning and showed that other variables, such as learner variables (age, vocabulary knowledge), treatment variables (spaced learning, visual support, engagement, range in number of encounters), and methodological differences (nonword use, forewarning of upcoming comprehension test, vocabulary test format), moderated the effect of repetition and explained variability across the studies reviewed.

Recent eye-tracking studies have investigated readers' on-line processing of unknown lexical items while reading and have shown that, although initial exposures to new lexical items require more processing effort for both L1 and L2 readers, reflected in longer reading times and higher number of fixations (e.g., Godfroid, Boers, & Housen, 2013; Pellicer-Sánchez, 2016), the speed with which new words are read gets faster as the number of exposures increases. Notably, the number and duration of fixations to unknown vocabulary items decreases with exposure both for L1 readers (e.g., Joseph, Wonnacott, Forber, & Nation, 2014) and L2 readers (e.g., Elgort, Brysbaert, Stevens, & Van Assche, 2018; Godfroid et al., 2018; Mohamed, 2018; Pellicer-Sánchez, 2016). Thus, repeated exposures to target items in a text appear not only to facilitate the knowledge of the form and meaning of new lexical items but also the fluency and speed with which those words are read in context. Moreover, some studies demonstrated a significant relationship between the time that readers spent processing new lexical items and the readers' learning gains (e.g., Godfroid et al., 2013; Pellicer-Sánchez, 2016). Whether methods of instructional intervention, such as pre-reading instruction, would modify the online processing of new lexical items over repeated encounters has yet to be explored.

Pre-Reading Instruction of Vocabulary

Successful vocabulary learning from reading is dependent upon learners' engagement with the unknown vocabulary. More attention and engagement with new lexical items have been related to higher learning gains (Laufer, 2017; Schmitt, 2008), which supports the view that deeper processing of information is related to superior recall and retention (Craik & Lockhart, 1972). The notion of depth of processing has been defined in L2 acquisition research "as the relative amount of cognitive effort, level of analysis, elaboration of intake together with the usage of prior knowledge, hypothesis testing and rule formation employed in decoding and encoding some grammatical or lexical item in the input" (Leow & Mercer, 2015, p. 71). For vocabulary learning, depth of processing would entail, for example, decoding a word, establishing the link between its form and its meaning, and connecting the word with other similar words already existing in the lexicon (Leow & Mercer, 2015). In the vocabulary learning literature, the concept of depth of processing has been operationalized in the involvement load hypothesis (Hulstijn & Laufer, 2001), which postulates that learning and retaining unfamiliar words depend on the amount of need (i.e., the wish to use a lexical item for task completion), search (i.e., the attempt to find out the meaning of an item), and evaluation (i.e., the comparison of the target item with other items to ensure context appropriateness) that the task imposes. The main assumption is that higher involvement leads to better learning and retention of new lexical items. However, learners do not always notice unknown items while processing input for meaning (Laufer, 2005) and might not process them in a way that is conducive to learning (Indrarathne & Kormos, 2017). This has led researchers to investigate techniques that make target items in the input more salient and that might therefore increase learners' attention and engagement with those items.

In the L2 acquisition context, salience has been defined as "how noticeable or explicit a linguistic structure is in the input" (Loewen & Reinders, 2011, p. 152), with salience making items easy to perceive (Gass, Spinner, & Behney, 2018). The construct of salience has been approached from two main angles, *perceptual salience* and *constructed salience* (Gass et al., 2018). Perceptual salience refers to linguistic features that are intrinsically more noticeable. For example, longer morphological markers are more salient than shorter ones and are therefore easier to detect (Behney, Spinner, Gass, & Valmori, 2018). Constructed salience "occurs when some outside source creates a context for some feature to become prominent" and leads learners to notice and potentially process that particular feature (Gass et al., 2018, p. 7). Different methods to achieve constructed salience have been employed in vocabulary research, with the majority of studies focusing on the role of input enhancement (e.g., Barcroft, 2003; Kim, 2006) and input flooding (e.g., Webb, Newton, & Chang, 2013). Pellicer-Sánchez and Boers (2019) have described these as semi-incidental approaches to vocabulary learning, characterized as learning conditions in which learners are expected to engage in a text primarily for its content, but certain other features (e.g., repetition, bolding) are intended to make learners pay attention to target vocabulary.

An important, albeit underresearched, method of creating constructed salience in vocabulary learning is pre-reading instruction. Direct teaching of vocabulary is a common pre-reading activity because it "can add to the incidental learning of the same [i.e., pre-taught] words and can raise learners' awareness of particular words so that they notice them when they meet them while reading" (Nation, 2001, p. 157). Many reading lessons include a pre-reading stage to tap into prior knowledge, introduce important reading strategies, introduce the topic of the text, stimulate interest in the text, and, importantly, provide information that students might not have but that they will need to comprehend the text, that is, vocabulary (Grabe & Stoller, 2011). The role of pre-reading instruction has also been examined in the task-based language teaching literature. Ellis (2003) says that the purpose of the pre-task phase is "to prepare students to perform the task in ways that will promote acquisition" (p. 244). As Ellis explained, these activities that are designed to prepare learners for the linguistic demands of a task often focus on vocabulary. The majority of studies examining pre-reading vocabulary instruction have focused on its effect on reading *comprehension*. Vocabulary teaching before reading has been shown to improve reading comprehension (e.g., Carlo et al., 2004; Taglieber, Johnson, & Yarbrough, 1988; Webb, 2009) and to speed up reading without a detrimental effect on comprehension (e.g., Alessi & Dwyer, 2008). However, when compared to other pre-reading strategies, vocabulary instruction has proven to be less effective for comprehension than pre-questioning, that is, previous presentation of comprehension questions (e.g., Mihara, 2011) and pictorial context (e.g., Taglieber et al., 1988). However, very few studies have examined the role of pre-reading vocabulary instruction on L2 vocabulary learning.

Biemiller and Boote (2006) explored the role that teachers' explanations of word meaning before and during reading play in primary school learners' L2 vocabulary gains. Two sets of target items were selected from reading texts: one set of items that was the focus of explicit instruction and another set of items that only appeared in the readings. In the explicit instruction condition, some words were explained before the reading started, but others were explained during the reading. Learners' knowledge of the target items was assessed in meaning recall pretests and posttests. Results showed that adding word explanations increased the gains from reading by 10% relative to the condition in which items only appeared in the texts. However, the study did not explore any potential differences between explaining word meanings before or during reading, and thus, no claims could be made about the effectiveness of providing word meanings specifically prior to reading.

File and Adams (2010) empirically tested the distinction between pre-reading and during-reading vocabulary instruction in a study with English foreign language learners. Vocabulary posttests compared performance on items that had been taught prior to reading or during reading and another set of items that only occurred in the reading, that is, an incidental learning condition. Results showed that both instructional conditions led to higher vocabulary gains than did the reading-only condition, with both types of instruction leading to similar gains.

Although it is expected that the additional exposures provided by instruction in pre-reading or during-reading conditions will lead to an advantage over reading-only conditions in terms of vocabulary learning, as File and Adams (2010) demonstrated, it is still not known how pre-reading instruction changes the actual reading of target items in context and, importantly, whether subsequent exposures in reading would contribute further to vocabulary development above and beyond the gains that accrue from the initial, explicit instruction. One study, to our knowledge, has looked at the impact of one type of constructed salience (boldfacing) on learning and processing L2 collocations in enhanced and unenhanced conditions (Choi, 2017). Notably, textual enhancement led to higher gains and longer reading times. Overall, however, results from previous vocabulary research have been based solely on offline measures that cannot show how (or if) pre-reading instruction, specifically, actually increased learners' attention to the target vocabulary.

The Present Study

Very little is known about the effect that methods of constructed salience have on on-line processing of vocabulary and whether this potentially altered processing in turn influences learning gains. In the current study, we investigated the impact of pre-reading instruction. Contradictory hypotheses about the role of pre-reading instruction on attention have been put forward; pre-reading instruction may lead to increased attention on target items or to fewer guessing strategies that would result in less attention to lexical items. The present study aimed to provide empirical evidence to test these two contrasting hypotheses. In addition, as we argued previously, the contribution of exposure to the words during reading in the pre-reading instruction conditions, above and beyond the vocabulary gains accrued from the initial, explicit instruction, has not been demonstrated. To address these aims, we examined the processing and learning of target items by L2 and L1 participants in four conditions: pre-reading instruction, reading-only, instruction-only, and reading-baseline (matched reading task). We addressed the following research questions:

1. To what extent does pre-reading instruction lead to larger gains than reading-only and pre-reading instruction-only conditions?
2. What is the effect of pre-reading instruction on the on-line processing of newly learned vocabulary?
3. Is there any relationship between on-line processing and learning?

In order to examine the effect of pre-reading instruction on vocabulary gains and the potential contribution of exposure during reading in this condition, we compared vocabulary gains from the pre-reading instruction condition (i.e., explicit teaching + exposures in reading) to gains in the reading-only (i.e., exposures in reading) and the instruction-only conditions (i.e., explicit teaching). We examined the effect of pre-reading instruction on the on-line processing of newly learned items by comparing the processing of newly learned items in the pre-reading instruction condition to the processing of the same items in the reading-only condition as well as to the processing of known (control) items in the reading-baseline condition.

Methods

Participants

We recruited 92 English L1speakers to participate in the study. They were all majoring in English at a British university. Their mean vocabulary size, measured by the V_YesNo (Version 1.01) vocabulary test (Meara & Miralpeix, 2015) was 8,682.04 words (*SD* = 740.28, 95% CI [8,529, 8,835]). Also, 88

English L2 speakers participated in the study. Their mean vocabulary size score was 6,924.40 words (SD = 1,153.30, 95% CI [6,680, 7,169]). The L2 speakers were all studying at a British university: 79 were postgraduate students, and nine were undergraduates. They came from a variety of L1 backgrounds. They were asked to self-rate their knowledge of English on a 10-point Likert scale (speaking: M = 7.03, SD = 1.46, 95% CI [6.73, 7.34]; listening: M = 7.74, SD = 1.32, 95% CI [7.46, 8.02]; and reading: M = 7.97, SD = 1.28, 95% CI [7.69, 8.24]).

Materials

Reading Texts

Pellicer-Sánchez (2016) developed the story used for this study. We created two versions of the same text. The original version of the story contained six target pseudowords repeated eight times throughout the text and was used for the reading-only and pre-reading instruction conditions. For the reading-baseline condition, we created a second version in which high frequency words replaced the pseudowords. The two versions were of equal length (2,290 words), and we controlled the vocabulary in the story to ensure that comprehension would not hinder potential vocabulary learning. Knowledge of the 4,000 most frequent words in English provided a lexical coverage of 98% in the text with the pseudowords and 99% in the version where these were replaced by existing words. Because the participants' average vocabulary size was 6,924 words, it could be assumed that they had knowledge of the first 4,000 most frequent words in English and that they would not have had difficulty in understanding the text (see Appendix S6 in the online Supporting Information for complete reading texts and openly available at [https://www.iris-database.org/iris/app/home/detail?id=york%3a938223&ref=search]). The story was displayed over 25 screens on a computer monitor. Each screen had eight lines of text and the number of words in each screen ranged from 82 to 103 words. No more than two pseudowords appeared on a screen. Target pseudowords/control words were never placed in initial or final position in a sentence. We also used a comprehension test developed by Pellicer-Sánchez (2016) to check participants' general comprehension of the story. It contained 12 true-false statements. We also used the practice story (423 words) and practice comprehension questions from Pellicer-Sánchez (2016) in this study to accustom the participants to the experimental procedure.

We created another reading text for the instruction-only condition. To ensure that the time between the vocabulary instruction and posttests was equivalent in the pre-reading instruction and the instruction-only conditions, participants in the instruction-only condition read a text of similar characteristics to the experimental text but without the target words. The text was a story about Sherlock Holmes adapted from a graded reader available online. The length of the text was 2,175 words and knowledge of the 4,000 most frequent words in English provided a lexical coverage of 98% (i.e., the same coverage as in the text containing the pseudowords). The story was also presented on the computer monitor over 28 screens. We also designed a set of eight true-false statements to check general comprehension of the text and to ensure that the participants in the instruction-only group engaged in the same kind and amount of activities as the pre-reading instruction group between the instruction and the vocabulary tests.

Target Items

Pellicer-Sánchez, Siyanova-Chanturia, and Parente (2020) had developed the pseudowords embedded in the experimental text. They had selected the pseudowords from the ARC Nonword Database (Rastle, Harrington, & Coltheart, 2002), controlling for neighborhood size, number of body neighbors (words that share the same orthographic rime, e.g., cleat, wheat and heat are body neighbors of cheat), and number of phonological neighbors (minimum = 1, maximum = 5). The pseudowords had undergone several stages of piloting. Pellicer-Sánchez, Siyanova-Chanturia, and Parente first asked 15 English L1 speakers to rate the pseudowords according to how likely the forms of the items were plausible English words. All target words received a minimum score of 4 on a 6-point Likert scale (6 = *very likely to be an English word*). The researchers asked another 10 English L1 speakers to rate the likelihood of the connection between the pseudoword and their corresponding meaning. All selected pseudowords had a score below 3 on a 6-point scale (6 = *very likely that this is the meaning of the pseudowords*). This second stage of piloting had shown that there were no apparent connections between the forms and their corresponding meanings. Six pseudowords (*glabe, trobe, redaster, blaunts, nuse, salp*) replaced high-frequency words in the story. Those high-frequency words were the target items in the reading-baseline condition (*house, bowl, criminal, ring, noise, clothes*). The real nouns and the pseudowords were of the same length (in characters and syllables).

Pre-Reading Activities

The aim of the pre-reading instruction phase was to present participants with the pseudowords and their corresponding meanings and ensure that they had successfully created the form-meaning link. Participants completed two activities. In the first activity, we presented the pseudowords in a list alongside their definitions. We asked the participants to carefully read the words and their definitions and to memorize them. The second activity aimed at ensuring that the participants had successfully created the form-meaning link with the completion of a matching exercise in which they had to link the pseudowords (presented in a different order) and their definitions. We checked that participants had correctly matched the pseudowords and their meanings. If participants made any mistakes in the matching activity (which was very rare), they were allowed to check the list of pseudowords and definitions. The definitions for the pseudowords were the definitions of the real words that the pseudowords replaced and were taken from the Merriam-Webster online dictionary (www.merriam-webster.com/). All words in the definitions belonged to the 4,000 most frequent words in English. We used these same activities for the instruction-only condition.

Vocabulary Measures

We measured the participants' vocabulary learning using three immediate tests that measured form recognition, meaning recall, and meaning recognition. The three tests were a modified version of the instruments used in Pellicer-Sánchez (2016). The first test (form recognition) assessed participants' ability to recognize the correct form (spelling) of the pseudowords among five options presented (the key, three distractors, and an "I don't know" option). The second test (meaning recall) assessed the participants' ability to recall the meaning of the pseudowords. We presented the participants with the list of pseudowords and asked them to write down everything that they knew about the meaning of those items. Finally, we assessed the participants' ability to recognize the correct meaning of the pseudowords by a multiple-choice test presenting the pseudowords and five options (the key [the word that the pseudowords replaced], three distractors, and an "I don't know option"; see Appendix S5 in Supporting Information online for test items and openly available at [https://www.iris-database.org/iris/app/home/detail?id=york:938021]).

Procedure

We collected data by meeting participants individually in a psycholinguistics laboratory. We randomly assigned the participants to one of the four conditions: (a) pre-reading instruction (L1: $n = 21$; L2: $n = 24$); (b) instruction-only (L1: $n = 31$; L2: $n = 22$); (c) reading-only (L1: $n = 21$; L2: $n = 21$); and (d) reading-baseline (L1: $n = 19$; L2: $n = 21$). Participants first read the information sheet and provided their written consent. Participants in the pre-reading instruction and instruction-only conditions then completed the vocabulary activities. We told them that they were going to learn some new labels for concepts that were already familiar to them. They completed the two activities with no time pressure, but most participants completed this learning phase within 10 minutes. All participants then completed the vocabulary size test V_YesNo (Version 1.0; Meara & Miralpeix, 2015), and the L2 participants additionally completed a language background questionnaire. The participants in the pre-reading instruction, reading-only, and reading-baseline conditions then went on to read a story on a computer screen while their eye movements were recorded. They read the practice text and completed the practice comprehension questions before reading the experimental text. To proceed from one screen to the next, the participants had to press "enter" on the keyboard. When the story finished, the comprehension statements appeared one by one, and participants had to indicate whether they were true or false by pressing a key on the keyboard. Participants in the instruction-only condition read the unrelated text (i.e., with no exposures to the target items) on the computer screen following the same procedure, but their eye movements were not recorded. We then asked the participants in the pre-reading instruction, reading-only, and instruction-only groups to complete the three vocabulary tests. The participants in the reading-baseline condition did not complete the post-reading vocabulary tests because they had not been exposed to the target items. The whole procedure lasted around one hour for the pre-reading instruction and instruction-only groups (as they had both instruction and a text to read), 50 minutes for the reading-only group, and 40 minutes for the reading-baseline group.

We recorded eye movements with a desktop-mounted EyeLink 1000 Plus (SR Research, Canada) eye-tracker, which samples data at 1,000 Hz, with an accuracy of 0.25–0.5° and a precision of <0.01°. Recording was monocular (right eye), and in the head-stabilized mode. We presented the text in black over white background in Courier New font, size 18, with double spacing. We conducted an initial 9-point calibration before the practice session and another one before the experimental session. We performed a drift correction before each experimental screen and carried out additional calibrations when we considered them necessary.

Analysis

First, we checked the answers to the comprehension questions to ensure that the participants had paid attention to the texts. The L1 group answered on average 86.68% of the questions correctly (*SD* = 13.81, 95% CI [83.82, 89.55]), and the L2 group answered on average 89.96% (*SD* = 12.68, 95%

CI [85.97, 92.23]) of the questions correctly, showing good comprehension of the texts.

We analyzed the experimental data using the R software (Version 3.4.4; R Core Team, 2013). Because each target word received eight repeated observations, we considered the exposures to be a time-course variable (Godfroid et al., 2018), and we conducted a growth curve analysis to examine how eye-movements on target items changed over time (Cunnings, 2012). The advantage of these models is that they can accommodate nonlinear vocabulary learning (Godfroid et al., 2018). Participants encountered the target words eight times in the text, and the effect of these repeated exposures over time might have been nonlinear. To account for this, we added higher-order polynomial terms to the models. In order to further explore the changes in reading patterns, we examined reading behavior at specific exposures. We fit linear mixed-effects models to take into account by-item (target word) and by-subject variation in the same model. We conducted growth curve analysis using the nlme package (Pinheiro, Bates, DebRoy, Sarkar, & Core Team, 2019) to be able to specify the covariance structures. We fit other linear models using the lme4 package (Bates, Maechler, Bolker, & Walker, 2014). We estimated *p* values using the lmerTest package (Kuznetsova, Brockhoff, & Christensen, 2015) and we used an alpha level of .05 for all statistical tests (specific *p* values are reported with each test). We analyzed interactions using the phia package (Rosario-Martinez, 2015) and plotted the interactions with the effects package (Fox, 2009). We carried out pairwise comparisons of different categories in the models with the multcomp package (Hothorn, Bretz, & Westfall, 2008).

We log transformed all of the continuous outcome variables (first fixation duration, first-pass reading time, total reading time) before conducting the analyses. We also log transformed the participants' vocabulary scores to make sure that all of the predictor variables were on the same scale. Our tested models, depending on the research question, included the experimental condition (pre-reading instruction, reading-only, or reading-baseline condition), participant group (L1 or L2), vocabulary scores of the participants, and number of exposures to the target word in the text (Exposures 1 to 8), as well as interactions between condition, group, and exposure number. We also added length of the target words as a covariate. We could have used the participants' self-ratings as an indication of their proficiency in the models, but their ratings strongly positively correlated with their vocabulary scores, $r = .56, p < .001$, which we thought provided a more objective measure.

We have chosen to report the best models based on likelihood ratio tests and on Akaike information criterion (AIC) scores for the models. Models always included random intercepts for item and for participant. We included random slopes for condition or exposure number by item or exposure number by participant when they improved the model fit (based on model AIC scores). We did not keep random effects maximal because Bates, Kliegl, Vasishth, and Baayen (2015) have warned that the maximal structure of random effects may make a model too complicated and may lead to a poor fit or difficulties in interpretation. We have provided random effect structures for each model in the model summary tables.

Results

In this section, we present the results of the analysis in relation to each of the research questions.

Research Question 1: To What Extent Does Pre-Reading Instruction Lead to Larger Gains Than Reading-Only and Instruction-Only Conditions?

Table 1 presents the summary of learning in the pre-reading instruction, reading-only, and instruction-only conditions for both L1 and L2 participants. We did not analyze the reading-baseline condition because we presented no target words to the participants in this condition.

In order to compare learning across the three conditions, we fit a separate mixed effects model for each type of knowledge (see Tables 2–4). Because the outcome variables were binary (each word was either learned or not), we fit generalized linear models with binomial distributions. We always kept language group (L1, L2) and the experimental condition in the model regardless of their significance because they were core predictors for this research question. The baseline condition in the model was the instruction-only condition. We checked vocabulary score, word length, and the interaction between the group and condition as predictors, but only kept them in the model when they were significant or improved the model fit.

Tables 3 and 4 show that the L1 participants did better than the L2 participants on the tests of meaning recognition and meaning recall, but, for form recognition (see Table 2), both groups had similar scores. For form recognition and meaning recall, word length also played a role, with longer words being better learned. That the model also revealed a significant effect of condition was important. We performed pairwise comparisons for the three learning conditions (with Tukey adjustment) within each type of vocabulary knowledge. For form recognition, scores in the pre-reading instruction condition were significantly higher than in reading-only, $M_{diff} = 4.13$, $SE = 1.17$, 95% CI [1.44;

Table 1 Descriptive statistics for vocabulary learning for three types of knowledge by language group in the three learning conditions

	Type of knowledge					
	Form recognition		Meaning recognition		Meaning recall	
Group/Learning condition	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI	*M* (*SD*)	95% CI
L1						
Pre-reading instruction ($n = 21$)	5.95 (0.22)	[5.85, 6.05]	5.52 (0.60)	[5.25, 5.80]	5.62 (0.67)	[5.31, 5.92]
Reading-only ($n = 21$)	5.52 (0.87)	[5.13, 5.92]	4.71 (1.23)	[4.15, 5.27]	3.71 (1.55)	[3.01, 4.42]
Instruction-only ($n = 31$)	4.94 (1.63)	[4.34, 5.53]	5.16 (0.45)	[4.99, 5.33]	5.10 (1.01)	[4.73, 5.47]
L2						
Pre-reading instruction ($n = 24$[a])	6.00 (0.00)	[6.00, 6.00]	5.67 (0.64)	5.40, 5.94]	5.41 (0.88)	[5.04, 5.79]
Reading-only ($n = 21$)	5.10 (0.89)	[4.69, 5.50]	4.10 (1.22)	[3.54, 4.65]	2.33 (1.35)	[1.72, 2.95]
Instruction-only ($n = 22$)	5.32 (1.06)	[4.84, 5.80]	4.73 (0.91)	[4.31, 5.14]	4.45 (2.04)	[3.53, 5.37]

[a]Due to poor eye-tracking data quality for two participants, the data of only 22 participants were analyzed in this condition for Research Questions 2 and 3.

Table 2 Effect of condition on form recognition scores

Fixed effects	*b*	95% CI	*SE*	*z*	*p*
Intercept	0.20	[−2.85, 3.43]	1.36	0.14	.886
Pre-reading instruction	4.43	[2.58, 7.51]	1.15	3.84	<.001
Reading-only	0.30	[−0.77, 1.38]	0.53	0.57	.567
L2 group	−0.06	[−1.12, 0.96]	0.51	−0.12	.902
Length	0.52	[−0.05, 1.08]	0.24	2.13	.033

Random effects	Variance	*SD*
Participant (Intercept)	3.31	1.82
Item (Intercept)	0.49	0.70

Table 3 Effect of condition on meaning recognition scores

Fixed effects	*b*	95% CI	*SE*	*z*	*p*
Intercept	2.21	[1.09, 3.39]	0.51	4.35	<.001
Pre-reading instruction	1.30	[0.68, 1.97]	0.32	4.05	<.001
Reading-only	−0.68	[−1.19, −0.19]	0.25	−2.77	.006
L2 group	−0.46	[−0.92, −0.03]	0.22	−2.07	.039

Random effects	Variance	*SD*
Participant (Intercept)	0.17	0.41
Item (Intercept)	1.24	1.11

Table 4 Effect of condition on meaning recall scores

Fixed effects	*b*	95% CI	*SE*	*z*	*p*
Intercept	−0.47	[−3.54; 2.65]	1.35	−0.35	.729
Pre-reading instruction	1.56	[0.62; 2.57]	0.49	3.19	.001
Reading-only	−2.28	[−3.23; −1.46]	0.44	−5.14	<.001
L2 group	−1.04	[−1.79; −0.31]	0.37	−2.81	.005
Length	0.61	[0.05; 1.17]	0.24	2.51	.012

Random effects	Variance	*SD*
Participant (Intercept)	2.43	1.56
Item (Intercept)	0.57	0.76

6.82], $z = 3.54$, $p < .001$, and instruction-only, $M_{diff} = 4.43$, $SE = 1.15$, 95% CI [1.77; 7.09], $z = 3.84$, $p < .001$, conditions. We also found an advantage for pre-reading instruction over instruction-only for meaning recognition, $M_{diff} = 1.30$, SE = 0.32, 95% CI [0.55; 2.04], $z = 4.05$, $p < .001$, and meaning recall, $M_{diff} = 1.56$, $SE = 0.49$, 95% CI [0.41; 2.70], $z = 3.19$, $p = .004$. Scores in the reading-only condition were similar to those in the instruction-only condition for form recognition, $M_{diff} = 0.30$, $SE = 0.53$, 95% CI [−0.91; 1.52], $z = 0.57$, $p = .827$, but significantly lower than the instruction-only group for meaning recognition, $M_{diff} = -0.68$, $SE = 0.25$, 95% CI [−1.26, −0.11], $z = -2.77$, $p = .015$, and meaning recall, $M_{diff} = -2.28$, $SE = 0.44$, 95% CI [−3.32; −1.24], $z = -5.41$, $p < .001$.

Overall, explicit instruction plus the additional exposure during reading led to the highest vocabulary scores across the three types of word knowledge. The lexical knowledge accrued from explicit instruction in the pre-reading instruction condition seemed to be further developed through the subsequent exposures during reading. Incidental acquisition from reading-only, on the other hand, led to the smallest amount of learning.

Research Question 2: What Is the Effect of Pre-Reading Instruction on the On-Line Processing of Newly Learned Vocabulary?

In order to explore reading behavior in all three conditions (i.e., pre-reading instruction, reading-only, and reading-baseline), we analyzed four eye-tracking measures: first fixation duration, first-pass reading time, total reading time, and fixation count (tables with descriptive statistics for all eye-movement measures are included in Appendix S1 in the Supporting Information online). Figure 1 presents the mean total reading times across the eight exposures for L1 and L2 readers (figures presenting the other measures are also included in Appendix S2 in Supporting Information held online).

In order to analyze reading behavior across the eight exposures to the target items, we first carried out a growth curve analysis. The growth curve models included higher-order polynomial terms for the exposure number to discover which one of them best described the change in reading behavior over time. We started from the fourth degree polynomial (Exposure^4). The models also included interactions of experimental condition with language group and with the exposure number (its linear, quadratic, and cubic effect, see Tables 5–8). We added word length and participants' vocabulary size as covariates. We kept the interactions, higher degree polynomials for the exposure number, vocabulary score, and word length in the model only when they were

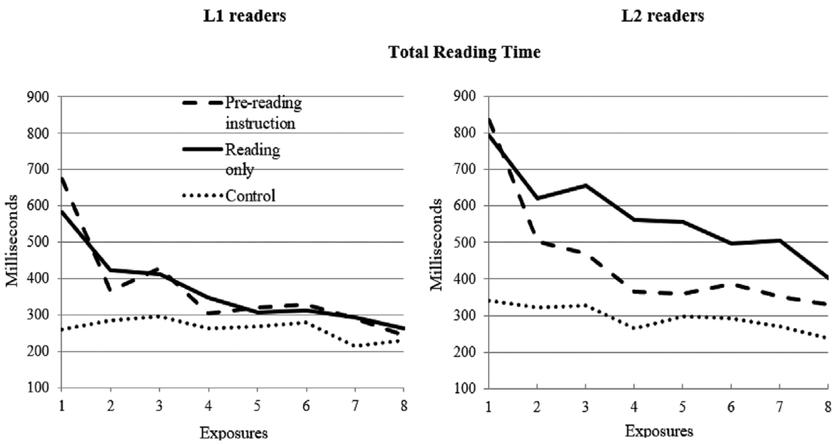

Figure 1 Mean total reading times for L1 and L2 readers by condition and number of exposures. In the reading-baseline condition the readers encountered high frequency, known words; in the other two conditions, they encountered the target pseudowords.

significant or improved the model fit. We kept language group, experimental condition, and exposure number in the models regardless of their significance.

Overall, as we had expected, there was a decrease in reading times and number of fixations across the eight exposures to the target items. Table 5 shows that, for first fixation duration, the decrease in reading times was linear, but for the other measures—first-pass reading time (Table 6), fixation count (Table 8), and total reading time (Table 7)—the effect of the number of exposures was cubic. First the reading time decreased more steeply, then the decrease leveled out slightly and then again decreased in a steeper fashion (see Figure 2 for the comparison between the linear decrease in first fixation duration and cubic decrease in total reading time). We further explored the interactions between experimental condition and cubic effects, quadratic effects, and the linear effect of number of exposures. We fit separate models for total reading time for each experimental condition to explore the effect of number of exposures to target words in that particular condition (see models in Appendix S3 in the Supporting Information online). These models showed that the change in total reading time was curvilinear for the new words, both in the pre-reading instruction and reading-only conditions. In the pre-reading instruction condition, the initial change in reading times was steeper, but for the reading-only condition, the change was more gradual. For the reading-baseline condition, the decrease of total reading times was linear.

Table 5 Omnibus models of eye movements: First fixation duration

Fixed effects	*b*	95% CI	*SE*	*t*	*df*	*p*
Intercept	8.03	[6.58, 9.47]	0.74	10.91	4,461	<.001
Pre-reading instruction	0.15	[0.06, 0.25]	0.05	3.16	116	.002
Reading-only	0.11	[0.01, 0.20]	0.05	2.19	116	.030
Exposure	−0.01	[−0.02, 0.00]	0.00	−2.14	4,461	.033
L2 group	0.00	[−0.09, 0.08]	0.05	−0.09	116	.932
Vocabulary score	−0.30	[−0.46, −0.14]	0.08	−3.69	116	<.001
Length	−0.01	[−0.01, 0.00]	0.00	−2.14	614	.033
Pre-reading instruction × Exposure	−0.01	[−0.02, 0.00]	0.01	−2.56	4,461	.010
Reading-only × Exposure	−0.01	[−0.02, 0.00]	0.01	−1.46	4,461	.145
Pre-reading instruction × L2	0.08	[−0.04, 0.19]	0.06	1.36	116	.176
Reading-only × L2	0.14	[0.02, 0.25]	0.06	2.33	116	.022
Random effects						*SD*
Participant (Intercept)						0.12
Item (Intercept)						0.00
Residual						0.35
Correlation structure: AR(1), $\Phi = .009$						

Table 6 Omnibus models of eye movements: First-pass reading time

Fixed effects	*b*	95% CI	*SE*	*t*	*df*	*p*
Intercept	10.23	[8.46, 12.00]	0.91	11.31	4,455	<.001
Pre-reading instruction	0.63	[0.41, 0.85]	0.11	5.60	116	<.001
Reading-only	0.42	[0.19, 0.64]	0.11	3.71	116	<.001
Exposure	0.08	[−0.05, 0.21]	0.07	1.16	4,455	.245
$Exposure^2$	−0.02	[−0.05, 0.01]	0.02	−1.21	4,455	.228
$Exposure^3$	0.00	[0.00, 0.00]	0.00	1.09	4455	.278
L2 group	−0.01	[−0.12, 0.10]	0.06	−0.21	116	.835
Vocabulary score	−0.57	[−0.77, −0.38]	0.10	−5.76	116	<.001
Length	0.04	[0.03, 0.05]	0.00	8.94	614	<.001
Pre-reading instruction × Exposure	0.36	[−0.54, −0.18]	0.09	−3.86	4,455	<.001
Reading-only × Exposure	−0.19	[−0.37, −0.01]	0.09	−2.11	4,455	.035
Pre-reading instruction × L2	0.11	[−0.03, 0.25]	0.07	1.60	116	.112
Reading-only × L2	0.20	[0.06. 0.34]	0.07	2.83	116	.006
Pre-reading instruction × $Exposure^2$	0.08	[0.03, 0.12]	0.02	3.24	4,455	.001
Reading-only × $Exposure^2$	0.04	[−0.01, 0.09]	0.02	1.73	4,455	.085
Pre-reading instruction × $Exposure^3$	−0.01	[−0.01, 0.00]	0.00	−2.96	4,455	.003
Reading-only × $Exposure^3$	0.00	[−0.01, 0.00]	0.00	−1.60	4,455	.110

Random effects	*SD*
Participant (Intercept)	0.14
Item (Intercept)	0.00
Residual	0.42
Correlation structure: AR(1), $\Phi = .017$	

Table 7 Omnibus models of eye movements: Total reading time

Fixed effects	*b*	95% CI	*SE*	*t*	*df*	*p*
Intercept	13.00	[10.60, 15.40]	1.23	10.61	4,455	<.001
Pre-reading instruction	1.30	[1.03, 1.57]	0.14	9.56	116	<.001
Reading-only	0.80	[0.523, 1.06]	0.14	5.84	116	<.001
Exposure	−0.02	[−0.17, 0.14]	0.08	−0.24	4,455	.809
Exposure^2	0.00	[−0.04, 0.041]	0.02	0.14	4,455	.890
Exposure^3	0.00	[0.00, 0.00]	0.00	−0.33	4,455	.740
L2 group	−0.05	[−0.19, 0.10]	0.07	−0.61	116	.543
Vocabulary score	−0.85	[−1.12, −0.59]	0.14	−6.32	116	<.001
Length	0.05	[0.04, 0.06]	0.01	8.57	614	<.001
Pre-reading instruction × Exposure	−0.68	[−0.89, −0.47]	0.11	−6.38	4,455	<.001
Reading-only × Exposure	−0.29	[−0.50, −0.08]	0.11	−2.70	4,455	.007
Pre-reading instruction × L2	0.07	[−0.12, 0.26]	0.10	0.73	116	.468
Reading-only × L2	0.24	[0.05, 0.43]	0.10	2.45	116	.016
Pre-reading instruction × Exposure^2	0.13	[0.08, 0.18]	0.03	4.90	4455	<.001
Reading-only × Exposure^3	0.05	[−0.01, 0.10]	0.03	1.79	4,455	.074
Pre-reading instruction × Exposure^3	−0.01	[−0.01, 0.00]	0.00	−4.12	4,455	<.001
Reading-only × Exposure^3	0.00	[−0.01. 0.00]	0.00	−1.46	4,455	.145

Random effects	*SD*
Participant (Intercept)	0.20
Item (Intercept)	0.22
Exposure by-item effect	0.03
Residual	0.49
Correlation structure: AR(1), Φ = .004	

Table 8 Omnibus models of eye movements: Fixation count

Fixed effects	*b*	95% CI	*SE*	*t*	*df*	*p*
Intercept	7.08	[4.54, 9.63]	1.30	5.45	5,156	<.001
Pre-reading instruction	0.91	[0.72, 1.09]	0.09	9.72	118	<.001
Reading-only	0.70	[0.52, 0.89]	0.09	7.52	118	<.001
Exposure	−0.22	[−0.33, −0.10]	0.06	−3.65	5,156	<.001
Exposure^2	0.06	[0.03; 0.08]	0.03	4.08	5,156	<.001
Exposure^3	−0.01	[−0.01, 0.00]	0.00	−4.87	5,156	<.001
L2 group	−0.04	[−0.16, 0.08]	0.06	−0.68	118	.495
Vocabulary score	−0.80	[−1.09, −0.52]	0.14	−5.63	118	<.001
Length	0.10	[0.09, 0.12]	0.01	15.88	614	<.001
Pre-reading instruction × Exposure	−0.29	[−0.37, −0.20]	0.04	−6.68	5,156	<.001
Reading-only × Exposure	−0.12	[−0.20, −0.04]	0.04	−2.83	5,156	.005
L2 × Exposure	0.02	[0.01, 0.04]	0.01	3.21	5,156	.001
Pre-reading instruction × Exposure^2	0.03	[0.02, 0.04]	0.01	5.33	5,156	<.001
Reading-only × Exposure^2	0.01	[−0.00, 0.02]	0.01	1.64	118	.101

Random effects	*SD*
Participant (Intercept)	0.21
Item (Intercept)	0.11
Residual	0.78
Correlation structure: AR(1), $\Phi = .009$	

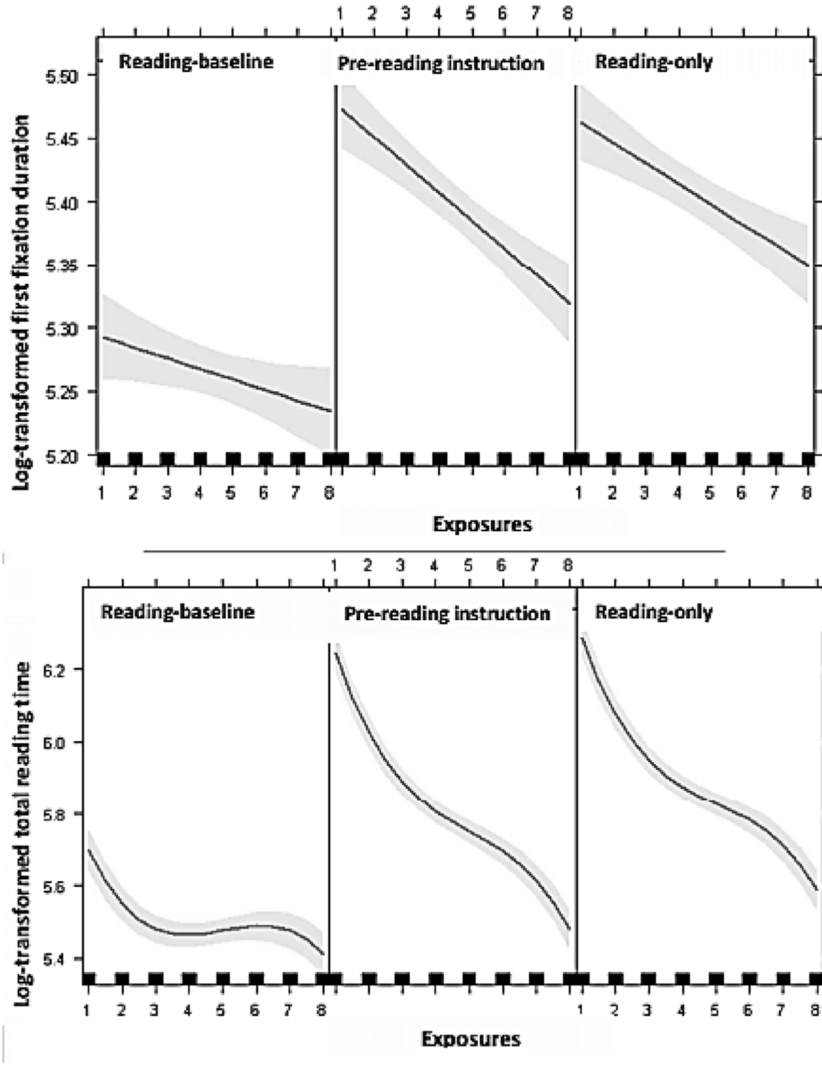

Figure 2 Effect of number of exposures in the growth curve model for total reading time (lower panel) and first fixation duration (upper panel).

To further investigate significant interactions of the exposure number and experimental conditions, we fit separate models for reading behavior at different exposures. Figure 1 shows that the second and third exposures appeared to be where the most pronounced change in reading behavior occurred. We examined these exposures as well as the first and last exposures (Appendix S4 in Supporting Information online contains the mixed-effects models for these four exposures.).

For the first exposure, in the pre-reading instruction and reading-only conditions the participants fixated on the target words for longer and the target words had more fixations relative to the control words in the reading-baseline condition, with no differences between the reading-only and the pre-reading instruction conditions in any of the measures. There were no interactions of language group and condition, suggesting that both the L1 and L2 participants fixated on target words in the pre-reading instruction and the reading-only conditions for longer than on control words in the reading-baseline condition. There was also an effect of vocabulary size across all eye-movement measures, with those with larger vocabularies having shorter and fewer fixations in all eye-tracking measures.

During the second exposure, there were again no differences between L1 and L2 groups and no interaction of language group and experimental condition, but there was a consistent effect of vocabulary scores across all measures. Participants in the reading-only condition read pseudowords more slowly and fixated on them more times than they did for control words in the reading-baseline condition in all measures apart from first fixation duration. Participants fixated on pseudowords in the pre-reading instruction condition more times and read them more slowly than they did control words in the reading-baseline condition in all measures apart from total reading time. There were no significant differences between the pre-reading instruction and reading-only conditions in participants' reading of target items in any of the measures.

During the third exposure, for the first fixation duration there were no differences between the pre-reading instruction or the reading-only and the reading-baseline condition. When analyzing fixation count, we found that the participants fixated on target words in the pre-reading instruction and reading-only conditions more times than on control words in the reading-baseline condition. However, for first-pass reading time and total reading time, there was a significant interaction of group (L1, L2) and the experimental condition (see Figure 3). Analysis of this interaction showed that for first-pass reading time, there were no significant differences between the conditions for the L1 participants, but for the L2 participants, there was a significant difference between the reading-only and reading-baseline conditions, $\chi^2(1) = 12.45$, $p = .003$. For total reading time, there were no significant differences between the conditions for the L1 participants, although for the L2 participants, the reading-only condition was significantly different from the reading-baseline condition,

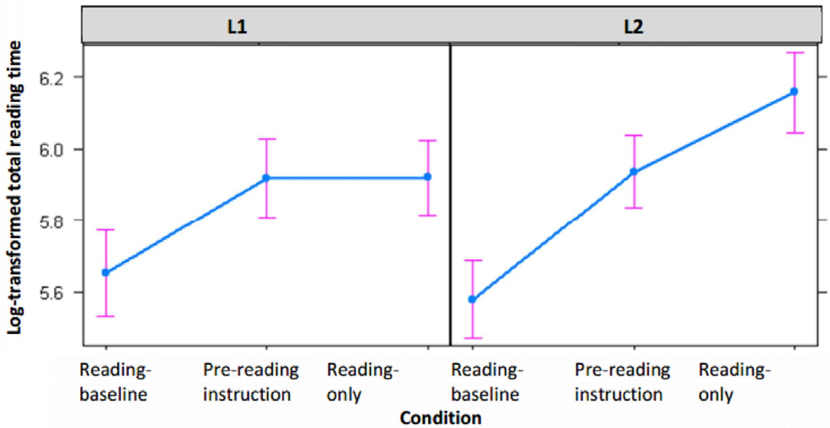

Figure 3 Interaction of language group with condition during the third exposure of the target word. [Color figure can be viewed at wileyonlinelibrary.com]

$\chi^2(1) = 21.56$, $p < .001$, and the pre-reading instruction condition was also significantly different from the reading-baseline condition, $\chi^2(1) = 7.92$, $p = .024$.

For the last (eighth) exposure, the differences between conditions were mostly nonsignificant. Crucially, though, there was a significant interaction of experimental condition and participant group in the first fixation duration and the total reading time (see Figure 4). Analysis of this interaction showed that for first fixation duration, there were no significant differences between the conditions for the L1 participants, but for the L2 participants, there was a significant difference between the reading-only and reading-baseline conditions, $\chi^2(1) = 9.91$, $p = .010$. For total reading time, there were also no differences for the L1 participants, but for the L2 participants, pseudowords in the reading-only condition were read more slowly than in reading-baseline condition, $\chi^2(1) = 16.77$, $p = <.001$. To further explore these significant differences, we calculated Cohen's d as a descriptive measure of standardized difference between the means for the L2 group. There was a medium effect size between reading baseline and reading-only condition both for first fixation duration, $d = 0.65$, 95% CI [0.35, 0.93], and for total reading time, $d = 0.74$, 95% CI [0.45, 1.03]. The effect sizes of the differences between pre-reading instruction and the other two conditions were small or very small though reliable (between pre-reading instruction and reading baseline: first fixation duration, $d = 0.41$, 95% CI [0.14, 0.69], and total reading time, $d = 0.45$, 95% CI [0.17, 0.73]; between

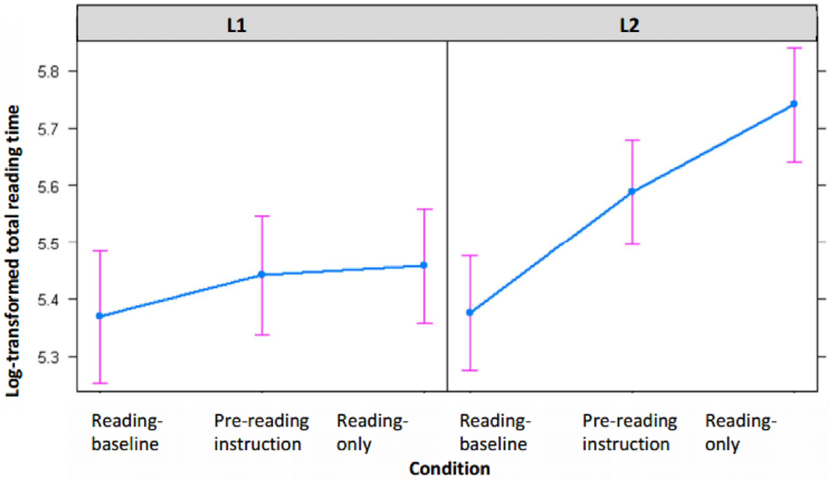

Figure 4 Interaction of language group with condition for the eighth exposure with the target items. [Color figure can be viewed at wileyonlinelibrary.com]

pre-reading instruction and reading-only: first fixation duration, $d = 0.28$, 95% CI [0.02, 0.54], and total reading time, $d = 0.27$, 95% CI [0.01, 0.53]). Overall, these effect sizes corroborated the finding that, for the L2 participants, pseudowords at the eighth exposure still took significantly longer (with a medium effect) to read in the reading-only condition than in the reading baseline condition, and only slightly longer (with a small/very small effect) to reading the pre-reading instruction than in the other two conditions.

The analysis of reading across the different exposures for the L1 and the L2 participants demonstrated that, when they first encountered the target items in the text, both groups spent more time reading the target items (i.e., pseudowords) in the pre-reading instruction and reading-only conditions than they did reading the control items in the reading-baseline condition. At the first exposure, there was no advantage for having explicitly learned the target items (i.e., pre-reading vs. reading-only). At the second exposure, in most eye-tracking measures there were still significant differences between pseudowords and existing words, further supporting this lack of advantage for the pre-reading instruction condition. By the third exposure, interactions of participant group and condition started to emerge. There were no differences between any of the conditions in the L1 group in most measures. However, differences remained for the L2 participants: pseudowords in the reading-only condition had longer first-pass reading times than existing words in the reading-baseline

Table 9 Effect of cumulative reading time on form recognition scores

Fixed effects	*b*	*SE*	*z*	*p*
Intercept	0.85	4.28	0.20	.842
Pre-reading instruction	3.66	1.07	3.43	.001
Cumulative reading time	−0.61	0.55	−1.11	.268
Length	1.35	0.36	3.76	<.001

Random effects	Variance	*SD*
Participant (Intercept)	1.18	1.09
Item (Intercept)	0.00	0.00
Version by-item effect	0.00	0.00

Note. It was not possible to estimate CIs for the coefficients for form recognition because the results are at ceiling for the pre-reading instruction condition.

condition; pseudowords in both the pre-reading and reading-only conditions had longer total reading times than existing words in the reading-baseline condition. In the final (eighth) exposure, L1 reading patterns were characterized by a lack of differences between the conditions, showing that by the eighth exposure the L1 participants read pseudowords, whether they had been taught or not, in a way very similar to how they read existing words. A somewhat similar pattern of effects was apparent in the L2 participants. By the eighth exposure they read pseudowords in the pre-reading instruction condition more similarly to how they read existing words. However, pseudowords in the reading-only condition still had clearly longer reading times than those in the reading-baseline condition, which pointed toward a processing advantage for pre-reading instruction, at least for the L2 participants.

Research Question 3: Is There Any Relationship Between On-Line Processing and Learning?

In order to explore the relationship between on-line reading behavior (amount of processing time for the target items) and learning, we fit three mixed effects models with tests of different components of vocabulary knowledge as outcome variables and reading times as predictors of the test results. We calculated total reading times across all eight exposures for each target item for each participant and labeled them as cumulative reading time in the analyses (Tables 9–11). We considered participant group

Table 10 Effect of cumulative reading time on meaning recognition scores

Fixed effects	*b*	95% CI	*SE*	*z*	*p*
Intercept	6.71	[1.63, 12.44]	2.71	2.47	.013
Pre-reading instruction	1.76	[1.09, 2.52]	0.36	4.93	<.001
Cumulative reading time	−0.68	[−1.38, −0.06]	0.33	−2.05	.040
Random effects		**Variance**			***SD***
Participant (Intercept)		0.52			0.72
Item (Intercept)		0.55			0.74

Table 11 Effect of cumulative reading time on meaning recall scores

Fixed effects	*b*	95% CI	*SE*	*z*	*p*
Intercept	−0.95	[−7.15, 5.07]	3.05	−0.31	.755
Pre-reading instruction	3.46	[2.61, 4.53]	0.48	7.19	<.001
L2 group	−1.02	[−1.88, −0.23]	0.41	−2.51	.012
Cumulative reading time	−0.22	[−0.96, 0.53]	0.37	−0.58	.562
Length	0.60	[−0.02, 1.23]	0.27	2.20	.028
Random effects		**Variance**			***SD***
Participant (Intercept)		1.22			1.10
Item (Intercept)		0.67			0.82

(L1, L2) as a predictor in the analysis and dropped it when it was not significant.

The analysis showed that the cumulative reading time was not a significant predictor for form recognition or meaning recall. However, there was a significant effect of cumulative reading times on meaning recognition: the longer participants spent reading a target word, the better they were at identifying the correct meaning. No significant interactions emerged.

It could be the case that cumulative reading times during the first exposures with the target items, as opposed to cumulative reading times across the eight exposures, were better predictors of learning, as the steepest decrease in reading times took place during these earlier exposures. In order to further explore the relationship between reading times and vocabulary scores, we performed similar analyses with different reading time measures: reading times during the first exposure only; cumulative reading time of the first and second exposures; and cumulative reading time of first three exposures. However, the effect of reading times during the first exposure, first two exposures, or first three exposures was not significant for any type of word knowledge that we analyzed.

Discussion

The present study provides evidence about the effect of pre-reading instruction on attention while reading and on vocabulary learning. First, results of this study confirmed that the participants' repeated exposures to the target pseudowords in reading-only led to incidental vocabulary learning, in line with previous studies in the L1 (e.g., Joseph et al., 2014; Nagy et al., 1985; Saragi et al., 1978) and the L2 (e.g., Brown et al., 2008; Godfroid et al., 2018; Pellicer-Sánchez, 2016; Pellicer-Sánchez & Schmitt, 2010; Pigada & Schmitt, 2006; Waring & Takaki, 2003; Webb, 2005, 2007a, 2007b). It is important to note that, although the amount of learning from the reading-only condition was the smallest, repeated exposures to the target pseudowords in the text still led to substantial learning.

In response to the first research question, as we had expected, the results showed a clear advantage for the pre-reading instruction over the reading-only condition for lexical learning, supporting findings from earlier studies (e.g., Biemeller & Boote, 2006; File & Adams, 2010). The advantage of the pre-reading instruction condition over the reading-only condition could be explained by the fact that the tests closely resembled the instruction received in the pre-reading instruction condition. Perhaps more important then was that gains in the pre-reading instruction condition were superior to gains in the instruction-only condition. We had also expected this advantage given the greater number of exposures to the target items in the pre-reading instruction group. This advantage provides further support for the important role of frequency of exposure in vocabulary learning (see Peters, 2020, for a review of the role of frequency of occurrence in the learning of single words). The findings also suggest that the vocabulary gains arise not only from the initial explicit instruction but that subsequent exposures during reading further contribute to vocabulary development. The advantage of the pre-reading instruction condition over the instruction-only condition can be interpreted as support for Ellis's (1993) exemplar-based account of L2 acquisition. Ellis proposed that explicit exemplars paired with contextualized instances (i.e., rules + instances) accelerates learning. The explicit exemplars in the current study were provided at the initial, explicit instruction phase. After the initial explicit exemplars, learners in the pre-reading instruction condition were exposed to the target items eight more times in context (i.e., contextualized instances). These further exposures to the target items in context appear to have strengthened the initial representations created in the deliberate instruction phase, resulting in the advantage of the pre-reading instruction condition over the instruction-only condition. The pattern of vocabulary gains also lend support to the depth of processing hypothesis (Craik & Lockhart, 1972) and the involvement load hypothesis (Hulstijn & Laufer, 2001). A deeper level of processing and higher level of engagement with the target items during deliberate instruction could explain the advantage of the pre-reading instruction and instruction-only conditions over the reading-only condition. The contextual encounters with the recently learned words in the pre-reading instruction condition seemed to lead to increased engagement with the target items, which then resulted in better learning for participants in the pre-reading instruction condition than for those in the instruction-only condition.

The overall better learning in the pre-reading instruction condition demonstrated the positive effect of input enhancement on vocabulary learning (e.g. Barcroft, 2003) and casts doubt on the assertion that pre-reading instruction might negatively affect learning gains (Nation & Coady, 1988). Another explanation for the superiority of pre-reading instruction over reading-only is that, when readers encounter unknown words for the first time in a text, they try to infer their meanings from context, and those inferences might be correct or incorrect (Elgort, 2017). However, in the pre-reading instruction group, incorrect guesses were less likely because the meanings had been taught.

Contrary to the claim that learners do not always notice unknown items in the input (Laufer, 2005), the participants in the reading-only condition attended to the target items. The participants fixated on the unknown items in the reading-only condition, and these unknown items elicited more processing time than did existing words in the reading-baseline condition. Further, multiple exposures to the pseudowords in the reading-only condition had an effect not only on the participants' knowledge of their form and meaning but also on the speed and fluency with which they read items in context. Initial exposures to the pseudowords required more processing effort compared to high frequency, known words. However, reading times and number of fixations decreased with subsequent exposures, supporting findings from recent eye-tracking studies (Elgort et al., 2018; Godfroid et al., 2018; Joseph et al., 2014; Mohamed, 2018; Pellicer-Sánchez, 2016) and providing further evidence for the repetition effect found in many eye-movements studies (Joseph et al., 2014).

The fundamental question addressed by the present investigation was whether pre-reading instruction affects processing in reading (Research Question 2). Results from the growth curve analysis showed that reading times for pseudowords decreased in a similar manner in both the pre-reading instruction and reading-only conditions. The reading patterns found in these conditions demonstrate some similarities with the patterns shown by Godfroid et al. (2018). They found an initial rapid decrease from the first to the fourth exposure to new words (initial stage), followed by a significant increase from the seventh to the 10th exposure (middle stage), and a final gradual decrease from the 11th to the last exposure (final stage). The reading patterns in the current study were also characterized by an initial rapid decrease from the first to the third exposures (Figure 2), especially in the pre-reading instruction condition. However, rather than an increase in the middle stage, the present study showed a more gradual decrease. This difference in reading patterns across the two studies could be due to the different number of exposures included in the model. The overall decrease in reading times could reflect increasing familiarity with the target words across repeated exposures and a faster decoding of words over time (as suggested by Godfroid et al., 2018).

Further exploration of the interaction of condition and exposures showed interesting differences between the conditions. Pre-reading instruction did not appear to affect attention in the L1 or the L2 when the newly learned pseudowords were first encountered in the text. Even though the pseudowords had been deliberately learned in the pre-reading instruction condition, and the initial form-meaning link had been established, the relative unfamiliarity with the newly learned words might have led to similar reading patterns to those in the reading-only condition, where the pseudowords were seen for the first time. Thus, it might be that, in the first exposure, participants who had learned the new words were trying to access their knowledge about them and integrate this into a new context, a process that requires cognitive effort. Participants in the reading-only condition needed to decode an unfamiliar lexical form and map it to a meaning. Thus, the relatively longer reading times in these two conditions, for the initial occurrences of pseudowords, could indicate different but similarly effortful processes. Notably, differences between the processing of the target pseudowords (pre-reading instruction and reading-only) and the existing words (reading-baseline) started to disappear after the second exposure. Differences between conditions for the L1 participants disappeared from the third exposure, whereas for the L2 participants, differences between the pre-reading instruction and reading-baseline conditions did not disappear until the eighth exposure. By the eighth exposure, L2 readers processed the target pseudowords in the pre-reading instruction condition in a fairly similar manner to existing words in the reading-baseline condition. However, they still clearly spent more time processing pseudowords in the reading-only condition relative to the reading-baseline condition, pointing to a processing advantage for pre-reading instruction.

One explanation for the pattern of results is that during text comprehension, readers have to relate the meaning of a word to their understanding of the text in what is referred to as word-to-text-integration. Elgort et al. (2018) examined lexical access (measured by first fixation duration and gaze duration) and word-to-text integration (measured by total reading time, go-past time, fixations, and regression rates) in contextual word learning and found that both lexical access and word-to-text integration of the unknown, low-frequency words became like those of the control (known) words by the eighth occurrence. This is in line with the processing patterns observed for the pre-reading instruction condition in this study. The lack of statistically significant differences (albeit with small effect sizes) between the pre-reading instruction and the reading-baseline conditions at the eighth exposure might signal the development of both lexical access and word-to-text integration. More precisely, integration might be easier due to the disambiguation of meaning provided by the pre-reading instruction and reading activities.

It is notable that the advantage of pre-reading instruction over reading-only that was observed in vocabulary learning was not reflected in increased attention to target items during reading, at least not as reflected by our eye-movement measures. This goes against the assumption that pre-reading instruction leads to increased attention (Paribakht & Wesche, 1993, 1996). Thus, it could be that the advantage of pre-reading instruction is not reflected in the amount of attention but in the manner in which lexical items are processed. Crucially, other methods of constructed enhancement have demonstrated that these methods lead to longer fixation durations on target items (Choi, 2017). This points to potential differences among methods of constructed salience. The increased attention to target items produced by typographical enhancement (e.g., bolding, underlining, color, etc.) seems to be reflected in longer reading times, as shown by Choi (2017), whereas the effect of pre-reading instruction, although leading to more learning, did not seem to lead to increased attention in the current study. It might be the case that, for increased attention to be reflected in reading times, salience needs to be achieved by manipulating features of the target items at the point where their processing is being assessed rather than by instructional interventions. An interesting avenue for future research would be to compare different methods within the same experimental design.

Finally, concerning the relationship between attention and vocabulary learning (Research Question 3), results from the present study provide evidence for a connection between cumulative processing times and meaning recognition in line with what recent studies have shown for grammar learning (e.g., Indrarathne & Kormos, 2017) and for vocabulary learning (e.g., Godfroid et al., 2013, 2018; Mohamed, 2018; Pellicer-Sánchez, 2016). Notably, no relationship existed between attention and the other components of lexical mastery that we examined, that is, meaning recall and form recognition. This, together with the lack of positive relationship reported by recent studies (e.g., Elgort et al., 2018), calls for more research.

Limitations and Future Directions

It is important to note that the results of the present study are limited to a particular type of word learning: exposing learners to new labels for concepts that they already have in their mental lexicon and for which they probably already have a L2 label. Although this represents a type of vocabulary learned by L2 adult learners, other contexts might involve different types of vocabulary learning. For example, in the English for specific purposes context, learners often have to learn technical vocabulary that involves the acquisition of a new form and a new concept. Future studies will need to replicate the current findings with other types of lexical items. In addition, the vocabulary learning reported in the present study were demonstrated in an immediate test. Future studies will need to examine how durable lexical learning is from pre-reading instruction, instruction-only, and reading-only.

As we noted previously, we expected the advantage of the pre-reading instruction condition over reading-only and instruction-only conditions that we found, and this advantage was likely largely due to the extra exposures to the target items provided by the pre-reading instruction condition. The present design allowed us to explore the effect of pre-reading instruction on learners' allocation of attention to the target items (comparing processing in reading-only with pre-reading instruction), which was indeed the main aim of the study. It also allowed us to examine whether the learning in pre-reading instruction was due to the initial explicit instruction and if/how the extra exposures during reading contributed to lexical development in this condition (comparing pre-reading instruction with instruction-only). Although this emphasizes the ecological validity of the study and its potential to inform pedagogical practices, it also means that frequency of exposure was a confounding variable in the design. Future research should attempt to explore differences among types of interventions while maintaining frequency of exposures constant across conditions.

Furthermore, in the pre-reading instruction condition, we ensured that all participants had correctly created the form-meaning link for the six new lexical items, ruling out the possibility of incorrect inferences in the reading task. Future research could explore learners' attention when they have not yet successfully created such links during a pre-reading task and the relationship between attention and learning.

Conclusions

This study is the first to provide empirical evidence for the effect of pre-reading instruction on attention and vocabulary learning. The results show that pre-reading instruction led to an advantage in vocabulary learning over reading-only and instruction-only, likely caused by the extra exposures in this condition. These extra exposures during reading could have contributed to the further development of the vocabulary knowledge that was initially encoded in the explicit instruction phase. Crucially, the results suggest that pre-reading instruction also seems to lead to an interesting processing advantage. Processing differences between pre-reading instruction and reading-only did not emerge until the second exposure. Reading of pseudowords became like that of high-frequency, known words around the third exposure of the word for L1 readers, and almost like the reading of high-frequency, known words at the eighth exposure for L2 readers. These findings suggest that, contrary to earlier claims, pre-reading instruction does not always lead to increased attention (at least not as measured by eye movements). The processing advantage of pre-reading instruction seems to facilitate word-to-text integration.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1. Summary Descriptive Statistics for Eye-Tracking Measures.
Appendix S2. Mean Total First Fixation Duration, First Pass Reading Time, and Fixation Count for L1 and L2 Readers by Condition and Number of Exposures.
Appendix S3. Mixed-Effects Models of Total Reading Times.
Appendix S4. Mixed-Effects Models for Eye-Movement Measures by Number of Exposures.
Appendix S5. Post-Reading Vocabulary Tests.
Appendix S6. Experimental Reading Texts Used in the Pre-Reading Instruction, Reading-Only, and Reading-Baseline Conditions.
Supplementary Material

Appendix: Accessible Summary (also publicly available at https://oasis-database.org)

The Benefits of Teaching Vocabulary Before a Reading Activity

What This Research Was About and Why It Is Important

Researchers believe that teaching new vocabulary before reading makes the new words more salient when reading them and makes them easier to learn. However, we have little actual evidence showing us how learners treat vocabulary when its taught ahead of reading compared to when it is encountered for the first-time during reading. Our study tracked eye movements to assess the amount of attention learners paid to new vocabulary that had been taught before reading a story compared to new vocabulary that was encountered for the first-time in the story. We found that teaching words before reading, lead to more word-learning than simply encountering them in a story. In addition, the eye-tracking showed that after seeing the new words several times in the story, words that had been pre-taught were also easier to read for L2 learners.

What the Researchers Did

- Participants were L1 speakers of English (n = 92) and advanced L2 English learners (n = 88), all studying at a UK university.
- Participants were assigned to one of four groups: *Pre-reading instruction*: teaching of six new words + reading a story with those six words repeated eight times each; *Instruction-only*: teaching of six new words + reading a

different text without the new words; *Reading-only*: reading a story with the six new words repeated eight times each; *Reading baseline*: reading a story with six known (real, high frequency) words.
- The amount of attention that learners paid to the new words during reading (in the pre-reading instruction and reading-only groups) was examined through recordings of their eye movements.
- Participants knowledge of the new words was measured with three tests: form recognition (selecting the correct spelling); meaning recognition (selecting the correct meaning); meaning recall (giving the meaning).

What the Researchers Found
- Pre-reading instruction led to more word learning.
- When L1 and L2 readers first encountered the novel words in the story, they paid more attention to them (took longer to read them) compared to known items, regardless of whether they had been taught before or not.
- For L1 readers, eye-movements when reading the new words became like eye-movements when reading known words around the third encounter of the word.
- For L2 readers, on seeing the new words for the eighth time in the story, they still spent longer reading the new words if they had *not* been taught beforehand (compared to known words); in contrast, new words that *had* been taught beforehand were read quite similarly to known words.
- No relationship was found between amount of attention to new words (time spent reading) and word learning.

Things to Consider
- The better word learning in the pre-reading instruction group is expected, as participants in this group saw the new words more times.
- Participants learned better if the words were taught before the reading, but this was not due to more time spent on the words during reading (when compared to reading without having been taught the words beforehand).
- Results are limited to words for concepts that were already known, and do not reflect long-term retention.

Materials and data: Materials are publicly available at https://www.iris-database.org.

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