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Learning new words by reading books: Does semantic information help?

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Abstract

Encountering new words during reading is a common experience of any adult reader and it constitutes an important source of word knowledge. Despite the ubiquity of this phenomenon, studies remain scarce in adults. Here, we addressed new word acquisition in adults using a natural contextual exposure, and we focused on the influence of context informativeness on orthographic learning. Indeed, previous studies suggest that the availability of semantic information plays an important role in orthographic learning in adults, but no such advantage was found in children. We hypothesised that this discrepancy comes from the fact that new word learning was examined almost only through artificial settings in adults. On the contrary, in the present study, adult participants were exposed to new words by reading a book. Half of the new words were embedded in informative contexts (easy to infer new word meaning) and the other half in less informative contexts. Both recall and recognition tasks were used to assess orthographic and semantic learning. The results showed efficient learning of the orthographic form and no reliable effect of the context informativeness. Regarding semantic learning, we found that if a word was correctly spelled, its definition was more likely to be retrieved. This shows that the orthographic and semantic dimensions of a word co-occurring in context are likely to influence each other during lexical acquisition. More generally, the present experiment showed that using an ecological learning design is essential to understand the mechanism of new word learning.

Keywords

Reading; incidental vocabulary acquisition; novel word learning

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Introduction

Encountering new words during reading is a common experience of any adult reader and it can be seen as an opportunity to increase the vocabulary size. The efficient storage of word knowledge is a rare cognitive domain resistant to progressive decline with ageing, and vocabulary increases continuously throughout the lifespan (e.g., Keuleers et al., 2015; McCabe et al., 2010; Park et al., 2002). Although one can use a dictionary to look for information about an unknown word, word acquisition usually takes place incidentally, by mere exposure to new words embedded in sentences (e.g., Nagy et al., 1987). Accordingly, studies using eye-tracking techniques reported that when reading meaningful sentences, adults spent more time on unfamiliar than on familiar words (Williams & Morris, 2004), and when new words are encountered repeatedly, the fixation duration decreases with every occurrence (Joseph et al., 2014). Despite the fact that incidental word learning during text reading may constitute an important source of word knowledge, studies tackling this issue in adults remain scarce. Here, we addressed new word acquisition in adults using a natural contextual exposure, namely fictional story reading.

Novel word learning in text reading

The first experimental study investigating incidental vocabulary acquisition during long narrative text reading was reported by Saragi et al. (1978). Native English-speaking

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participants were asked to read Anthony Burgess's novel *A Clockwork orange* containing a large number of Russian-based slang words ($N=241$) occurring between 1 and 209 times in the book (the total text length was about 60,000 words). Several days after reading, a surprise four-alternative choice recognition test on meaning knowledge of a sample of 90 new words was administrated. Participants recognised word meaning for 76% of the items, and accuracy was correlated with the number of word occurrences ($r=.34$). According to the authors, this finding shows that repeated exposure facilitates learning, but the moderate correlation also suggests that other factors may play a role, such as the meaningfulness of contexts in which new words are embedded.

Subsequently, several studies addressed the issue of word learning during narrative text reading and re-examined the factors studied by Saragi et al. (1978). In an ERP study, Batterink and Neville (2011) directly investigated the role of context meaningfulness. Participants read stories (4,500 words) with 20 embedded novel words. Half of these words appeared in meaningful contexts (consistent meaning at each occurrence) and the other half in less meaningful contexts (variable meaning at each occurrence). The ERP results indicated a reduction of the N400 component across the subsequent occurrences of new words. This reduction was more important for new words embedded in meaningful than in less meaningful contexts, potentially ensuing from semantic integration of the new words encountered in meaningful contexts. After the reading session, the participants performed a meaning recognition task for words occurring in meaningful contexts, and the rate of correct responses (~72%) was similar to the one obtained in Saragi et al. (1978).

The effect of the number of occurrences in new word learning was investigated by Hulme et al. (2019). Participants read a short story (about 2,350 words), with embedded new words presented two, four, six, or eight times. Word learning was assessed immediately after exposure and 1 week later with word forms used as cues in a meaning recall task. The performance increased with the number of occurrences, in the immediate and the delayed test. In addition, the participants recalled the correct meanings of 40% of the words occurring only twice, revealing the importance of initial encounters for learning.

Only a few studies used narrative texts to investigate first language (L1) novel word learning in adults, but this method was used many times in second language (L2) word learning (e.g., Bordag et al., 2015; Elgort & Warren, 2014; Godfroid et al., 2018; Horst et al., 1998; Laufer & Shmueli, 1997; Pellicer-Sánchez & Schmitt, 2010; Pulido, 2007; Waring & Takaki, 2003). Such studies showed that the number of occurrences was an important predictor of word acquisition (e.g., Godfroid et al., 2018). In addition, the length of narrative texts could influence word learning outcomes. Indeed, Laufer and Shmueli (1997) found that L2 participants who learned words embedded in simple sentences recognised more word meanings during the subsequent four-alternative forced-choice task than participants who learned words embedded in a longer text (~600 words).

Surprisingly, all the above-mentioned studies investigating word learning in adults mainly focused on meaning acquisition (irrespective of the L1/L2 language background). However, when exposed to an unknown word, readers need to process both its form and its semantic content. Furthermore, according to the lexical quality hypothesis, readers have to build high-quality interconnected orthographic and semantic representations for any new item, so that they can easily access the corresponding meaning from the orthographic input in future encounters (e.g., Perfetti, 2007; Perfetti & Hart, 2002). It is therefore essential to understand what the mechanisms of orthographic word learning are. It is also important to understand how the orthographic and semantic features of words influence each other during lexical acquisition.

Orthographic learning and the impact of semantics

Historically, orthographic learning has been largely investigated in children. Share (1995, 1999) proposed the self-teaching hypothesis to explain how autonomous reading is a central element of orthographic learning in developing readers. According to this hypothesis, each contextual encounter with a word constitutes an opportunity to decode its orthographic form and to memorise it. Phonological decoding is assumed to be a central mechanism making it possible to draw the reader's attention to the specific letter combinations of new visual stimuli. Hence, any successful decoding attempt gives the opportunity to the reader to build up a precise orthographic representation and to interconnect this dawning representation with the semantic and phonological contents already stored in long-term memory. Accordingly, children's decoding skills predict orthographic learning outcomes (e.g., Cunningham, 2006; Cunningham et al., 2002; Nation et al., 2007), although they account for a small portion of variance (Nation et al., 2007). The self-teaching hypothesis has given rise to a rich set of studies in children investigating the efficiency and limits of orthographic learning based on autonomous text reading. Especially, studies showed that orthographic learning takes place during both reading aloud (e.g., Cunningham et al., 2002; Share, 1999) and silent reading (e.g., Bowey & Miller, 2007) of short stories (100–200 words). Furthermore, orthographic learning is remarkably efficient since a single encounter can be enough to establish precise and long-lasting orthographic representations (e.g., Nation et al., 2007; Share, 2004), even if any additional experience with the visual stimulus enhanced orthographic learning (Nation et al., 2007).

In adults, orthographic learning has been principally investigated through more artificial lab-oriented settings. To expose participants, tasks such as single word reading aloud (Maloney et al., 2009), repetitive typing (Bowers et al., 2005), consonant group counting (Chalmers & Burt, 2008), progressive demasking-like task (Salasoo et al., 1985) or picture-word association tasks (Angwin et al., 2014; Qiao & Forster, 2013; Suárez-Coalla & Cuetos, 2017) were used. In such tasks, words are mostly presented in isolation, without any contextual support (e.g., Bowers et al., 2005; Chaves et al., 2020; Maloney et al., 2009; Qiao et al., 2009). This places participants in a very different situation compared with novel word exposure through text reading, which is used in children or in adults to investigate meaning acquisition (e.g., Batterink & Neville, 2011; Hulme et al., 2019; Saragi et al., 1978). As in studies using more ecological designs in children, the results showed that limited exposure to new words leads to orthographic learning (e.g., Rueckl & Olds, 1993) with learning effects persisting over time (e.g., Salasoo et al., 1985). However, some divergent results were obtained in studies investigating how the semantic content associated with new words influences orthographic learning. Studies with lab-based settings in adults reported that the provision of semantic information seems to be beneficial to orthographic learning (e.g., Angwin et al., 2014; Chalmers & Burt, 2008; Rueckl & Olds, 1993; Suárez-Coalla & Cuetos, 2017) contrary to what was reported in children with natural reading experiments (e.g., Nation et al., 2007; Ricketts et al., 2011). For example, Chalmers and Burt (2008) asked adult participants to count the consonant groups in pseudowords presented without context to create a situation of new word exposure. Pseudowords were presented according to four conditions: in isolation (without semantic and phonological information), with semantic information only, with phonological information only or with both semantic and phonological information. The performance in an orthographic recognition task was higher when the semantic and/or phonological information was provided during learning than when words were presented without information. This suggests that orthographic learning benefits from the presence of semantic or phonological information. Another example is an ERP study, in which Angwin et al. (2014) specifically investigated the role of semantic information on orthographic word learning. Across four sessions, the adult participants learned new words used to refer to different aliens. Each time, the words were presented with a picture of an alien accompanied with either two adjectives describing the characteristics of the alien or two proper names. After each learning session, the participants completed a recognition and recall test. Although there was no clear difference between the two conditions in the recall task, a clear advantage for words presented with two adjectives describing the aliens was found in the recognition task. This advantage was the strongest after the first learning session and gradually decreased and disappeared after the fourth learning session. This suggests that the availability of semantic information may play a role in the initial stages of orthographic word learning.

Taken together, these studies suggest that the availability of semantic information plays an important role in orthographic learning in adults. In children, data are less clear and different patterns were obtained. For example, Wang et al. (2011) obtained a beneficial effect of the semantic context, specifically for words with irregular orthography. This effect was present in an orthographic decision task but not in spelling and in an orthographic choice task. Consistently, Ouellette (2010) reported a beneficial effect of semantic information in an artificial learning setting during which children were asked to process pseudowords in isolation, with semantic information provided orally. A detrimental effect has also sometimes been reported. For example, Landi et al. (2006) showed that post-test reading performance was lower for pseudowords exposed in the context of a meaningful sentence when compared with performance after exposure to words in isolation. However, other studies did not find any advantage of semantic information availability in children (Nation et al., 2007; Ricketts et al., 2011). For example, Ricketts et al. (2011) asked 8-year-old children to read aloud short stories with new words while the context meaningfulness was manipulated. Half of the new words were inserted in contexts containing a clear cue about its meaning, whereas the other half provided ambiguous cues. The context did not affect the performance in orthographic learning assessed with an orthographic recognition task and a spelling-to-dictation task.

Overall, the absence of impact of semantic information on orthographic learning in children diverges from what is observed in adults. This discrepancy could be partly explained by the fact that the age ranges of children included in previous studies corresponded to a period of intense orthographic lexical growth, possibly leading to higher reliance on visuo-orthographic analysis at first than on semantic content when encountering new stimuli. Hence, the weight of different determinants on word learning (orthography, semantics) could be different in children and in adults. However, the discrepancy between adults and children may also lie in the method used, exposure to new words being usually carried out through texts in children whereas more artificial learning paradigms are used in adults. It is therefore possible that the conflicting results simply reflect the underlying methodological differences. In artificial learning settings, given that the to-be-learned words appear in isolation, the amount of resources available during encoding could be optimal to bind orthographic and semantic information. On the contrary, in the case of contextual exposure, some resources need to be allocated to text comprehension in addition to novel word processing, so that the link between orthography and the semantics could be weakly established. Finally, in contextual exposure, the learning goals are less explicit, minimising possible strategic effects.

The present study

In the present study, we investigated the role of semantic information on orthographic learning in adults with a natural reading design. Natural text reading was rarely used in L1 studies with adults, and if so, only the meaning acquisition of new words was assessed. Here, we examined both semantic and orthographic learning. This has enabled us to fill the current knowledge gap in adults and to obtain a point of comparison with previous studies on orthographic learning in children, which used more ecological learning designs. Moreover, the joint interest for orthographic and semantic learning made it possible to closely examine how the orthographic and semantic features of words develop and influence each other during lexical acquisition. As predicted by the lexical quality hypothesis, both dimensions are necessary for a coherent and reliable retrieval (e.g., Perfetti, 2007; Perfetti & Hart, 2002).

We asked native French-speaking adults to read a long narrative text with embedded pseudowords used as novel words. We operationalised the availability of semantic information as context informativeness. Half of the pseudowords were inserted in clearly informative contexts (enabling readers to easily infer the new word meaning), and the other half in less informative contexts (making it hard to grasp a precise meaning). We hypothesised that if context informativeness enhances orthographic learning, we should observe a higher performance in tasks assessing learning (recall and recognition) for new words in more informative contexts than for new words in less informative contexts.

Method

Pilot study

Before running the experiment, we carried out a pilot study to define which parameters should be used. A detailed presentation of this pilot study is available at https://osf.io/rxpsh/ and here, we provide only basic information to justify the parameters used in the main experiment. In total, 33 volunteers completed the pilot study. We created 96 pseudowords and inserted half of them in 12 short science-fiction stories by Ray Bradbury. We used the other half as control items. In each story, four pseudowords were standing for plausible new words. We inserted two of them in contexts that were highly informative about their meaning and two of them in contexts that were not informative. Each pseudoword occurred four times in the story. We gathered the 12 stories and print them as a book. The participants received the book in the morning of a given day and were instructed to read it entirely before going to sleep. They were not informed about the presence of new words. The following day, they completed a spelling-to-dictation task (orthographic learning assessment) and a 6-alternative force choice task (semantic learning assessment).

The results showed that this procedure enabled readers to learn new words. Indeed, after exposure to the narrative story, the participants spelled correctly about 20% of the new words as compared with 10% of the control pseudowords. Contrary to our hypothesis, the participants spelled better the new words encountered in less informative contexts (25%) than in highly informative contexts (16%). We reasoned that this counterintuitive result may be due to item-specific confounds, such as the easiness with which a new word could be correctly spelled despite a lack of exposure. To eliminate this possibility, we decided to use a counterbalanced design in the following experiment (i.e., each of the to-be-learned pseudoword was presented in a less informative context in half of the participants, and in a more informative context in the other half of the participants). In addition, we noticed that the exposure conditions were not ideal since 11 out of 44 initial participants gave up the experiment, and some of the remaining 33 participants found it challenging to read the whole book in a single day. Hence, we gave 1 week to the participants to read the book in the experiment instead of 1 day. We also included two additional occurrences per pseudoword to limit forgetting (leading to six occurrences per word in total). Finally, we decided to add two more tasks, namely an orthographic 6-AFC and a semantic definition task, to get both recall and recognition tasks for each dimension. The objective was to balance the difficulty of tasks assessing orthographic and semantic learning, and to properly evaluate a possible interrelation between the two dimensions (Eskenazi et al., 2018; Perfetti, 2007; Perfetti & Hart, 2002).

Participants

A sample of 48 volunteers (39 women) completed the experiment. They were all adult native French speakers (18–31 years) without history of reading disorders and declared having normal or corrected-to-normal vision. All participants were recruited among university students from different fields (psychology, law, sciences) and received 40€ for their participation.

Material

We used 96 pseudowords, selected from a larger pool of 178 pseudowords devised by ourselves from French hermit words (i.e., words without any orthographic neighbour, e.g., *hamac*) by substituting one letter for another (e.g., *hamal*). All pseudowords were legal in French

Table 1. Characteristics of items used to create different sets of pseudowords used as "new words" (mean values and standard deviations—in brackets) in the experiment.

	Non-exposed pseudowords	Exposed pseudowords	*Cohen's d*	Pseudoword Set 1	Pseudoword Set 2	*Cohen's d*
	M (*SD*)	*M* (*SD*)		*M* (*SD*)	*M* (*SD*)	
Base-words						
Number of letters	7.00 (0.97)	6.96 (0.99)	0.04	6.96 (0.99)	6.96 (0.99)	0.00
Number of syllables	2.17 (0.35)	2.10 (0.37)	0.17	2.12 (0.34)	2.08 (0.41)	0.11
Number of morphemes	1.06 (0.24)	1.04 (0.20)	0.09	1.04 (0.20)	1.04 (0.20)	0.00
OLD20[a]	2.41 (0.35)	2.41 (0.33)	0.02	2.42 (0.29)	2.41 (0.38)	0.05
Lexical frequency[b]	2.54 (2.44)	2.76 (2.20)	0.09	2.70 (2.10)	2.82 (2.33)	0.06
Summed bigram frequency[c]	16,219 (14,933)	14,836 (12,097)	0.10	15,667 (11,461)	14,006 (12,893)	0.14
Pseudowords						
Number of letters	7.00 (0.97)	6.96 (0.99)	0.04	6.96 (0.99)	6.96 (0.99)	0.00
Summed bigram frequency	14,980 (13,132)	14,918 (12,911)	0.00	17,616 (13,985)	12,220 (11396)	0.42
Spelling pre-test[d]	4.01 (4.51)	3.78 (4.15)	0.05	3.86 (3.70)	3.70 (4.63)	0.04

[a]OLD20: orthographic Levenshtein distance (Yarkoni et al., 2008).
[b]Lexical frequency: frequency count in number of occurrences per million, based on subtitles in Lexique (New et al., 2004).
[c]Summed bigram frequency: token bigram frequencies (subtitles) computed on Lexique 3.80 (New et al., 2004).
[d]The spelling pre-test score corresponds to the percentage of pre-test participants producing the correct spelling collapsed over items in the given set.

orthography. For the purpose of the spelling-to-dictation task, the phonological form of each pseudoword (e.g., /*amal/*) could lead to different spellings (e.g., *hamal, amale, amalle*). To select the final set of 96 pseudowords, another sample of 27 participants (similar characteristics) performed a spelling-to-dictation pre-test with the 178 initial pseudowords. They had to type the pseudowords heard one by one through headphones. Then, we selected only items for which the "correct spelling" (i.e., spelling derived from the corresponding orthographic neighbour, e.g., *hamal*) was rarely produced (by less than 15% participants). We chose this selection criterion to ensure that the correct spelling would not be spontaneously produced by participants, that is, without any exposure to those "new words" embedded in stories. In addition, pseudowords exhibiting a transparent morphological feature with the base-word were excluded. Half of the selected pseudowords (48) was embedded in stories so that the participants were incidentally exposed to them whereas the other half was a control set, non-exposed to the participants. The 48 exposed pseudowords were additionally divided in two subsets of 24 pseudowords. These two sets of pseudowords were presented in stories in highly informative contexts (condition *context+*) or in less informative contexts (condition *context−*). These sets were also counterbalanced, so that half of the participants were exposed to a given pseudoword in highly informative context and the other half of participants saw this pseudoword in a less informative context. As presented in Table 1, the base-words used to create the pseudoword sets were matched on the number of letters, syllables and morphemes, orthographic similarity, lexical frequency and bigram frequency. The pseudoword sets were matched on the number of letters, bigram frequency, and the spelling pre-test success. A list of the 96 pseudowords used is presented in the online Supplementary Material.

The 48 exposed pseudowords were inserted in 12 short stories by Ray Bradbury that were translated into French (about 5,000 words each). In each story, new sentences were created to introduce four pseudowords standing for plausible new words. Two pseudowords were embedded in contexts that were informative about their meaning (context+), two of them in contexts that were not (context−). An example is given in Table 2. The text extracts for each new word occurrence are available at https://osf.io/rxpsh/.

Each pseudoword was repeated six times within a story. The meaning of the 24 pseudowords inserted in highly informative contexts systematically referred to concrete objects belonging to a common semantic category among 12 (e.g., animal, tree, tool; see Léger et al., 2008). Each semantic category was used for two different context+ pseudowords in two different stories but the semantic context of each pseudoword included distinct features allowing one to clearly distinguish between the two items (e.g., "a night bird with very large wings, "a scavenger bird living in Africa"). Finally, we also carried out a pilot to associate the exposed pseudowords to the semantic categories (another sample of 35 participants). If more than 11% of participants (range: 0%–11% of participants) selected a given category for a pseudoword, this semantic category was not used for that specific pseudoword.

We gathered 12 stories to print them as a book. Twenty-four different versions of the book were created to counterbalance the order of the stories across participants. The total length of the text read by the participants was 62,384

Table 2. Examples of highly and less informative contexts (in French and English).

	Example of the insertion context
Highly informative context (context +)	*. . . Puis les bruits: le piétinement éloigné d'une antilope sur l'herbe, le froissement sec des ailes d'une hapnose. Une ombre passa dans le ciel. Elle battit au-dessus du visage levé de George Hadley, qui transpirait.—Quels oiseaux dégoûtants! Entendit-il dire à sa femme.* *. . . And now the sounds: the thump of distant antelope feet on grassy sod, the papery rustling of the wings of a hapnose. A shadow passed through the sky. The shadow flickered on George Hadley's upturned, sweating face. "Filthy birds," he heard his wife say.*
Less informative context (context -)	*. . . Il y avait une belle forêt verte, une rivière ravissante, des scitres, des montagnes violettes, des chants, et Rima la fée, adorable et mystérieuse, qui se cachait dans les arbres parmi des vols colorés de papillons, nonchalante, avec sa longue chevelure. La brousse africaine avait disparu* *. . . There was a green, lovely forest, a lovely river, scitres, a purple mountain, high voices singing, and Rima, lovely and mysterious, lurking in the trees with colorful flights of butterflies, like animated bouquets, lingering in her long hair. The African veldtland was gone.*

Note. The exposed pseudowords are underlined here but they were not highlighted in the book received by the participants.

words with one pseudoword occurring each 217 words on average.

Procedure

On the first day, the participants received the book with the instruction to read it at home during the upcoming week at the rate of two stories per day, without consulting any external sources. They were told that the experiment aimed at evaluating their overall reading comprehension and were not informed about the new words in the text.

They also received a form to fill in during the reading to collect information about reading times and the reading context for each story (i.e., day of reading, breaks, level of concentration, appreciation of the story). Participants also completed three tests measuring their pre-existing orthographic and vocabulary skills. To assess their general orthographic knowledge, we used the BOQS test (Chetail et al., 2019) that consists of a French standardised paper and pencil spelling-to-dictation task. We evaluated the vocabulary knowledge with the Mill Hill (Deltour, 1993) and the Binois Pichot (Binois & Pichot, 1959) vocabulary tests, each consisting of selecting the correct synonym for a target word from a list of six alternatives provided.

One week later, the participants came back to the laboratory for the testing session. A spelling-to-dictation task and six-alternative forced choice task (6-AFC) evaluated orthographic learning. In the spelling-to-dictation, the participants had to type down the exposed and non-exposed pseudowords presented in isolation, one at a time, through headphones. In the 6-AFC, they were asked to identify the correct orthographic form (i.e., the orthographic form encountered during reading) between five orthographically and/or phonologically highly similar foils (e.g., *hamal, amale, hamal, ahmal, hamale, ahmale*). After each response, the participants evaluated their confidence about the response by choosing between three possibilities (*I responded by chance*; *I am unsure about my answer*; *I am quite sure about my answer*).

A definition task and a 6-AFC (with the same confidence judgement scale described above) evaluated meaning learning. In the definition task, the participants typed a brief definition of the word, and in the 6-AFC, they had to choose the correct word meaning among six different definitions. In each trial, three of the definitions corresponded to the meaning of to be learned items (of which one was the correct answer for the target item of the trial), and three definitions were new non-exposed meanings. These new distractor definitions were from the same semantic categories as the exposed items, but they included features absent in stories (e.g., "a bird with red feathers imitating the song of other birds"). Each definition appeared three times (i.e., for the exposed meanings, once as a target and twice as a distractor for other pseudowords). Note that it was not possible to assess semantic learning for the exposed new words in less informative contexts because these contexts did not provide enough semantic features (see examples in Table 2). Therefore, the meaning acquisition was evaluated only for pseudowords exposed in context+ condition. All tasks were conducted with the PsychoPy software (version 1.90.1, Peirce, 2007).[1] After the experiment, we briefly questioned the participants about their reading experience during the experiment.

Results

All analyses were run with the R software (version 4.0.2, R Core Team, 2020) under the RStudio environment (RStudio Team, 2020). The generalised linear mixed effect models were computed with the use of lme4 package (version 1.1-23, Bates et al., 2015) and sjPlot (version 2.8.7, Lüdecke, 2021). All the raw data and scripts for analyses are

Table 3. Descriptive statistics (mean, standard deviations, minimal and maximal values) in all reported tasks.

		M (%)	SD (%)	Min (%)	Max (%)
Comprehension task		85	11	63	100
Spelling-to-dictation	*Non-exposed*	7	5	0	25
	Exposed	20	12	2	48
	Context+	20	13	0	54
	Context−	20	14	0	63
Orthographic 6-AFC	*Context+*	47	14	21	75
	Context−	48	13	21	83
Definition task (Context+)		9	9	0	42
Semantic 6-AFC (Context+)		34	11	8	58
BOQS		67	18	28	100
Vocabulary		67	7	49	78

6-AFC: six-alternative forced choice task.

available at https://osf.io/rxpsh/. The descriptive statistics of all tasks are summarised in Table 3.

Comprehension task

On average, participants responded correctly to 85% of questions about the content of stories they have read (*SD*=11%, range: 63%–100%).

Spelling-to-dictation task

Two separate generalised linear mixed effect models were computed to explain the performance in the spelling-to-dictation task, with exposure (exposed/non-exposed pseudowords) and context informativeness (context+/context−) used as fixed factors (this was done because the context informativeness was not meaningful for non-exposed items). We added the percentage of participants who correctly spelled a given item in the independent pre-test as a by-item covariate in the model comparing the exposed and non-exposed pseudowords. The maximal random structure of these models included the random intercepts and random slopes (by-participant: both models, by-item: model using context informativeness as a fixed factor). We simplified overfitting or non-converging models with the maximal random structure by removing the random effects associated with the lowest part of the variance. A summary of these models is presented in Table 4.

The effect of the exposure was significant, $\chi^2(1)=53.43$, $p<.001$, odds ratio=2.15, 95% CI = [1.75, 2.64], with higher percentage of correct spellings for exposed pseudowords (*M*=20% *SD*=12%, range: 2%–48%) than for non-exposed pseudowords (*M*=7%, *SD*=5%, range: 0%–25%). The effect of the spelling pre-test was also significant: $\chi^2(1)=27.50$, $p<.001$, odds ratio=1.13, 95% CI = [1.08, 1.18]. There was no effect of context informativeness, $\chi^2(1)=0.04$, $p=.85$, odds ratio=1.02, 95% CI = [0.86, 1.20], as the participants spelled equally well the context+ pseudowords (*M*=20%, *SD*=13%, range: 0%–54%) as the context− pseudowords (*M*=20%, *SD*=14%, range: 0%–63%). The summary of participants' performance in the spelling-to-dictation task is shown in Figure 1.

Orthographic recognition: 6-AFC

The overall performance (*M*=47%, *SD*=12%, range: 29%–79%) was significantly above chance level, $t(47)=18.23$, $p<.001$, 95% CI = [44.00; 50.79], and strongly correlated with the performance in the spelling test, $r=0.87$, $p<.001$, 95% CI = [0.77; 0.92]. We computed a linear mixed effect model to assess the effect of context informativeness. In the orthographic recognition task, there was no effect of the context informativeness, $\chi^2(1)=0.12$, $p=.73$, odds ratio=1.02, 95% CI = [0.93, 1.11], with similar performances in both conditions (context+: *M*=47%, *SD*=14%, range: 21%–75%, context−: *M*=48%, *SD*=13%, range: 21%–83%).

Definition task

In the definition task, the response was evaluated as correct if the precise definition (e.g., "night bird"), precise category (e.g., "bird") or clearly synonymic definition (e.g., "sort of owl") was given. In all other cases, the response was evaluated as incorrect. The scores were rather low, with 9% of correctly recalled meanings on average (*SD*=9%, range: 0%–42%), and with an overall floor effect (75% of all participants could recall between 0 and 2 items). A generalised linear mixed effect model was computed to evaluate the effect of orthographic learning on semantic learning with the individual by-item spelling success used as a fixed effect in the model. The spelling success predicted the success in the definition task, $\chi^2(1)=25.89$, $p<.001$, odds ratio=3.69, 95% CI = [2.23, 6.11]. Table 5 presents the contingency table of this effect.

Table 4. Summary of the fixed effects evaluated with generalised linear mixed models for the main analysis.

	Predictor	Odds ratio	95% CI	z	χ^2	p-value
Spelling task						
Exposure	Intercept	0.05	0.04–0.07	−16.29	265.38	<.001***
	Exposure	2.15	1.75–2.64	7.31	53.43	<.001***
	Pre-Test	1.13	1.08–1.18	5.24	27.50	<.001***
Context informativeness	Intercept	0.17	0.12–0.24	–9.72	94.61	<.001***
	Context	1.02	0.86–1.20	0.19	0.04	.85
Orthographic recognition	Intercept	0.89	0.69–1.15	–0.90	0.81	.37
	Context	1.02	0.93–1.11	0.34	0.12	.73
Definition task	Intercept	0.04	0.02–0.07	−12.45	154.94	<.001***
	Spelling	3.69	2.23–6.11	5.09	25.89	<.001***
Semantic recognition (all responses)	Intercept	0.43	0.34–0.56	–6.38	40.73	<.001***
	Orth. Rec.	1.22	0.93–1.59	1.44	2.07	.15
Semantic recognition ("by chance" responses excluded)	Intercept	0.49	0.35–0.69	–4.16	17.27	<.001***
	Orth. Rec.	1.58	1.11–2.27	2.51	6.30	.01*

CI: confidence interval.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

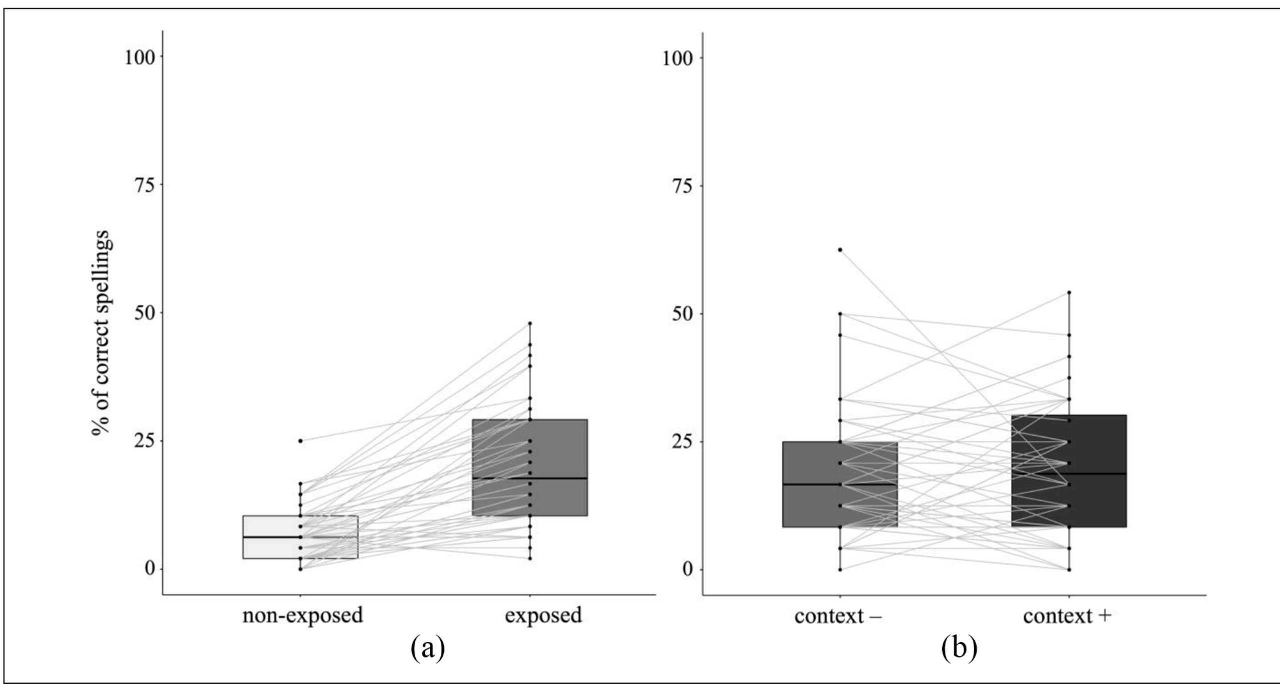

Figure 1. Percentage of correct responses in the spelling-to-dictation task (a) according to exposure and (b) context informativeness (boxplots with grey lines representing individual tendencies).

Meaning recognition: 6-AFC

On average, the participants recognised correctly the meaning of 34% of pseudowords embedded in informative contexts ($SD = 11\%$). There was a high inter-individual variability, with some participants performing very poorly (8%) and others performing well (58%). The scores were significantly above chance level, $t(47) = 10.92$, $p < .001$, 95% CI = [30.55, 36.82], and the participants' performance in the recognition task was correlated with their performance in the definition task, but this correlation was rather modest, $r = .49$, $p < .001$, 95% CI = [0.24, 0.68], probably due to the floor effect in the definition task. We computed the same generalised linear mixed effect model as for the definition task, with the individual by-item success in the orthographic recognition task used as the fixed effect in the model. The orthographic recognition did not predict the success in the meaning recognition task, $\chi^2(1) = 2.07$, $p = .15$, odds

Table 5. Number of correct and incorrect responses in the definition task by the correct and incorrect responses accuracy in the spelling-to-dictation task.

	Incorrect/absent definition	Correct definition	Total
Incorrect spelling	870	57	927
Correct spelling	180	45	225
Total	1,050	102	1,152

Table 6. Number of correct and incorrect responses in the semantic 6-AFC by the number of correct and incorrect responses in the orthographic 6-AFC with and without "by chance" responses excluded.

	Incorrect choice of meaning	Correct choice of meaning	Total
All responses			
Incorrect choice of orthographic form	419	191	610
Correct choice of orthographic form	345	197	542
Total	764	388	1,152
Exclusion of "by chance" responses			
Incorrect choice of orthographic form	202	105	307
Correct choice of orthographic form	182	153	335
Total	384	258	642

ratio = 1.22, 95% CI = [0.93, 1.59]. Note that when "by chance" responses were excluded from both tasks based on confidence judgements (44% of responses excluded), the score of orthographic recognition did predict the success in the meaning recognition task, $\chi^2(1) = 6.30$, $p = .01$, odds ratio = 1.58, 95% CI = [1.11, 2.27]. Table 6 presents the contingency table corresponding to this effect.

Spelling skills (BOQS) and vocabulary knowledge (Mill Hill, Binois Pichot)

We computed the percentage of correct responses for all three tests. Given the correlation between the two scores of vocabulary ($r = .60$, $p < .001$, 95% CI = [0.38, 0.75]), we averaged the scores to obtain a unique indicator of the lexical knowledge for each participant. The mean performance in vocabulary was 67% ($SD = 7$, range: 49%–78%), as well as in BOQS ($M = 67\%$, $SD = 18\%$, range: 28%–100%).[2] We carried out an exploratory analysis about a possible role of pre-existing knowledge on orthographic and semantic learning of new items. We used the same generalised linear mixed effect models as previously, to which we added spelling skills and vocabulary knowledge as by-participant fixed effects. The overfitting and other convergence issues were handled by simplification of the model based on removing the random effect associated with the lowest portion of variance. A summary of these models is presented in Table 7. This exploratory analysis showed that spelling skills significantly contributed to the performance of orthographic learning in the spelling-to-dictation task: $\chi^2(1) = 9.09$, $p = .003$, odds ratio = 12.02, 95% CI = [2.39, 60.56] and in the orthographic recognition task: $\chi^2(1) = 10.54$, $p = .001$, odds ratio = 4.55, 95% CI = [1.82, 11.35]. On the contrary, spelling skills did not significantly contribute to semantic learning, be it in the definition task $\chi^2(1) = 0.01$, $p = .93$, odds ratio = 0.91, 95% CI = [0.10, 8.67] or in the semantic recognition task: $\chi^2(1) = 0.62$, $p = .43$, odds ratio = 0.67, 95% CI = [0.25, 1.81]. The vocabulary knowledge did explain the performance only in the semantic recognition task: $\chi^2(1) = 5.97$, $p = .02$, odds ratio = 24.35, 95% CI = [1.88, 315.55].

Discussion

The present study aimed to investigate new word learning in natural reading in adults, with a special focus on the role of context informativeness in orthographic learning. The experiment showed that adults learned the orthographic form of new words while reading a long narrative text. Moreover, the results suggest that context informativeness does not influence orthographic learning. Finally, the results showed that successful orthographic learning might enhance semantic learning.

Orthographic learning

The present study showed that reading a long narrative text with embedded pseudowords leads to orthographic learning. The participants correctly spelled about 20% of items they had encountered while reading. Given the performance in the non-exposed pseudoword set (7%), this

Table 7. Summary of the fixed effects evaluated with generalised linear mixed models for the exploratory analysis.

	Predictor	Odds ratio	95% CI	z	χ^2	*p*-value
Spelling task						
Exposed items only	Intercept	0.02	0.00–0.23	–3.22	10.37	<.001***
	Context	0.98	0.84–1.15	–0.21	0.04	.83
	BOQS	12.02	2.39–60.56	3.02	9.09	.003**
	Vocabulary	0.94	0.01–58.91	–0.03	0.00	.98
	Pre-Test	1.10	1.03–1.17	2.90	8.43	.004**
Orthographic recognition (all responses)	Intercept	0.26	0.07–0.95	–2.04	4.15	.04*
	Context	1.02	0.93–1.11	0.34	0.12	.73
	BOQS	4.55	1.82–11.35	3.25	10.54	.001**
	Vocabulary	1.42	0.14–14.69	0.29	0.08	.77
Orthographic recognition ("by-chance" responses excluded)	Intercept	0.29	0.07–1.14	–1.78	3.16	.08
	Context	1.02	0.93–1.13	0.45	0.20	.65
	BOQS	3.00	1.13–7.94	2.21	4.86	.03*
	Vocabulary	2.29	0.19–27.62	0.65	0.43	.51
Definition Task	Intercept	0.00	0.00–0.14	–3.11	9.64	.002**
	Spelling	3.64	2.19–6.06	4.97	24.71	<.001***
	BOQS	0.91	0.10–8.67	–0.08	0.01	.93
	Vocabulary	25.67	0.07–9886	1.07	1.14	.29
Semantic recognition (all responses)	Intercept	0.07	0.02–0.28	–3.69	13.60	<.001***
	Orth. Rec.	1.22	0.93–1.59	1.42	2.01	.16
	BOQS	0.67	0.25–1.81	–0.79	0.62	.43
	Vocabulary	24.35	1.88–316	2.44	5.97	.02*
Semantic recognition ("by-chance" responses excluded)	Intercept	0.06	0.01–0.55	–2.47	6.10	0.01*
	Orth. Rec.	1.60	1.11–2.30	2.54	6.46	0.01*
	BOQS	0.45	0.09–2.20	–0.98	0.96	.33
	Vocabulary	54.67	0.89–3365	1.90	3.62	.06

CI: confidence interval.
*$p < .05$. **$p < .01$. ***$p < .001$.

means that they genuinely learned the form of six (13%) novel words after reading a single book. This learning rate could seem modest, especially when compared with previous studies. In self-teaching studies using the spelling task, for example, children correctly spelled between 28% and 70% of items after learning (Cunningham, 2006; Cunningham et al., 2002; Martin-Chang et al., 2017; Share, 1999). However, these studies used a limited set of novel words compared with the present study (4–25 vs. 48 in the present study), and the final number of learned words learned corresponded to 1–10 items, which closely meets what we found here with a more demanding set up (long text reading here vs. short text reading). In addition, none of the previous experiments used a baseline condition (non-exposed pseudowords), meaning that the learning rates reported are very likely overestimated. On the contrary, the percentage of learned items observed here is very close to the one recently reported in adult orthographic learning in Chaves et al. (2020). The authors found that 17% of pseudowords were correctly spelled (1.17 words out of 7) after an exposure phase performed through a reading aloud task in which each pseudoword was presented twice in isolation. Finally, considering the total length of the text in our experiment (around 60,000 words) and the limited occurrence rate of the novel words (six times), the percentage of learned words can be considered as a substantial one. Indeed, assuming that most of regular fictional books entail new words and that an average reader goes through 18 books a year (Ipsos, 2021), 90–108 new word forms would be learned by the end of 1 year (see Nagy et al., 1985, for similar reasoning in children). This would be a massive lexical growth. Undoubtedly, increasing the number of new word occurrences in the setting we used would increase the learning rate (Elgort & Warren, 2014; Godfroid et al., 2018; Hulme et al. 2019; Pellicer-Sánchez & Schmitt, 2010), but it could also create a less realistic situation because of an over-exposure to the new orthographic forms.

Unsurprisingly, the participants performed better in the orthographic recognition task than in the recall-based spelling task, and both tasks were strongly correlated ($r = .86$). The participants recognised around 50% of exposed pseudowords among five highly similar homophonic and/or orthographic foils. Some participants even recognised up to 75% of the correct orthographic forms. Hence, orthographic learning taking place through an ecological design may be slightly more powerful than what is suggested by the performance in the spelling task. The participants may have encoded the rough orthographic form of many new words (leading to very good results in the recognition task), but the detailed orthographic form of only a few items may have been encoded. Only these high-quality representations enabled the participants to provide the orthographic details necessary for correct spelling productions (Perfetti & Hart, 2002). Crucially, this difference between recognition and recall also points out that orthographic learning can hardly be considered as an all-or-nothing process. Rather, orthographic representations are gradually built up, going from barely specified, barely stable, and context-dependent to precise, stable, and context-independent representations (e.g., Perfetti, 2007). In that perspective, the simultaneous use of spelling and orthographic recognition tasks seems to be an important way to address orthographic learning as a gradual phenomenon.

Regarding the effect of context informativeness, our results are consistent with the findings obtained in studies with children during which exposure to new words took place through natural reading settings (e.g., Nation et al., 2007; Ricketts et al., 2011). As in children, we did not find any effect of context informativeness on orthographic learning. Hence, so far, the putative effects of semantic information on orthographic learning have been found only in more artificial training paradigms (in adults: Chalmers & Burt, 2008; Rueckl & Olds, 1993, in children: Ouellette, 2010). According to us, those two lines of results are not necessarily conflicting. It could be the case that the cognitive benefit of semantic information on orthographic learning is too subtle to be detected in real-life situations of reading such as the one used in the present study. Indeed, more artificial learning settings are useful when the learning situation needs precise controls or when a large set of items is used to increase statistical power. That being said, the learning paradigms with high ecological validity makes it possible to examine real-life dynamics and determinants of learning and reinforces or questions the practical significance of effects reported in more controlled, lab-based studies (e.g., Angwin et al., 2014; Chalmers & Burt, 2008; Rueckl & Olds, 1993; Suárez-Coalla & Cuetos, 2017).

Semantic learning

As a reminder, semantic learning was investigated only for words presented in informative contexts. Indeed, it was not possible to assess semantic learning for the exposed new words in less informative contexts due to the lack of semantic features provided by such contexts. In informative contexts, the overall learning rate was low. On average, the participants recalled 9% of the word meanings (2–3 out of 24 words) with 75% of the participants recalling the meaning for only 0, 1, or 2 new words. The results are slightly lower but consistent with results reported in L1 and L2 studies using similar meaning recall tasks and similar occurrence rates (e.g., L1: Hulme et al., 2019: 2 learned words out of 4 new words; L2: Pellicer-Sánchez & Schmitt, 2010: 3–4 out of 34 items). As in orthographic learning assessment, the recognition task yielded better results compared with the recall task. Participants correctly recognised 34% of new word meanings. These results are lower than those reported in Saragi et al. (1978, i.e., 72% of correctly recognised meanings) but they are consistent with those reported by Pellicer-Sánchez & Schmitt (2010, 33%–45% for new words occurring 2–4 times and 5–8 times, respectively) who used a similar occurrence rate to ours. Due to the previously described floor effect in the definition task, the correlation between semantic definition and recognition task was only moderate ($r = .49$).

Importantly, in our study, the orthographic form of words was used to cue their meaning retrieval in both semantic tasks. This means that what we tested did not directly correspond to semantic learning per se, but to form-meaning mapping learning. Consequently, the cue may be efficient only if the link between the orthographic form and the meaning content of the novel words is already established. On several occasions, the participants spontaneously reported that they could recall more meanings than they did (in both tasks) but that they failed to remember with which word form a given meaning was associated. Hence, semantic learning as it is assessed with form-cued tasks could depend on the quality with which both orthography and form-meaning mapping of new words are learned.

To investigate the relationship between orthographic learning and the ability to recall/recognise word meaning, we conducted an analysis that took into account both spelling and orthographic recognition performance to explain the scores in the definition and semantic recognition tasks, respectively. The results showed that when the correct orthographic form was provided in the spelling task, the meaning of the item was more likely to be correctly recalled. The same pattern was found when we considered the semantic and orthographic recognition tasks, once the by-chance responses were excluded. Although these results seem to support our claim regarding the importance of orthographic learning for semantic learning, the analyses are correlational in essence, limiting any causal inference. Moreover, even if the overall relationship between the performance in the orthographic tasks and the semantic tasks is statistically significant, the link is not systematic. In many cases, a correct definition was given or recognised for word forms incorrectly spelled or recognised and vice versa. Nevertheless, our results are consistent with several studies on vocabulary acquisition in children, which reported that presenting the orthographic form of words could be beneficial for phonological and semantic learning (e.g., Ricketts et al., 2009; Ricketts et al., 2021; see Colenbrander et al., 2019 for a review). In adults, it has been reported that high-quality orthographic representations could facilitate novel word meaning acquisition (e.g., Eskenazi et al., 2018, see also

Balass et al., 2010; Bolger et al., 2008). At a theoretical level, this interrelation between orthographic and semantic learning is in agreement with the lexical quality hypothesis according to which only a stable and specified orthographic representation enables readers to efficiently access word meaning (e.g., Perfetti, 2007).

Lexical skills

Exploratory analyses showed that pre-existent vocabulary knowledge was a significant predictor of performance in the semantic recognition task, but it did not explain the score in the definition task. Interestingly, when we discarded by-chance responses from the semantic recognition task, the link with vocabulary knowledge was no longer significant. This link could be, at least in part, driven by strategies developed when a forced choice between several answers is required (both vocabulary knowledge and semantic recognition were assessed with a 6-AFC task), which is consistent with the absence of association between pre-existing vocabulary knowledge and the accuracy in the definition task. Conversely, the spelling skills explained orthographic learning (spelling and orthographic recognition) but not semantic learning (definition and semantic recognition), suggesting that having good spelling skills might be an advantage to store new orthographic representations. This view is consistent with studies in children reporting that prior orthographic knowledge is associated with successful orthographic learning (e.g., Cunningham, 2006; Cunningham et al., 2002; Wang et al., 2017). However, one should keep in mind that the exploratory nature of our analysis limits the possibility of drawing strong conclusions. We believe that the present results advocate for the more systematic inclusion of measures of individual differences in studies addressing new word learning in adults. They also highlight the need to design studies to refine our understanding of the contribution of individual characteristics to the successful learning of new words in adults.

Conclusion

To conclude, the present study provides evidence that reliable orthographic learning in adults is relatively efficient when reading a long narrative text. This demonstrates that natural reading is a major source of word knowledge not only in children (Nagy et al., 1987), but throughout the life span. This is consistent with previous studies reporting a link between the amount of reading and vocabulary size (see Mol & Bus, 2011, for a review). Moreover, we showed that context informativeness does not influence orthographic learning, suggesting that the effect of semantic information obtained in previous lab-oriented experiments (e.g., Chalmers & Burt, 2008; Rueckl & Olds, 1993) is negligible in real-life conditions. In addition, even if we found no evidence that context informativeness influence orthographic learning, our data suggest that semantic and orthographic aspects of word learning need to be jointly considered since successful orthographic learning seems to foster word meaning acquisition. More generally, it seems important to consider the different word features (form, meaning, syntactic information) when investigating novel word learning since all these dimensions co-occur and are likely to interact during learning as soon as a new item is encountered in situations of natural reading. Finally, the present study showed that using real-life reading conditions to investigate novel word learning is essential since it makes it possible to nuance our current understanding of the processes underlying word learning and to examine the weight of its determinants.

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Data accessibility statement

All the materials, raw data, and scripts for analyses are available on Open Science Framework: https://osf.io/7r86k/.

Supplementary material

The supplementary material is available at qjep.sagepub.com.

Notes

1. The participants completed one more task during the testing session, namely, a lexical decision task on base-words used to create the experimental pseudowords. It was administrated after both tasks assessing orthographic learning. As it was a part of another study, with an independent research question, the results are not reported here.
2. The BOQS was normed on a large sample of higher-education students with 50% correct responses corresponding to the centre (Chetail et al., 2019).

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