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Does the availability of orthography support L2 word learning?

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Abstract
Availability of orthography during word learning has been found to facilitate learning the word's spelling and pronunciation and has been proposed to facilitate learning its meaning. This has not been studied in second language (L2) learning yet, in which word learning often corresponds to translation learning. Therefore, an L2 word learning experiment was carried out. Grade 6 Dutch students ($n = 92$) were taught English words, with orthography available or absent. Words were divided into those that are spelled entirely like they sound (consistent, e.g., *lilt*) and those that are not (inconsistent, e.g., *budgie*). Students learned the words using forward translation (Dutch to English) or backward translation (English to Dutch). At post-test spelling, reading and forward as well as backward translation were measured. Results indicate that availability of orthography mainly facilitated word spelling and reading. There was a trend for orthography to affect learning the translation. Learning consistent words benefited most from orthography, especially when the post-test demanded forward translation. As forward translation requires retrieval of the word's pronunciation, it is likely that students used orthographic mapping to better remember the pronunciations of the English words. Forward translation was easier if words were learned in the same direction, but backward translation was not affected by learning direction. Together, these results imply that orthography supports translation learning, although this is likely caused by learning the word's pronunciation and not by establishing a direct link between orthography and word meaning.

Keywords Orthography · L2 word learning · Vocabulary acquisition · Spelling · Reading · Learning

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Introduction

Vocabulary is one of the most basic building blocks in (foreign) language acquisition, crucial for any kind of meaningful understanding and expression. Vocabulary is arguably the most important component, because: "Without grammar very little can be conveyed, without vocabulary nothing can be conveyed" (Wilkins, 1972). Learning novel words entails the acquisition of the meaning (semantics), spelling (orthography) and pronunciation (phonology). It is important in both first and second language learning and its importance is appreciated by foreign language learners (Barcroft, 2004). In their first language children first form connections between pronunciation and meaning. Orthography is added when they begin to read and encounter words in print. However, learning a second language often starts in school, and L2 words are often encountered in print first. How does seeing the spelling affect the word learning process?

One possibility is that the availability of a word's orthography during learning has a direct effect on the acquisition of its meaning. According to the lexical quality hypothesis (Perfetti, 2007; Perfetti & Hart, 2002), high quality word representations are characterized by tight associations among its constituents, orthography, phonology and meaning. On the basis of this hypothesis, orthographic representations increase the overall lexical quality of words (Perfetti & Hart, 2002). The orthography is an additional cue for successful meaning retrieval (Ricketts, Bishop, & Nation, 2009), pointing to the importance of learning word spellings. Connectionist models of reading (Harm & Seidenberg, 2004) also suggest a direct connection between orthography and meaning. When a word has been well-learned, seeing the orthographic form can directly activate the corresponding meaning in the mental lexicon instead of through activation of the words phonology (Harm & Seidenberg, 2004). Thus, knowing the spelling of the word can act as a cue and directly facilitate meaning retrieval.

Direct and indirect effects of orthography on L1 word learning

Consistent with the lexical quality hypothesis and connectionist models, studies have reported that the presence of the written form during word learning leads to better learning of a word's meaning (Ricketts et al., 2009; Rosenthal & Ehri, 2008). For example, Rosenthal and Ehri (2008) taught kindergarten children novel words. In a visual–verbal paired-associate learning task, children had to learn the association between a word and a picture and to learn the definition of the novel word. The picture was either accompanied by the orthography, printed underneath the picture, or not. The results showed that at posttest children were better able to provide the correct word when prompted by its picture when its orthography had been present during learning. The degree of learning was also measured in two other tasks: A task in which children heard the word and had to recognize it from an array of pictures and one in which they had to provide its definition. On these two tasks the presence of orthography during learning did not lead to better performance. This was probably due to the fact that children performed at ceiling level. Subsequent

word learning studies using a similar paradigm have replicated both the finding that the availability of orthography boosts word learning when measured by word recall, as well as the ceiling effects in tasks demanding correct picture selection (Chambré, Ehri, & Ness, 2017; Hu, 2008; Jubenville, Sénéchal, & Malette, 2014; Miles, Ehri, & Lauterbach, 2016; Ricketts et al., 2009). Thus, evidence so far has lent little support for a direct effect of orthography on the learning of a word's meaning. An effect is found when semantics is measured by word recall, i.e., when the pronunciation has to be provided, but it is not yet clear whether the availability of orthography during learning facilitates the acquisition of its meaning.

Another account of the relationship between word spelling and word learning is that orthography has an indirect effect on the acquisition of a word's meaning through its influence on the acquisition of a word's phonology (Ricketts et al., 2009; Rosenthal & Ehri, 2008). Orthography can help children acquire the pronunciation of a word because it might act as a mnemonic device that is less transient than phonology (e.g., Ehri, 2014). Mapping the graphemes in the written form to the phonemes in its spoken form helps to secure the phonology in memory. In turn, learning the phonology more quickly might facilitate learners to connect the phonology to the semantics (Rosenthal & Ehri, 2008). In L2 learners the extent to which orthography might act as a mnemonic device to acquire the phonology of a word might be affected by the orthographic distance between L1 and L2, as it is easier to process the orthography if L1 and L2 are orthographically similar (Geva & Siegel, 2000; Koda, 2007). For instance, for L2 English reading, there is more cross-linguistic transfer for students with Spanish as L1 than for students with Chinese as L1, because Spanish and English both have alphabetic scripts, whereas Chinese and English use different scripts. Consequently L1 Spanish students can depend more than Chinese students on their L1 orthographic knowledge as a resource for learning English (Pasquarella, Chen, Gottardo, & Geva, 2015). Similarly, Zeguers, van den Boer, Snellings, and de Jong (2018) found that Dutch students show differences in the acquisition of word reading in Spanish (Dutch and Spanish both being alphabetic languages) and Chinese (different orthography from Dutch).

The relationship between phonology and semantics is qualitatively different from the orthography–phonology relationship. Phonemes do not help in deciphering the meaning of a word. Therefore, as a third possibility, orthography might have no effect at all on learning the meaning of words, neither directly nor indirectly. In this view, orthography merely affects the acquisition of the phonology of words (Chambré et al., 2017). Evidently, word recall as a measure of word meaning cannot be used to disentangle these different accounts of the relationship between orthography and word learning as this measure reflects both the acquisition of phonology and meaning (Ricketts et al., 2009).

Role of orthography in L2 word learning

Whether orthography can facilitate word learning has thus far mostly been examined in first language (L1) word learning. However, it is of interest to investigate word learning in the early stages of second language (L2) learning as well. One evident

reason to do so is because such information can speak to educational practices of L2 word learning. This requires specific insight into the variables that shape L2 word learning, These are not necessarily the same for L1 and L2 learning, since there are some important similarities and differences between L1 and L2 word learning. For both L1 and L2 word learning, the orthography and phonology of a new word has to be learned. The important difference between L1 and L2 lies in how word meaning is learned and how it can be measured. Especially for novice learners, it has been proposed that, rather than creating a new concept, L2 learners link the word to the translation in their first language (De Groot, Dannenburg, & Van Hell, 1994; Jiang, 2000). For example, if English students have to learn the Spanish word *manzana*, they will learn that the Spanish word *manzana* is a translation for the English word *apple* and vice versa. Measuring whether someone knows what *manzana* means can therefore be measured in two ways: learners can be asked whether they know the L1 English word for L2 *manzana* (backward translation), or they can be asked whether they know the Spanish word for *apple* (forward translation). Thus far, the few studies on orthographic facilitation in L2 word learning consisted of associating a novel picture to a pronunciation (Hu, 2008; Zhang, Li, Liu, & Chen, 2020), however whether the availability of orthography can also facilitate learning the translations of word has not been studied yet.

Translation can go in two directions. Forward translation, similarly to word recall, requires the retrieval of both the pronunciation and meaning of the (novel) L2 word. During backwards translation, however, a learner has to provide only the L1 meaning of the L2 word. Consequently, for forward translation more precise representations in memory are necessary and forward translation is considered more difficult than backward translation (Steinel, Hulstijn, & Steinel, 2007). If the availability of orthography during learning has an effect on learning the meaning, either directly or through phonology, it should have an effect on both backward and forward translation. However, if it has no effect on the acquisition of meaning, but only on learning phonology, then only an effect on forward translation is anticipated. In backward translation, the pronunciation of the word has not to be given and only has to be recognized and thus does not need to be known completely. Therefore, to gain more understanding into how the availability of orthography could facilitate word learning, we examine whether orthography has the same effect on forward translation (requiring a word's pronunciation) as on backward translation (not requiring a word's pronunciation).

The importance of spelling consistency in word learning

If orthography has an effect on the acquisition of a word's phonology, the effect size would reflect the difficulty of mapping the orthography to phonology. The consistency of spellings is a reflection of the difficulty of mapping. In words with consistent spellings orthography and phonology are easy to map, because they are spelled just like their pronunciation (e.g., *pig*). In contrast, a word such as *reindeer* is inconsistent, because using standard grapheme to phoneme mapping, most people would spell the word *raindeer* after hearing it. During word learning, children tend to acquire the

meanings of consistent words more quickly than inconsistent words (Ricketts et al., 2009). Monolingual English speakers also recall more words if the words are shown with a consistent instead of an inconsistent spelling (Jubenville et al., 2014). A similar result was found in a study with Chinese children (Li et al., 2016): In a visual–verbal paired associate learning task, pictures were either accompanied by Chinese characters or not, and these Chinese characters either contained phonetic radicals which matched the pronunciation (consistent spelling) or contained phonetic radicals that did not match the pronunciation (inconsistent spelling). Although the presence of orthography did not have an effect on the learning of consistently spelled words, but an inconsistent orthography impeded word learning. Overall, consistent words seem easier to learn than inconsistent words, supporting the view that orthography is a better mnemonic when the correspondence between graphemes in the written form and phonemes in the spoken form is more consistent. Since the current study focuses on how orthography can facilitate word learning in L2, the consistency of a word's spelling is also taken into account. If the availability of orthography mainly facilitates learning the pronunciation of a word, the effect of orthography is likely larger for consistent words (when mapping the spelling onto the pronunciation is straightforward) than for inconsistent words (when mapping the spelling onto pronunciation is more difficult).

Translation direction during learning and testing

In most previous L1 word learning experiments, children learned the word meaning and pronunciation at the same time. In L2 this would correspond to an experiment in which children learn the words using forward translation. However, L2 studies have shown that whether words are learned using forward translation (forward learning) or backward translation (backward learning) makes a difference in learning outcomes: translations are learned better if they are learned in the same direction (Mondria & Wiersma, 2004; Steinel et al., 2007; Webb, 2009). Especially for the more difficult forward translation, performance is better when the words are also learned using forward translation instead of using backward translation. So if the goal of translation learning is production of the L2 word, it is important that this is also practiced in the learning phase. Of particular interest in the present study is that pronunciation is practiced more during forward learning than backward learning. Accordingly, children are expected to learn more of the L2 word form during forward learning (Webb, 2009). In the current study, we study the effect of orthography on learning the L2 pronunciations and L1 meanings. Therefore, the distinction between forward and backward translation during learning is of interest in the current experiment.

Present study

The overall research question of this study was whether Dutch students can profit from the availability of orthography during word learning on acquiring the translations of L2 English words. Therefore, we carried out a word learning experiment in which students either learned the translation of novel words with orthography present or absent. We also examined *how* the orthography facilitates translation

learning, that is whether availability of orthography facilitates translation learning directly, indirectly by facilitating acquisition of the pronunciation, or whether it *only* affects learning the pronunciation. We addressed three specific questions.

First, we explored whether effects of orthography are mainly focused on acquiring the phonology. Are effects of orthography found on both a forward translation test (which requires phonology) and on a backward translation test (which does not require phonology)? Our main expectation was that if orthography has a direct effect on learning the meaning of words, both forward (Dutch to English) and backward translations (English to Dutch) would improve, provided that orthographic learning was successful. Since Dutch and English are both alphabetic languages, we expected that students would have no major problems with orthographic learning in L2 English. Second, if the orthography has an effect on learning phonology, the complexity of the orthography–phonology connection should also matter, as straightforward connections could be easier to acquire than more complex ones. Therefore, the second question was: does the availability of orthography have a differential effect depending on whether words have a consistent or an inconsistent spelling? If orthography has an indirect effect on learning meaning, this effect of orthography would be larger for consistent words than for inconsistent words. In contrast, if availability of orthography during learning affects learning the pronunciation, orthography would only affect spelling and reading, and perhaps forward translation.

Finally, we also investigated whether the condition in which words are learned matters, since this has been found to interact with the performance on forward translation and backward translation tests. We expect that performance on the translation task is better if the translation direction of the post-test is the same as the direction of the word learning phase. These research questions were addressed in a word learning experiment in which the associations between 12 Dutch words and their English translation had to be learned. During word learning, children either saw the orthography of the English words in every learning trial, or never saw the orthography at all. Half of the English words were spelled consistently, the spelling of the other half was consistent. To investigate whether translation directions matter during learning, half of the children were taught the translations from Dutch to English (forward learning) and half from English to Dutch (backward learning). The two independent variables were crossed, resulting in four learning conditions: (1) No orthography and backward learning, (2) orthography available and backward learning, (3) no orthography and forward learning, (4) orthography available and forward learning. After completing the word learning task, both forward and backward translation were tested in all participants. A precondition for examining if orthography facilitates *translation* learning is that orthographic learning actually takes place. As indicators of orthographic learning we included both spelling and reading measures of the exposed words (Share, 1999). Additionally, the reading measure was a way to measure whether children had learned to connect the written word to the correct pronunciation.

Methods

Participants

Participants were 92 Grade 6 children from 5 classrooms in 5 different schools in the region of Amsterdam. In the Netherlands Grade 6 is the last year of primary school. Some English education is obligatory from Grade 5, but formal English instruction by specialized teachers starts when students begin high school in Grade 7. Typically, English education in primary school takes around 30–60 min per week and is mostly focused on communication and vocabulary. These lessons are provided by the class teacher, who also teaches all other topics (Thijs, Trimbos, Tuin, Bodde, & De Graaff, 2011). Informed consent was obtained at least 2 weeks before data collection started. Within each classroom, quadruplets of children were created of the same gender (if possible) and the same English literacy proficiency. Each child in a quadruplet was randomly assigned to a different condition, resulting in four groups of children with similar English skills in four conditions. Due to absence or illness during the test period eight children only completed the general language measures and did not participate in the word learning experiment. Analyses were performed on the remaining sample of 84 children that completed all phases of the study. The 39 boys and 45 girls were 11 years and 9 months on average (Range 11–13 years, SD = 5 months). There were no significant differences between the four conditions on word reading, decoding, and spelling, as shown by a MANOVA, $F(12,237) = 0.214$, $p = .998$ (see Table 1).

Design

The current experiment had a 2×2×2 factorial design with orthography (absent or present) and translation direction (backward learning or forward learning) as between-subject variables and target word consistency in spelling (consistent or inconsistent) as within-subjects variable. The dependent variables were backward

Table 1 Demographics (SD in months) and means (SD) of general language measures per condition

Variable	Backward translation		Forward translation	
	O−	O+	O−	O+
N	23	20	21	20
Age in years; months	11;9 (4)	11;9 (5)	11;9 (6)	11;10 (6)
Percentage girls	52%	50%	52%	60%
L2 spelling	4.96 (2.25)	5.4 (4.01)	5.14 (2.74)	4.65 (2.68)
L2 word reading	55.56 (9.27)	55.20 (11.43)	55.05 (10.87)	55.00 (10.64)
L2 decoding	38.13 (11.52)	36.60 (9.60)	37.33 (8.67)	36.80 (8.75)
L2 vocabulary	39.09 (5.66)	39.7 (6.11)	38.52 (6.1)	38.55 (6.29)

O− = no orthography; O+ = orthography available

translation, forward translation, spelling and reading, and were measured in an immediate and delayed post-test.

Background measures of English reading and spelling ability

The following measures were used to asses general English reading and spelling ability, on which experimental conditions were matched.

English word reading and decoding ability

Word reading and decoding ability was measured with the Sight Word Efficiency and Phonemic Decoding Efficiency subtests of the Test of Word Reading Efficiency second edition (TOWRE, Torgesen, 2012). These subtests consist of a list of 108 words for Sight Word Efficiency and a list of 66 non-words for Phonemic Decoding Efficiency. The child was given 45 s per list to read as many words as accurately as possible.

As the children were not native speakers of English and spoke English with a Dutch accent in English, experimenters were less stringent on articulation errors. For example, the <th> is difficult for Dutch children, so pronouncing the word <thing>with the voiceless dental fricative replaced by voiceless labio-dental fricative/f/, <fing>, was considered correct, but pronouncing it as a voiced alveolar fricative, <zing>, was considered incorrect. Decoding errors were scored as incorrect, for example pronouncing the word <thing>as <think>, as this referred to lexical errors and/or errors of English and Dutch graphemes (ng and nk). Experimenters were trained by the researchers by scoring two word reading tests and comparing these with the scores of the lead experimenter until agreement was reached on how to score the pronunciations. The score was the total number of words read correctly, with a maximum score of 108 for Sight Word Efficiency and 66 for Phonemic Decoding Efficiency. For native English speakers the test is known to be reliable, with an internal consistency ranging from .86 to .97 (Hayward, Stewart, Phillips, Norris, & Lovell, 2008).

English spelling ability

General English spelling ability was measured using a dictation task (developed by S. van Viersen and E.H. de Bree, personal communication, October 2016). The task consisted of 25 target words embedded in a sentence, which the experimenter read aloud to the child. The first 20 words were nouns, adjectives and adverbs and the last 5 words were verbs. Words increased in word length and complexity (starting with *two* and ending with *mathematician*). The experimenter read the sentence and subsequently repeated the target word (i.e., "This flower looks beautiful—*beautiful*"). The child wrote down the target word. The experimenter scored the answers as either correct or incorrect. The maximum score was 25. The reliability of the task was acceptable with a Cronbach's alpha of .77.

Word learning task

Stimuli

The task consisted of 6 consistent and 6 inconsistent target words of one or two syllables. The words were selected from the lexical database with age of acquisition (AoA) ratings (Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012). To ensure that the English target words were unknown to the children, words were selected with an AoA rating between 12.5 and 13 years for native English speakers. This age range was slightly above the age of the children included in the study. We selected only adjectives and nouns with a straightforward Dutch translation (e.g., the word *froth* and its Dutch translation *schuim* was included, but *fritter* was excluded because it does not have a clear Dutch translation). Furthermore, cognates were excluded (e.g., the English *wasp* and Dutch *wesp*), as well as words that were homophones with a Dutch word (e.g., English *beat* and Dutch *biet* [meaning *beetroot* in English] or an English word [e.g., *feat* and *feet* in English]). This resulted in a list of 20 words (see "Appendix").

The selected target words were coded for the consistency of their English spellings by using sound-spelling rules as reported by van Berkel (2006). Words with a spelling that can be correctly predicted from the pronunciation using GPC rules were coded as consistent (e.g., *lilt*); words with a spelling that that cannot be predicted from GPC rules were coded as inconsistent. (e.g., the/i:/in *peat* is spelled <ea but this sound can also spelled as <ie>, <e>, <ey> or <ei> as in *field*, *he*, *key*, *seize*. In addition, the words were translated to Dutch using Google Translate. For words with multiple translations the shortest word with the highest frequency in Dutch was chosen.

A pilot word learning experiment with 41 students was conducted to test the difficulty of learning 20 words in total (data available on request). Learning 20 words in such a short time proved to be very difficult for the students. Based on the pilot results we selected 6 consistent and 6 inconsistent words that were of intermediate difficulty to acquire. The AoA of the Dutch translations of these 12 target words ranged from 5.94 to 10.59 years, indicating that the Dutch words were likely to be known by the students (Brysbaert, Stevens, De Deyne, Voorspoels, & Storms, 2014). English words were low in frequency (on average 0.22 per million). There were no differences between the consistent and inconsistent target words in terms of English and Dutch AoA, frequency, letter count, and syllable (see the "Appendix" for the word list and details).

Overall the AoA of the English target words was higher than their translations. This is due to the fact that the English target words were often low-frequent synonyms of high-frequent words, such as *prudent*, which is a low-frequent synonym for *careful*. For these low-frequent words, the chosen Dutch translation has a high frequency, in this case *voorzichtig* (which could be translated as both *prudent* and *careful*). It is important to note that for some target words the Dutch translation was a cognate with an English word. This was unavoidable, because our selection criterion was that the English word was unknown whereas the accompanying Dutch word was well-known to the students. English and Dutch share a high number of cognates. For

example, the word *tempest* is translated into *storm,* which is both a Dutch translation and an English synonym for *tempest*. However, this presence of cognates does not pose a problem for the interpretation of the findings in the current experiment. Since the students had no prior associations between the English *tempest* and the Dutch *storm*, it is unlikely that they already associated the English *tempest* with the English *storm.* This was also evident from the fact that in the forward translation task none of the students gave the English word *storm* as a translation for the Dutch word *storm*. We therefore assume that students only learned the correct L2–L1 association. Most importantly, the main goal of this experiment was to investigate the effects of availability of orthography, and the manipulation of orthography pertains only to the English target word and not to the Dutch translation of that word.

Design of the task

The goal of the task was to learn the translation of 12 target words. Students were familiarized with the translation of each target word in one exposure trial followed by four training trials in which the student translated the word and received feedback. The target words were divided in 2 sets, each containing 3 consistent and 3 inconsistent words. The sets were presented in blocks of 6 exposure or training trials. The word learning task started with a block of exposure trials for the first set, followed by a block of training trials for the first set. The task then continued with a block of exposure trials for the second set, followed by a block of training trials for that set. For the remainder of the task, the first and the second sets were alternated in each block of training trials, until each word was presented in 4 training trials. The task, administered on a computer, was programmed in E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA).

In the no orthography condition the English spelling was never shown during the trials, while in the orthography available condition, the English spelling accompanied the English pronunciation every time. In the forward learning conditions, the words were always translated from Dutch to English (e.g., "What is the English word for *voorzichtig*?"), while in the backward translation learning conditions, words were taught and practiced from English to Dutch (e.g., "What is the Dutch word for *prudent*?").

Additionally, the type of response in the forward translation learning condition and backward translation condition differed. In the forward learning condition children were asked to say their answer out loud, whereas in the backward learning condition children were asked to type in their answer. These responses were chosen to match the modality in which words were presented in the learning trials. In the forward translation learning condition, the English word was always heard (but not always seen), therefore students were asked to give the English pronunciation. In the backward learning condition, the Dutch word was always seen (but not heard), therefore students were asked to give the Dutch spelling.

Exposure trials

Forward learning condition The exposure trial in the forward learning condition started with a fixation cross (500 ms) followed by the written form of the Dutch word (3000 ms). Subsequently, the audio of the English word was presented either with orthography (orthography condition) or without (no orthography condition) (see Fig. 1a, b). The student had to repeat the target word to the experimenter, to make sure that the student was able to pronounce the words. If the pronunciation was correct, the experimenter started the next trial. If the pronunciation was incorrect, the experimenter gave the correct pronunciation and the student repeated the pronunciation until it was correct. A second repetition was rarely necessary.

Backward learning condition An exposure trial in the backward learning condition started with a fixation cross for 500 ms, followed by the pronunciation of the English target word accompanied by the English spelling (orthography condition) or not (no orthography condition) for 3000 ms (see Fig. 1c, d). Then the Dutch translation was shown for 3000 ms for both conditions.

Training trials

Forward learning condition A training trial in the forward learning condition (see Fig. 2a) started with a 500 ms fixation cross, followed by the written Dutch target word (for 3000 ms). Students then had to say the English translation out loud to the experimenter. The experimenter said whether the answer was correct or incorrect and pressed a corresponding button to present a screen with the word "correct" or "incorrect" and the correct English pronunciation for 2000 ms. The feedback was accompanied by the English spelling in the orthography condition, but not in the no orthography condition.

Backward learning condition Training trials in the backward translation condition started with a 500 ms fixation cross, followed by the pronunciation of the target word. In the orthography present condition the pronunciation was accompanied by the English spelling for 3000 ms. Then in both conditions, the student was asked to type the Dutch translation and confirm the answer with the enter key. After the student entered the translation, feedback was shown for 2000 ms. If the answer was incorrect, the incorrect answer was shown in red with the correct answer underneath in green. If the answer was correct, feedback consisted of only the correct answer in green letters.

Learning procedure

Before each phase the instructions for the student were shown on-screen and explained by the experimenter. Preceding the actual learning task, the task was practiced with simple English words that were already known by the students. These words were *bike* and *easy*, which are translated in Dutch as *fiets* and *makkelijk*. For

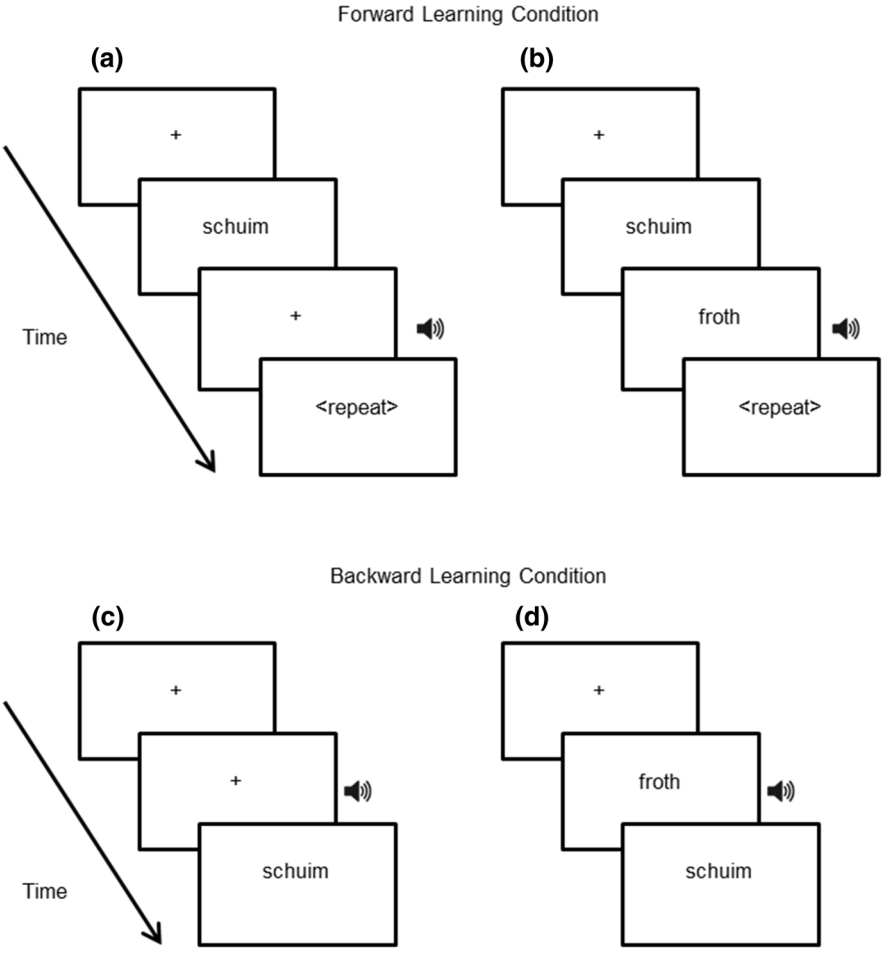

Fig. 1 Timelines of the exposure trials for the Forward Learning with (**a**) and without (**b**) and Backward Learning conditions with (**c**) and without (**d**) orthography. The speaker symbol indicates that the pronunciation was presented auditorily

each word, 2 training trials were given, without exposure trials. These training trials were identical to the training trials of the condition the student was assigned to. If students did not have any questions after the training trials, they continued with the task proper, starting with the first block of exposure trials. Trials within a block followed each other automatically, while in between blocks there was a short self-paced break.

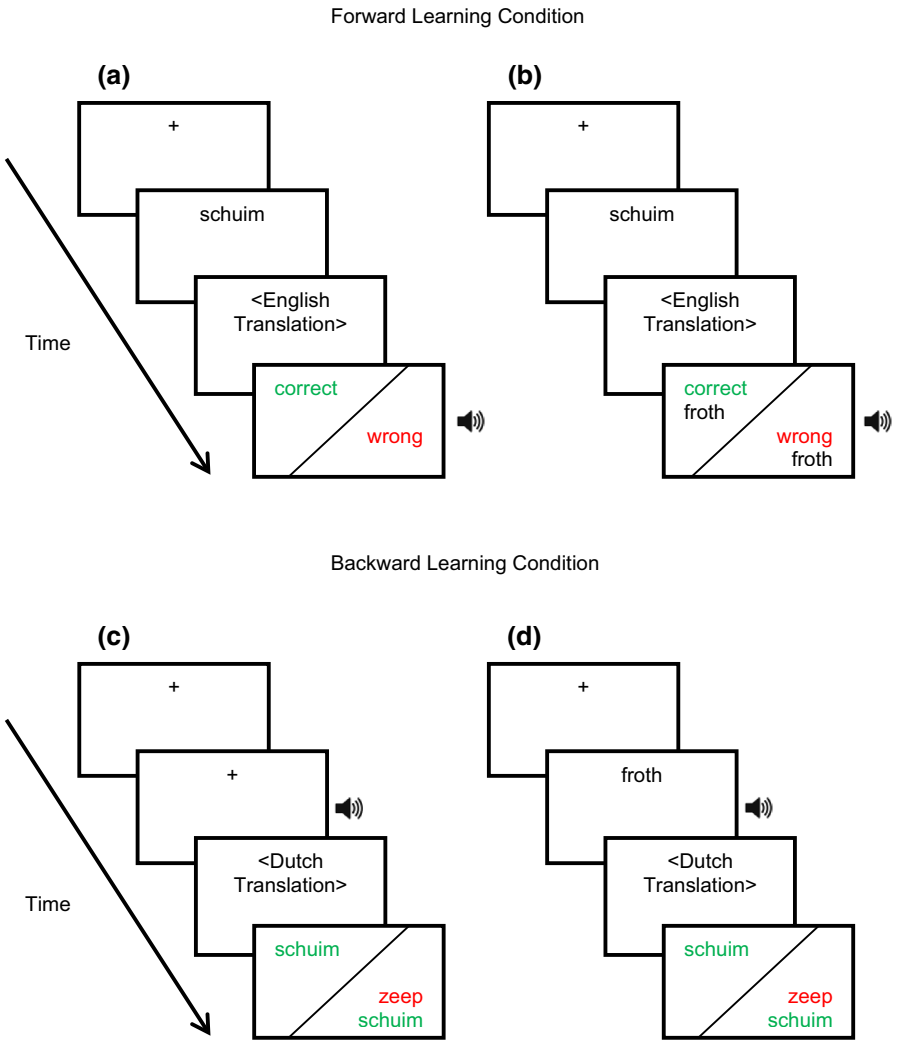

Fig. 2 Timelines of the training trials for the Forward Learning Condition with (**a**) and without (**b**) orthography and Backward Learning Condition with (**c**) and without (**d**) orthography. The left side of the feedback screens was shown when the student answered correctly and the right side was shown if the student answered incorrectly. The speaker symbol indicates that the pronunciation was presented auditorily

Post-test measures

Backward translation post-test

A fixation cross was presented for 5000 ms followed by the English pronunciation for one of the target words. The students were then asked to type in the Dutch translation. The score was the number of accurate translations with a maximum score of

12. Answers with small spelling errors (only 1–2 incorrect letters that did not result in a different Dutch word, for example if students spelled <vorzichtig>instead of <voorzichtig>) were scored as correct, as Dutch spelling ability is not the intended measured construct in this experiment. Students did not receive feedback.

Forward translation post-test

In the forward translation measure students were presented with a fixation cross for 5000 ms, followed by the Dutch written target word. They had to say the English translation out loud, which was scored by the experimenter as correct or incorrect, using the same rules as during the reading task. The score was the number of correct translations with a maximum score of 12. Students did not receive feedback.

Spelling post-test Spelling of the target words was measured in a dictation task. The pronunciation of the target word was given and students had to type the correct English spelling. If the word was spelled entirely correct, 1 point was given, resulting in a maximum score of 12.

Reading post-test Accuracy of target word reading was measured in a reading task. Students were given a sheet containing a list of the 12 target words in a randomized order and were asked to read the words aloud. They were instructed that they should only focus on accuracy and that they did not have to read as fast as possible. Student's pronunciations were recorded and the pronunciation for each word was scored as either correct or incorrect using the same considerations as in the English reading tasks.

Procedure

Prior to data collection, approval was obtained from the Ethics Review Board of the <Blinded> (project number <Blinded>). The study consisted of three sessions. All sessions were completed individually in a quiet room in the school with the experimenter.

In the first session background measures were administered. The background measures were administered in the following order: Dutch word reading and decoding, English word reading and decoding, English vocabulary, and English spelling. This session lasted 30 min.

The second session included the word learning task, which took around 30 min. The experimenter provided instructions about the task to each student individually and answered any questions the student had. After the task students completed a short distraction task. This was a computerized Digit Symbol Substitution Task (Wechsler, 2008), which took about 90 s. The distraction task was immediately followed by the post-tests. The post-tests consisted of backward translation, forward translation and spelling, in that order. Students were instructed to try and remember the words for the next day, but to not actively study the words at home.

The delayed posttests were administered 1 day after the word learning task in the third session. During the delayed posttest the same tasks were administered, followed by an additional reading task. The reading task was administered last and only on the delayed posttest to ensure that students in the no orthography condition had no exposure whatsoever to the orthography of the words before the other posttests had been done.

Results

Mean scores and standard deviations in the various conditions on the spelling and reading of the target words at posttest are presented in Table 2. There were no outliers on post-test measures, according to our criterion of a score of more than 3.29 standard deviations from the mean (Field, 2013).

The presentation of the results starts with the effects of orthography on orthographic learning, as measured by spelling and reading. This analysis can be regarded as a manipulation check, because a prerequisite for investigating whether orthography promotes translation learning is that orthographic learning actually takes place. Then the effects of the availability of orthography on the translation measures are examined in relation to the three research questions. In these analyses we first focused on whether effects of orthography differed depending on the translation direction at post-test, then the consistency of the word's spelling, and finally whether words were learned using backward translation or forward translation.

Spelling and reading

Spelling

Spelling accuracy of the target words was assessed to check whether the manipulation of orthography was successful. Spelling performance was analyzed in a Repeated Measures ANOVA with the between-subjects conditions presence of orthography (orthography present vs orthography absent) and learning condition

Table 2 Average number of correctly spelled and read words (SD) per condition

Test	Word type	Backward learning condition		Forward learning condition	
		O−	O+	O−	O+
Spelling day 1	Inconsistent	0.19 (0.51)	2.25 (1.55)	0.26 (0.54)	2.35 (1.84)
	Consistent	1.67 (1.24)	4.55 (1.19)	1.61 (1.08)	4.30 (1.75)
Spelling day 2	Inconsistent	0.24 (0.54)	2.80 (1.61)	0.26 (0.54)	3.15 (1.63)
	Consistent	1.90 (1.22)	5.00 (0.97)	1.48 (1.27)	4.65 (1.57)
Reading day 2	Inconsistent	3.87 (1.01)	5.25 (0.85)	4.24 (0.95)	5.35 (0.67)
	Consistent	4.65 (1.19)	5.40 (1.04)	5.05 (1.07)	5.70 (0.57)

O− = no orthography; O + = orthography available

(forward learning vs backward learning. The within-subjects conditions were consistency (consistent spelling vs inconsistent spelling), and time (immediate post-test vs delayed post-test). As expected, hardly any words were spelled correctly if orthography was not present during learning (see Table 2). The ANOVA showed that exposure to orthography greatly improved the spelling, $F(1, 80) = 141.594$, $p < .001$, $\eta_p^2 = .64$, and that the words were spelled better on day 2 than on day 1, directly following the word learning task, $F(1, 80) = 18.319$, $p < .001$, $\eta_p^2 = .19$. The effects of orthography and time were qualified by an interaction between presence of orthography and time, showing that the increase in spelling scores was only found in the condition in which orthography was present, $F(1,80) = 13.716$, $p < .001$, $\eta_p^2 = 0.15$. Simple effects showed that spelling improved between day 1 and 2 if students had seen the orthography, $F(1,80) = 30.450$, $p < .001$, $\eta_p^2 = .28$, but stayed the same if orthography had not been available, $F(1,80) < 1$, ns.

We also found that consistent words were spelled better than inconsistent words, $F(1, 80) = 177.416$, $p < .001$, $\eta_p^2 = 0.69$, but this effect was qualified by an interaction with exposure to orthography, $F(1, 80) = 4.870$, $p = .032$, $\eta_p^2 = .056$. In the no orthography condition, consistent words were spelled significantly better than inconsistent words, $F(1,80) = 65.004$, $p < .001$, $\eta_p^2 = .45$. When orthography was present, consistent words were also spelled better than inconsistent words, but the effect sizes indicate that the difference between consistent and inconsistent words was larger, $F(1,80) = 114.868$, $p < .001$, $\eta_p^2 = .59$. Overall, this indicates that consistent words benefited more from orthography than the inconsistent words. None of the other effects, including the difference between the learning conditions, were significant.

Reading

The reading test was administered to evaluate orthographic learning and whether students could produce the correct pronunciation from the orthography. Reading accuracy was analyzed using an ANOVA, with the independent variables presence of orthography, consistency, and learning condition. As expected, learners that were exposed to the orthography of the words read the target words better than learners that had not seen the orthography, $F(1, 80) = 31.476$, $p < .001$, $\eta_p^2 = .28$. Similar to the spelling outcomes, consistent words were read better than inconsistent words, $F(1, 80) = 21.245$, $p < .001$, $\eta_p^2 = .21$. This effect was qualified by an interaction with orthography, $F(1, 80) = 5.789$, $p = .018$, $\eta_p^2 = .07$. Inconsistent words benefited more from the presence of orthography, $F(1,80) = 41.463$, $p < .001$, $\eta_p^2 = .34$, than consistent words, possibly due to the fact that consistent words were already read quite well in the no orthography condition, $F(1,80) = 10.112$, $p < .05$, $\eta_p^2 = .11$.

Effect of availability of orthography on translation learning

Next, we move on the main question of whether the availability of orthography facilitated learning the translations. The effects of orthography on both the forward and backward translation measures were analyzed to assess whether orthography

affected learning the translation. With regard to the first research question, if orthography facilitated learning the translation (either directly or indirectly through learning the pronunciation), we expected an effect on both forward and backward translation. If orthography only facilitated learning the pronunciations, we expected an effect on only forward translation but no effect on backward translation. Furthermore, if orthography mainly facilitates learning the pronunciation, it is likely that the effect of orthography also depends on the consistency of words. Therefore, in the second question we examine the effects of consistency on translation learning and the interaction of consistency with translation direction at post-test. Finally, we report on the interaction between direction of learning and direction of testing.

The translation outcomes at post-test were analyzed using a Repeated Measures ANOVA. The independent variables were the between-subjects conditions presence of orthography (orthography present vs orthography absent), and learning condition (forward learning vs backward learning). The within-subjects conditions were translation direction at post-test (forward translation vs backward translation), consistency (consistent spelling vs inconsistent spelling), and time (immediate post-test vs delayed post-test). Below, the main effects and interactions of interest are discussed. For the translation measures, there was no effect of time, $F(1, 80) = .878$, $p = .352$) and time did not interact with any of the variables. Therefore, the average scores of day 1 and 2 are reported here (see Table 3).

Effects of availability of orthography on forward and backward translation

The overall effect of orthography on providing the translation approached significance, $F(1,80) = 3.466$, $p = .066$, $\eta_p^2 = .042$, implying a trend for target words to be translated correctly more often when orthography was available than when it was not. With regard to the first research question of whether effects of orthography depended on whether words had to be translated using forward translation or backward translation, we found that orthography did not interact with translation direction at post-test, so the effect of orthography seemed to be equal for translating words from English to Dutch or from Dutch to English, $F(1,80) = .375$, $p = .542$. This finding is most in line with the hypothesis that orthography has a direct effect that is not mediated by phonology.

Table 3 Average number (SD) of words correctly translated to Dutch and English per condition

Test	Word type	Backward translation condition		Forward translation condition	
		O−	O+	O−	O+
Forward translation	Inconsistent	0.98 (1.03)	1.55 (1.28)	2.10 (1.29)	1.80 (1.28)
	Consistent	0.79 (0.93)	2.25 (1.66)	1.83 (1.17)	2.20 (1.63)
Backward translation	Inconsistent	2.52 (1.65)	3.03 (1.69)	2.95 (1.08)	2.98 (1.27)
	Consistent	2.39 (1.43)	3.15 (1.61)	2.19 (1.24)	2.55 (1.77)

O− = no orthography; O + = orthography available

Effects of availability of orthography on learning consistent and inconsistent words

However, if orthography does have an indirect effect on learning the translation, whether the word is spelled with a consistent or inconsistent spelling should also matter. Therefore for the second research question we investigated whether orthography had a larger effect on words with a consistent than inconsistent spelling. The interaction of orthography with consistency was significant, $F(1,80) = 5.027$, $p = .028$, $\eta_p^2 = .06$. Simple effects analysis showed that availability of orthography did not facilitate translating inconsistent words, as can be seen in Fig. 3, $F(1,80) = .549$, $p = .461$. For consistent words on the other hand, more words were translated correctly when orthography was available than when it was not, $F(1,80) = 6.597$, $p = .012$, $\eta_p^2 = .08$. Therefore, availability of orthography only benefited the consistent words, but not the inconsistent words. Availability of orthography did not interact with whether the post-test consisted of forward translation or backward translation, $F(1,80) = 0.375$, $p = .542$, nor did orthography interact with the learning condition $F(1,80) = 1.993$, $p = .162$.

Whether target words were consistent or inconsistent also interacted with whether the post-test consisted of forward translation or backward translation, $F(1,80) = 9.559$, $p = .003$, $\eta_p^2 = .11$. The interaction between consistency and post-test reflects an effect regardless of whether orthography was available or not. However, interpretation of the interaction effect of consistency and post-test is not meaningful, because students in the no orthography condition could not know which words were inconsistent and which words were not. Although the three-way interaction between type of post-test, consistency, and orthography only approached significance, $F(1,80) = 2.438$, $p = .108$, we decided to examine the interaction in more detail in two separate ANOVAs for the no orthography and the orthography condition.

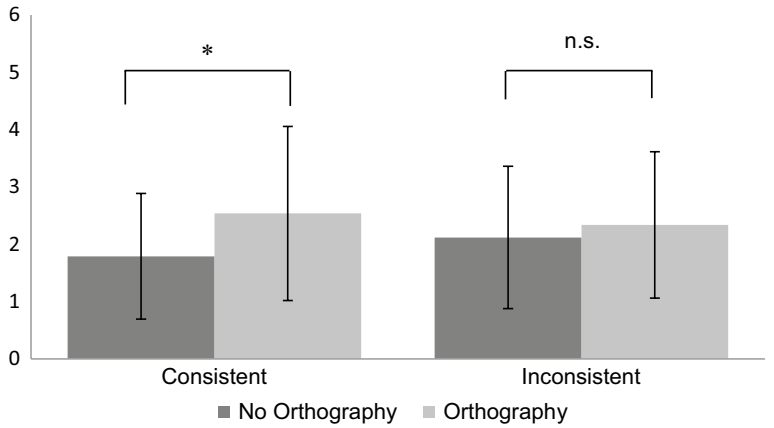

Fig. 3 Average number of correct translations for consistent and inconsistent words in the no orthography and orthography condition. Error bars represent standard deviations. * $p < .05$

We analyzed the interaction of consistency with translation direction at post-test separately in the orthography condition and in the no orthography condition. Therefore, we carried out two separate ANOVAs. The between-subject condition was learning condition, and the within-subject conditions were translation direction at post-test, consistency, and time. As expected, for students who did not see the orthography there was no interaction effect between post-test and consistency, $F(1,42)=1.108$, $p=.299$, whereas for students who did see the orthography, the interaction between post-test and consistency was significant, $F(1,38)=10.830$, $p=.002$, $\eta_p^2=.22$. In the orthography condition, when forward translation was used in the post-test, performance on consistent words was significantly higher than on inconsistent words, $F(1,38)=6.050$, $p=.019$, $\eta_p^2=.14$ (see Fig. 4). When backward translation was used in the post-test, consistent and inconsistent words did not differ significantly, $F(1,38)=0.350$, $p=.557$.

In the no orthography condition, there was a main effect of translation direction at post-test: Forward translation was more difficult than backward translation, $F(1,42)=93.016$, $p<.001$, $\eta_p^2=.69$. There was also a main effect of consistency, $F(1,42)=7.885$, $p=.008$, $\eta_p^2=.16$. Against our expectations, consistent words were more difficult to translate than inconsistent words. This contrasts with the findings in the orthography condition, in which consistent words were easier, especially when forward translation is used. This indicates that students benefited more from orthography in translating consistent than inconsistent words, and more so for forward translation than for backward translation.

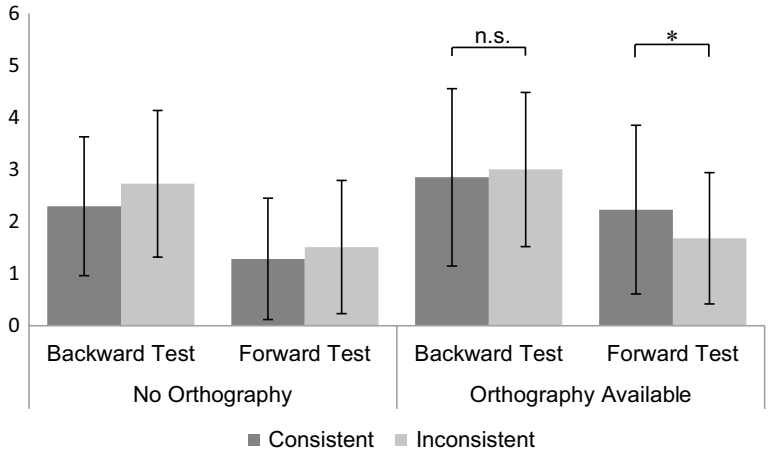

Fig. 4 Average number of correct translations on the backward translation and forward translation post-tests for consistent and inconsistent words in the no orthography and orthography condition. Error bars represent standard deviations. * $p<.05$

Forward and backward translation learning

The third question was whether performance on the translation task improves if the translation direction of the post-test is the same as the direction that words were learned in. During the word learning experiment, students either practiced the words using backward translation or forward translation. Afterwards, all students completed two translation tasks, a forward translation post-test and a backward translation post-test. There was no main effect of learning condition, F (1,80) = 0.932, p = .337, but as expected, forward translation at post-test was more difficult than backward translation, F (1,80) = 117.639, p <.001, η_p^2 = .60. The main effect of translation at post-test was qualified by an interaction between learning condition and post-test, F (1,80) = 13.380, p <.001, η_p^2 = .14. As can be seen in Fig. 5, when the translation direction at post-test consisted of forward translation, performance was better in the forward learning condition than in the backward learning condition, F (1,80) = 5.679, p = .019, η_p^2 = .07. When the post-test consisted of backward translation on the other hand, there was no significant difference between learning conditions, F (1,80) = 0.131, p = .719. So if learning condition and post-test matched, this had a positive effect on scores for forward translation measures, but this congruency effect did not affect scores for backward translation. These congruency affects did not interact with the availability of orthography, indicating that these effects are independent.

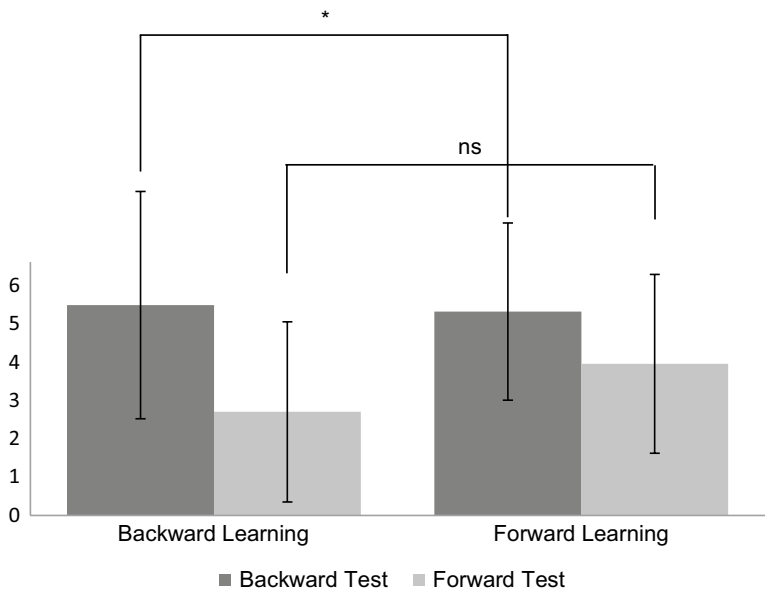

Fig. 5 Average number of correct translations on the forward and backward translation post-test per learning condition. Error bars represent standard deviations. * p <.05

Discussion

In this study we assessed whether word learning of second language learners is influenced by the availability of orthography and whether this potential effect of orthography is direct or indirect, or perhaps limited to merely learning the phonology. If orthography acts as an additional cue for retrieval, the effect would be direct. If orthography supports learning the pronunciation through orthographic mapping, which is subsequently connected to the meaning of the word, the effect would be indirect. We addressed this question by carrying out a word learning experiment in which Dutch Grade 6 students learned translations of a set of words either with orthography present or not present. To disentangle whether students learned the actual translation or just the pronunciation of the words, students were asked at posttest to translate the words both from Dutch to English (forward translation) and from English to Dutch (backward translation). The word list contained consistent (e.g., *lilt*) and inconsistent words (e.g., *budgie*). Direction of translation was manipulated during the learning trials, as students were taught the words either in a forward learning condition or a backward learning condition. Orthographic learning was assessed with a reading and a spelling test. Before considering the effects of availability of orthography on learning the translation, we examine its effects on orthographic learning.

Effects of orthography on L2 word reading and spelling

Availability of orthography had a positive effect on orthographic learning, as both spelling and reading of the words at posttest was better if orthography was available during learning. Spelling consistent words improved more from this availability than spelling inconsistent words. The finding that availability of orthography strengthened the spelling of words even with just 5 incidental exposures of the orthography shows that the manipulation in the current experiment was successful and that students paid enough attention to the written words to acquire orthographic knowledge. Moreover, we found that the orthographic representations of consistent words were stronger than those of inconsistent words. This is in accordance with the prediction from the self-teaching hypothesis (Share, 1995) that orthographic representations are acquired by phonological recoding of the written word. Phonological recoding is deemed easier for words with a spelling that is consistent with its pronunciation, as opposed to words with an inconsistent spelling (e.g., Wang, Castles, & Nickels, 2012).

Orthographic learning was also evident in the higher accuracy of word reading aloud by students who had learned words with orthography than those who had done so without orthography. The availability of orthography strengthened the relationship between the written word and its pronunciation in memory. Although previous word learning experiments have not administered reading aloud measures (Chambré et al., 2017; Jubenville et al., 2014; Miles et al., 2016; Ricketts et al., 2009; Rosenthal & Ehri, 2008), our findings are in line with orthographic learning studies

that have shown positive effects of orthography on reading speed (Cunningham, Perry, Stanovich, & Share, 2002; de Jong & Share, 2007). Interestingly, in our study, the availability of orthography during learning improved reading aloud accuracy in both the backward and forward learning condition. Words were never read aloud in either of these learning conditions. Nevertheless, in the forward learning condition students practiced the pronunciation. This was not the case in the backward learning condition. The occurrence of the reading aloud effect in both learning conditions suggests that phonological recoding is an automatic process for these students and that explicit practice of the pronunciation is not necessary for acquiring orthographic knowledge. This result is in agreement with results from orthographic learning studies showing that orthographic learning occurred during both oral and silent reading (de Jong, Bitter, van Setten, & Marinus, 2009; de Jong & Share, 2007). So our findings show that even when the pronunciations and spelling were not practiced, but only incidentally perceived by the students, the connection between the written word and its pronunciation was strengthened.

Effects of orthography on forward translation and backward translation

Turning to translation, we found a trend for availability of orthography to facilitate providing the translation, regardless of whether forward or backward translation had to be used. Even though this main effect was not significant ($p = .066$), we had specific reasons to explore whether availability of orthography interacted with translation direction at post-test, consistency, and translation direction during learning. We were interested in these interactions since they can provide insight into how orthography might facilitate translation learning. There was no interaction between the effect of orthography with translation direction of the post-test, so it seems that both forward and backward translation were affected similarly by orthography. Even though this finding is in line with the hypothesis that orthography directly affects acquisition of meaning (in the current study: translation), either directly or mediated by phonology, there are a number of indications that point to an interpretation that this effect might primarily be mediated by phonology: The effect of orthography depended on whether words had a consistent or an inconsistent spelling, and consistency interacted with the type of post-test.

Effects of orthography on translation of consistent and inconsistent words

We found that the availability of orthography facilitated translation of the consistent words, but not the inconsistent words. This is an indication that orthography facilitated providing the translation, but only when the orthography could easily be mapped onto the phonology. The finding that orthography had a greater effect on consistent than inconsistent words supports the interpretation that any effects of orthography on acquiring the forward translation would be mediated by phonology. If orthography could affect learning the translation directly, the relationship between orthography and phonology would not matter.

The difficulty of mapping orthography to phonology for inconsistent words might be exacerbated for students in our study if they were using L1 spelling strategies to read these L2 words, as has been reported previously (Figueredo, 2006). Using L1 spelling strategies would be especially problematic for the inconsistent words. For example, the consistent word *lilt* would be spelled the same if Dutch spelling rules would be used, but the inconsistent word *budgie* is not (using Dutch spelling rules, *budgie* would be spelled as *badzjie*). This inconsistency thus adds complexity to orthographic mapping for inconsistent words in L2. Consequently, the pronunciations of inconsistent words might not be encoded correctly in memory.

The interaction of consistency with type of post-test also indicates that the effect of orthography on acquiring meaning is likely mediated by phonology. As expected, this interaction was not significant when orthography was not available, but it was significant when orthography was available: Performance was higher for consistent than for inconsistent words, but only when words had to be translated from Dutch to English. For English to Dutch translations there was no difference between consistent and inconsistent words. So if it is easy to map the orthography to the phonology (i.e., consistent words), availability of orthography facilitates performance when the required response is also the correct phonology (i.e., forward translation). If it is more difficult to map the orthography to the phonology (i.e., inconsistent words), availability of orthography does not make it easier to provide the correct phonology. As the three-way interaction of orthography, post-test and consistency was not significant, this interpretation should be treated with caution. However, the consistency effect does resemble the moderating effect of consistency for monolingual learners reported earlier by Jubenville et al. (2014). They found that pronunciation recall benefitted more from orthography if the word had a consistent spelling than an inconsistent spelling. Thus in general, it seems that the underlying mechanism of orthographic facilitation is mapping the orthography to the phonology, and the effect is most prominent when the English translation has to be provided. Since orthographic mapping is easier for consistent words, this would result in higher translation scores for consistent words on forward translation.

For backward translation, the trend for a main effect of orthography suggests that orthography facilitated learning the translation regardless of translation direction. On the other hand, the findings also show that availability of orthography only facilitates forward translation, but not backward translation. Compared to measures in L1 studies, backward translation is most comparable to measures of receptive vocabulary, such as matching the word to the correct picture (Jubenville et al., 2014; Ricketts et al., 2009) or providing its definition (Chambré et al., 2017; Miles et al., 2016), or both (Rosenthal & Ehri, 2008). The results of these L1 word learning experiments show that orthography does not facilitate learning the meaning of words when meaning is measured as receptive vocabulary (Chambré et al., 2017; Jubenville et al., 2014; Miles et al., 2016; Ricketts et al., 2009; Rosenthal & Ehri, 2008). In that sense the finding of the main effect of orthography (for both forward and backward translation) is less in line with previous L1 studies than the outcomes of the interactions. However, it is unclear to what extent backward translation and receptive vocabulary measures are comparable. The learning process in our L2 study is perhaps more similar to a verbal–verbal paired associate learning task than learning

the meaning of a new concept (Litt, de Jong, van Bergen, & Nation, 2013), as is often the case in L1 studies. Possibly, orthography facilitates verbal–verbal learning, regardless of translation direction.

Effects of translation direction on word learning outcomes

Similar to other studies on translation direction (Mondria & Wiersma, 2004; Steinel et al., 2007; Webb, 2009), we found that forward translation was more difficult than backward translation. This makes sense, as more precise word knowledge is needed for forward translation than backward translation. However, performance on the translation tests also depended on the direction that words were learned in. Performance in the forward translation task, which was difficult, was better if students also learned the translations using forward translation rather than using backward translation. Correspondence between learning condition and test was thus beneficial for forward translation, supporting the idea that learning translations in the same way as they are tested is optimal. In contrast to previous studies (Mondria & Wiersma, 2004; Webb, 2009), performance on backward translations was equal for both learning directions. These results are partly in line with the findings of Steinel et al. (2007), who found that the correspondence effect was smaller for backward translation than for forward translations.

The lack of a congruency effect in backward translation might be attributed to differences in difficulty between backward and forward translation. To learn the correct forward translation, a student has to learn to link the L2 word to the L1 word and to produce the correct pronunciation. To learn the correct backward translation, a student also has to learn to link the L2 word to the L1 word, but production of the correct pronunciation is not needed. A backward translation task requires a link between the L2 and L1 translation and this link is acquired during backward and forward translation learning. On a forward translation task also the pronunciation of the L2 word has to be provided and this is only practiced during forward translation learning.

Importantly, these congruency effects were independent from availability of orthography during word learning. Thus, effects of orthography on forward and backward translation can be attributed to availability of orthography itself. Overall, our design included manipulation of spelling consistency and of translation direction, and outcome measures of translation knowledge, reading and spelling. This allowed us to look into the role of orthography in L2 word learning in a detailed fashion. The findings indicate that the facilitative effect of orthography on vocabulary acquisition, through translation learning, is limited: The availability of orthography facilitated vocabulary acquisition if the words had to be translated from Dutch to English (forward translation), and especially for words with a consistent spelling.

Implications

The implication of these findings is that orthography most likely facilitated only the acquisition of a word's pronunciation in L2, in line with previous studies in which

novel words are learned with pictures in L1 (Chambré et al., 2017; Ricketts et al., 2009; Rosenthal & Ehri, 2008) or L2 (Hu, 2008; Zhang et al., 2020). However, this is the first L2 study to show these type of effects when words are learned via translation learning. The interpretation that orthography facilitates pronunciation learning is supported by the finding that the effect was larger for words with a consistent than an inconsistent spelling. In addition, consistent words only benefited from orthography when words had to be translated from Dutch to English (which requires the word's pronunciation) than when words had to be translated from English to Dutch (which does not require the word's pronunciation). Thus, although the expectation on the basis of the lexical quality hypothesis (Perfetti, 2007; Perfetti & Hart, 2002) and connectionist models of reading (Harm & Seidenberg, 2004) could have been that a direct connection between orthography and meaning would be present, this does not seem to be the case. Instead, it is likely that students used the orthography as a mnemonic for learning the pronunciation, for example through orthographic mapping (Ehri, 2014). Orthographic mapping entails that students "glue" the orthography of a word onto the pronunciation using their knowledge of grapheme–phoneme-conversion (GPC) rules. This process is easier for words with a consistent than an inconsistent spelling. By mapping the spelling to a pronunciation, a connection between the orthography and pronunciation is formed in memory, consequently strengthening the memory for the pronunciation.

The findings have some educational implications. There is a general need to support L2 word learning, and this is especially prominent for the lingua franca English. Even though it may not facilitate acquisition of the actual meaning of a word, we found that the inclusion of orthography (even incidentally) leads to substantial orthographic learning and facilitates learning a word's pronunciation while, importantly, it does not distract from learning translations. Together, the findings suggest that attention to orthography is important in the language learning process of an opaque orthography, as the acquisition of both a word's orthography and phonology is essential for learning a word well (Perfetti & Hart, 2002). Therefore, one implication for practice is to present students with word learning exercises that always include a word's spelling. This might be increasingly the case, as learners will be exposed to longer texts, demanding more GPC skills and orthographic knowledge, and at the same time acquiring more orthographic knowledge to help them in the acquisition of pronunciations, as well as reading and spelling process.

Limitations

This study contains some limitations. Earlier studies on orthographic facilitation mostly compare two conditions (orthography present or orthography absent), and occasionally include a comparison for words with a consistent spelling or an inconsistent spelling. The current study however, added two extra factors: Translation direction during learning (forward learning or backward learning) and translation direction at posttest (forward translation or backwards translation). This resulted in the current design with possible three- or four-way interaction effects. However, it is likely that the power to detect those interactions is limited. We found, for example, that orthography interacted with consistency, and consistency in turn interacted with

type of post-test. However, the three-way interaction of orthography, consistency and post-test did not reach significance. Although the results do show a clear pattern, it is important to replicate these results.

A second limitation relates to the difference between translation learning in L2 and word learning in L1. In itself, it is important to know how orthography influences acquisition of the translation, since translation learning corresponds with how new words are often learned in L2 education (Hulstijn, 2001). However, we should acknowledge that learning a translation is (partly) different from actually acquiring a new concept or meaning for an unknown word. Therefore, we should be careful in extending the current findings on the way in which orthography relates to translation learning to implications regarding different models that describe the relationship between orthography and semantics, such as the lexical quality hypothesis (Perfetti, 2007; Perfetti & Hart, 2002) and connectionist models of reading (Harm & Seidenberg, 2004). Nevertheless, given that the overall results of our L2 word learning study are consistent with previous L1 studies, L2 translation learning and L1 word learning may be reasonably comparable.

Additionally, learning the orthography also differs between L1 and L2, which might affect the role that orthography plays in word learning. According to the script-dependent hypothesis (Geva & Siegel, 2000), reading development is determined by the specific features of the orthography. Since students rely on L1 literacy skills to read in a foreign language, this can be either beneficial or detrimental depending on the combination of the L1 and L2 (Figueredo, 2006; Koda, 2007). In the current study, Dutch children had to learn English words, so both the L1 and L2 were alphabetic languages. However, the question remains whether similar results would be found for students with a non-alphabetic L1. Alternatively, if L1 Dutch students learn words in a non-alphabetic language such as Chinese, they might not be able to use the orthography to their advantage in the same way, because they process the logographic Chinese orthography differently than the alphabetic Dutch or English language (Wang, Perfetti, & Liu, 2003; Zeguers et al., 2018). It is therefore important to bear in mind that this study was conducted using a specific L1 and a specific L2. Therefore more studies are needed to investigate whether facilitative effects of orthography also generalize to different types of L1 and L2.

Finally, a limitation is that the number of targets was low (12 words) but also that students found the word learning task difficult. Nevertheless, given that there was growth and that students successfully learned the spelling when orthography was present, it is clear that learning did take place. We looked at translation learning in a controlled experimental design, which is similar to how words are learned in flash card application (Nakata, 2011). However, it would be of interest to study orthographic facilitation in a more informal learning context, such as learning words from a text or conversation. Interestingly, one of the few studies in a more informal learning setting by Mitterer and McQueen (2009) found similar results: students' L2 pronunciations and spoken word recognition improved after watching TV-programs with L2 speech with L2 subtitles. This indicates that the advantage of orthography for learning pronunciations is not limited to controlled experiments. Additionally, it would be of interest to study the role of orthographic facilitation in vocabulary

growth spanning a larger period of time than the learning setting of the current experiment.

Conclusion

To our knowledge, this is the first study to examine the influence of the availability of orthography on translation learning. We found that availability of orthography had a clear positive effect on learning to spell and read aloud (pronounce) new L2 words. In contrast, the effects of orthography on learning the translations of these words were small and dependent on different factors. We found an effect on learning translations for words whose orthography was easy to map on the phonology (consistent words); in turn, consistency mainly affected translation when the response also required the pronunciation of the word. To sum up, we find some support that orthography also seems to affect learning translations, but not in all cases. The best-fitting interpretation is that availability of orthography mainly improves the acquisition of pronunciations and not their meaning.

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Appendix

See Table 4.

Table 4 Word characteristics for consistent and inconsistent words in experiment 2

Word	Dutch translation	Inconsistent graphemes[a]	Frequency per million	English AoA	Dutch AoA
Inconsistent					
Aerie	nest	<ae>	0.04	13.00	5.94
Budgie	parkiet	<dg> < ie>	0.04	12.90	6.93
Furrow	rimpel	<ow>	0.10	13.00	10.13
Quaint	vreemd	<uai>	0.12	12.79	7.03
Haughty	arrogant	<aught>	0.18	12.93	10.59
Ulcer	zweer	<c>	0.14	12.90	8.59
Consistent					
Prudent	voorzichtig	–	0.10	12.88	7.09
Lilt	wijsje	–	0.29	12.76	8.17
Humdrum	alledaags	–	0.02	12.89	9.17
Froth	schuim	–	0.41	12.78	6.53
Tempest	storm	–	0.04	12.88	6.46
Pith	kern	–	1.22	12.83	9.93

[a]Based on Van Berkel (2006)

References

Barcroft, J. (2004). Second language vocabulary acquisition: A lexical input processing approach. *Foreign Language Annals, 37*(2), 200–208. https://doi.org/10.1111/j.1944-9720.2004.tb02193.x.

Brysbaert, M., Stevens, M., De Deyne, S., Voorspoels, W., & Storms, G. (2014). Norms of age of acquisition and concreteness for 30,000 Dutch words. *Acta Psychologica, 150,* 80–84. https://doi.org/10.1016/j.actpsy.2014.04.010.

Chambré, S. J., Ehri, L. C., & Ness, M. (2017). Orthographic facilitation of first graders' vocabulary learning: Does directing attention to print enhance the effect? *Reading and Writing: An Interdisciplinary Journal, 30,* 1137–1156. https://doi.org/10.1007/s11145-016-9715-z.

Cunningham, A. E., Perry, K. E., Stanovich, K. E., & Share, D. L. (2002). Orthographic learning during reading: Examining the role of self-teaching. *Journal of Experimental Child Psychology, 82*(3), 185–199. https://doi.org/10.1016/S0022-0965(02)00008-5.

De Groot, A. M. B., Dannenburg, L., & Van Hell, J. G. (1994). Forward and backward word translation by bilinguals. *Journal of Memory and Language, 33,* 600–629. https://doi.org/10.1006/jmla.1994.1029.

de Jong, P. F., Bitter, D. J. L., van Setten, M., & Marinus, E. (2009). Does phonological recoding occur during silent reading, and is it necessary for orthographic learning? *Journal of Experimental Child Psychology, 104*(3), 267–282. https://doi.org/10.1016/j.jecp.2009.06.002.

De Jong, P. F., & Share, D. L. (2007). Orthographic learning during oral and silent reading. *Scientific Studies of Reading, 11*(1), 55–71. https://doi.org/10.1207/s1532799xssr1101_4.

Ehri, L. C. (2014). Orthographic mapping in the acquisition of sight word reading, spelling memory, and vocabulary learning. *Scientific Studies of Reading, 18*(1), 5–21. https://doi.org/10.1080/10888438.2013.819356.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. London: Sage Publications.

Figueredo, L. (2006). Using the known to chart the unknown: A review of first-language influence on the development of English-as-a-second-language spelling skill. *Reading and Writing: An Interdisciplinary Journal, 19,* 873–905. https://doi.org/10.1007/s11145-006-9014-1.

Geva, E., & Siegel, L. S. (2000). Orthographic and cognitive factors in the concurrent development of basic reading skills in two languages. *Reading and Writing: An Interdisciplinary Journal, 12,* 1–30.

Harm, M. W., & Seidenberg, M. S. (2004). Computing the meanings of words in reading: Cooperative division of labor between visual and phonological processes. *Psychological Review, 111,* 662–720. https://doi.org/10.1037/0033-295X.111.3.662.

Hayward, D. V., Stewart, G. E., Phillips, L. M., Norris, S. P., & Lovell, M. A. (2008). *At-a-glance test review: Test of word reading efficiency (TOWRE). Language, Phonological Awareness, and Reading Test Directory* (pp. 1–4). Edmonton, AB: Canadian Centre for Research on Literacy.

Hu, C. F. (2008). Use orthography in L2 auditory word learning: Who benefits? *Reading and Writing: An Interdisciplinary Journal, 21,* 823–841. https://doi.org/10.1007/s11145-007-9094-6.

Hulstijn, J. H. (2001). Intentional and incidental second language vocabulary learning: A reappraisal of elaboration, rehearsal and automaticity. In P. Robinson (Ed.), *Cognition and second language instruction* (pp. 258–286). Cambridge: Cambridge University Press.

Jiang, N. (2000). Lexical representation and development in a second language. *Applied Linguistics, 21*(1), 47–77. https://doi.org/10.1093/applin/21.1.47.

Jubenville, K., Sénéchal, M., & Malette, M. (2014). The moderating effect of orthographic consistency on oral vocabulary learning in monolingual and bilingual children. *Journal of Experimental Child Psychology, 126,* 245–263. https://doi.org/10.1016/j.jecp.2014.05.002.

Koda, K. (2007). Reading and language learning: Crosslinguistic constraints on second language reading development. *Language Learning, 57,* 1–44. https://doi.org/10.1111/0023-8333.101997010-i1.

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavior Research Methods, 44,* 978–990. https://doi.org/10.3758/s13428-012-0210-4.

Li, H., Zhang, J., Ehri, L., Chen, Y., Ruan, X., & Dong, Q. (2016). The role of orthography in oral vocabulary learning in Chinese children. *Reading and Writing: An Interdisciplinary Journal, 29,* 1363–1381. https://doi.org/10.1007/s11145-016-9641-0.

Litt, R. A., de Jong, P. F., van Bergen, E., & Nation, K. (2013). Dissociating crossmodal and verbal demands in paired associate learning (PAL): What drives the PAL-reading relationship? *Journal of Experimental Child Psychology, 115*(1), 137–149. https://doi.org/10.1016/j.jecp.2012.11.012.

Miles, K. P., Ehri, L. C., & Lauterbach, M. D. (2016). Mnemonic value of orthography for vocabulary learning in monolinguals and language minority English-speaking college students. *Journal of College Reading and Learning, 46*(2), 99–112. https://doi.org/10.1080/10790195.2015.1125818.

Mitterer, H., & McQueen, J. M. (2009). Foreign subtitles help but native-language subtitles harm foreign speech perception. *PLoS ONE, 4*(11), e7785. https://doi.org/10.1371/journal.pone.0007785.

Mondria, J.-A., & Wiersma, B. (2004). Receptive, productive, and receptive+productive L2 vocabulary learning: What difference does it make. *Vocabulary in a Second Language: Selection, Acquisition, and Testing, 15*(1), 79–100.

Nakata, T. (2011). Computer-assisted second language vocabulary learning in a paired-associate paradigm: A critical investigation of flashcard software. *Computer Assisted Language Learning, 24*(1), 17–38. https://doi.org/10.1080/09588221.2010.520675.

Pasquarella, A., Chen, X., Gottardo, A., & Geva, E. (2015). Cross-language transfer of word reading accuracy and word reading fluency in Spanish-English and Chinese-English bilinguals: Script-universal and script-specific processes. *Journal of Educational Psychology, 107*(1), 96.

Perfetti, C. (2007). Reading ability: Lexical quality to comprehension. *Scientific Studies of Reading, 11,* 357–383. https://doi.org/10.1080/10888430701530730.

Perfetti, C. A., & Hart, L. (2002). The lexical quality hypothesis. *Precursors of Functional Literacy, 11*(4), 67–86. https://doi.org/10.1080/10888430701530730.

Ricketts, J., Bishop, D. V. M., & Nation, K. (2009). Orthographic facilitation in oral vocabulary acquisition. *Quarterly Journal of Experimental Psychology, 62,* 1948–1966. https://doi.org/10.1080/17470210802696104.

Rosenthal, J., & Ehri, L. C. (2008). The mnemonic value of orthography for vocabulary learning. *Journal of Educational Psychology, 100*(1), 175–191. https://doi.org/10.1037/0022-0663.100.1.175.

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition, 55*(2), 151–218. https://doi.org/10.1016/0010-0277(94)00645-2.

Share, D. L. (1999). Phonological recoding and orthographic learning: A direct test of the self-teaching hypothesis. *Journal of Experimental Child Psychology, 72*(2), 95–129. https://doi.org/10.1006/jecp.1998.2481.

Steinel, M. P., Hulstijn, J. H., & Steinel, W. (2007). Second language idiom learning in a paired-associate paradigm: Effects of direction of learning, direction of testing, idiom imageability, and idiom transparency. *Studies in Second Language Acquisition, 29*(03), 449–484. https://doi.org/10.1017/S0272263107070271.

Thijs, A. M., Trimbos, B., Tuin, D., Bodde, M., & De Graaff, R. (2011). *Engels in het basisonderwijs: vakdossier [English in primary education: Subject file]*. Enschede: SLO.

Torgesen, J. K. (2012). *TOWRE 2: Test of word reading efficiency*. Pro-ed Austin, TX: In Test of word reading efficiency.

van Berkel, A. J. (2006). *Orthodidactiek van het Engels [Orthodidactics of English]*. Bussum: Coutinho.

Wang, H. C., Castles, A., & Nickels, L. (2012). Word regularity affects orthographic learning. *Quarterly Journal of Experimental Psychology, 65,* 856–864. https://doi.org/10.1080/17470218.2012.672996.

Wang, M., Perfetti, C. A., & Liu, Y. (2003). Alphabetic readers quickly acquire orthographic structure in learning to read Chinese. *Scientific Studies of Reading, 7*(2), 183–208.

Webb, S. (2009). The effects of receptive and productive learning of word pairs on vocabulary knowledge. *RELC Journal, 40,* 360–376. https://doi.org/10.1177/0033688209343854.

Wechsler, D. (2008). *Wechsler adult intelligence scale—Fourth edition (WAIS-IV)*. San Antonio, TX: The Psychological Corporation.

Wilkins, D. (1972). *Linguistics in language teaching*. London: Edward Arnold.

Zeguers, M. H. T., van den Boer, M., Snellings, P., & de Jong, P. F. (2018). Universal and language-specific predictors of early word reading in a foreign language: An analysis of the skills that underlie reading acquisition in three different orthographies. *Developmental Psychology, 54,* 2274–2290. https://doi.org/10.1037/dev0000606.

Zhang, J., Li, H., Liu, Y., & Chen, Y. (2020). Orthographic facilitation in oral vocabulary learning: Effects of language backgrounds and orthographic type. *Reading and Writing: An Interdisciplinary Journal, 33,* 187–206. https://doi.org/10.1007/s11145-019-09955-6.