The influence of graphotactic knowledge on adults' learning of spelling

Amélie Sobaco, Rebecca Treiman, Ronald Peereman, Gaëlle Borchardt & Sébastien Pacton

Memory & Cognition

ISSN 0090-502X

Mem Cogn
DOI 10.3758/s13421-014-0494-y

Springer

Mem Cogn
DOI 10.3758/s13421-014-0494-y

The influence of graphotactic knowledge on adults' learning of spelling

Amélie Sobaco · Rebecca Treiman · Ronald Peereman · Gaëlle Borchardt · Sébastien Pacton

Abstract Three experiments investigated whether and how the learning of spelling by French university students is influenced by the graphotactic legitimacy of the spellings. Participants were exposed to three types of novel spellings: AB, which do not contain doublets (e.g., *guprane*); AAB, with a doublet before a single consonant, which is legitimate in French (e.g., *gupprane*); and ABB, with a doublet after a single consonant, which is illegitimate (e.g., *guprrane*). In Experiment 1, the nonwords were embedded within texts that participants read for meaning. In Experiment 2, participants read the nonwords in isolation, with or without instruction to memorize their spellings; they copied the nonwords in Experiment 3. In all of these conditions, AB and AAB spellings were learned more readily than ABB spellings. Although participants were highly knowledgeable about the illegitimacy of ABB spellings, the orthographic distinctiveness of these spellings did not make them easier to recall than legitimate spellings. When recalling ABB spellings, participants sometimes made transposition errors, doubling the wrong consonant of a cluster (e.g., spelling *gupprane* instead of *guprrane*). Participants almost never transposed the doubling for AAB items. Transposition errors, biased in the direction of replacing illegitimate with legitimate orthographic patterns, show that graphotactic knowledge influences memory for specific items. An analysis of the spellings produced in the copy phase and final recall test of Experiment 3 further suggests that transposition errors resulted not so much from reconstructive processes at the time of recall but from reconstructive processes or inefficient encoding at earlier points.

Keywords Implicit learning · Reading · Recall · Spelling · Graphotactic regularities · Statistical learning

Although all alphabetic writing systems are based on the principle that letters represent phonemes, deep systems like English and French are more difficult to learn and master than shallow systems like Italian or Spanish (Seymour, Aro, & Erskine, 2003; Sprenger-Charolles, 2003). This is largely because there is often more than one spelling for a phoneme in the former systems (Hanna, Hanna, Hodges, & Rudorf, 1966 for English; Peereman, Lété, & Sprenger-Charolles, 2007 for French). One manifestation of this difficulty, in French, is choosing between single-letter and double-letter spellings of consonant phonemes. For example, /f/ is spelled as *f* in *moufle*, 'mitten' and *ff* in *souffle*, 'breath'. French spellers sometimes omit a required doublet, misspelling *souffle* as *soufle*, and sometimes double a letter when not required, misspelling *moufle* as *mouffle* (Manesse, Chervel, & Cogis, 2007).

Some researchers and educators have assumed that, because of the complexity of systems like English and French, their users must memorize a huge number of words in order to spell correctly (e.g., Jensen, 1962). Others have suggested that spellers can reduce the need for rote word-by-word memorization by using graphotactic regularities, that is, statistical

A. Sobaco · S. Pacton (✉)
Institut de Psychologie, Université Paris Descartes, INSERM U894, Centre de Psychiatrie et Neurosciences, Paris, France
e-mail: sebastien.pacton@parisdescartes.fr

R. Treiman
Psychology Department, Washington University in St. Louis, St. Louis, MO, USA

R. Peereman
Psychology Department, Université Grenoble Alpes, Grenoble, France

G. Borchardt
Psychology Department, Université de Nîmes, Montpellier, France

Published online: 24 December 2014

patterns concerning the arrangement of letters in words (e.g., Deacon, Conrad, & Pacton, 2008; Treiman, Kessler, & Bick, 2002). For example, spellers of French could use their knowledge that consonants cannot double in word-initial position or after a single consonant to avoid misspellings such as *ssoufle*, with an initial doublet, or *soufflle*, with a doublet after a single consonant.

Several recent studies have tested the idea that people's knowledge of graphotactic regularities influences their spelling by examining how they learn and remember novel spellings that they read in texts (Pacton, Borchardt, Treiman, Lété, & Fayol, 2014; Pacton, Sobaco, Fayol, & Treiman, 2013). Such tasks are well suited to investigate the learning of spelling and vocabulary, and they allow strict control over how often participants see each item (Burt & Fury, 2000; Brusnighan & Folk, 2012; Nation, Angell, & Castles, 2007; Share, 2004). Most directly relevant to the present study is the study of Pacton et al. (2013), in which French 9-year-olds were exposed to novel spellings in meaningful texts, without any instruction to remember the spellings. Pacton and colleagues investigated the influence of two graphotactic patterns on children's later memory for the spellings: consonants cannot double in word-initial position (Experiment 1) and consonants cannot double after single consonants (Experiment 2).

The texts in Experiment 1 of Pacton et al. (2013) included three types of novel spellings. No-doublet items, such as *mupile*, did not contain any doublets. Medial-doublet items, such as *muppile*, contained a doublet in a position that is legitimate in French, and initial-doublet items, such as *mmupile*, included a doublet in an illegitimate position. In a later spelling task, children recalled items without doublets better than items with doublets. Among items with doublets, children recalled spellings with a doublet in illegitimate word-initial position better than spellings with a doublet in legitimate word-medial position (60 % vs. 40 %). Almost all misspellings involved the omission of the doublet, as when children recalled *mupile* instead of *mmupile* or *muppile*.

In Experiment 2 of Pacton et al. (2013), the texts also included three types of novel spellings. One type of item, AB, contained a sequence of two different consonants (henceforth, A and B are used to represent different consonants). For example, *guprane* is an AB item. AAB items, such as *gupprane*, contained two occurrences of one consonant letter followed by another consonant, where the double consonant is in a position that is legitimate in French. Finally, ABB items such as *guprrane* contained a consonant letter followed by a doublet, where such doublets are illegitimate in French. As in Experiment 1, children recalled items without doublets better than items with doublets in the subsequent spelling task. However, contrary to Experiment 1, among items with doublets, they performed better on legitimate AAB items than on illegitimate ABB items. Omission of the doublet was the most frequent error on both AAB and ABB items. However, children also made some errors in which they doubled the wrong consonant. *Transposition errors* of this sort occurred on ABB items when the illegitimate *guprrane* was misspelled as the legitimate *gupprane*. Almost never did the children misspell a legitimate AAB item such as *gupprane* as *guprrane*. This pattern of transposition errors, together with the fact that AAB spellings were rarely used for AB items, suggests that children sometimes remembered the presence of doubling but not the specific letter that was doubled. Pacton et al. suggested, on the basis of these findings, that children sometimes reconstructed a spelling based on their knowledge of the position in which letters are most likely to double. This reconstruction yielded correct spellings for AAB items but transposition errors for ABB items.

To summarize, the children tested by Pacton et al. (2013) often remembered both the presence and the position of the doublet when the graphotactic violation was in the initial position. However, the children sometimes remembered that an item contained a doublet but not which letter was doubled when a doublet was in the medial position. Pacton et al. hypothesized that this difference in orthographic learning could reflect a difference in children's degree of graphotactic knowledge for initial and medial doublets. This knowledge was assessed by presenting children with pairs of nonwords and asking them which one looked more like a word (see Cassar & Treiman, 1997; Pacton, Perruchet, Fayol, & Cleeremans, 2001 for previous studies using such a task). The children were very knowledgeable that consonants never double in word-initial position, choosing the legitimate spelling 93 % of the time with pairs like *nummar – nnumar*. Children's knowledge that consonants cannot double after a single consonant was less strong. When presented with pairs like *apprulir* (legitimate) and *aprrulir* (illegitimate), children scored above chance, 76 %, but far from perfectly.

The idea that degree of graphotactic knowledge influenced children's learning of spellings is consistent with findings showing that, across a variety of domains, people recall items that they know to be highly unusual or distinctive more easily than less distinctive ones (see Hunt & Worthen, 2006 for a review). For example, Zechmeister (1972) found that adults were better at remembering that they had seen words containing very atypical letter combinations than words containing more typical letter combinations. Likewise, Nicolas and Marchal (1998) showed that adults remembered common images of objects less well than bizarre versions. For orthographic distinctiveness to affect memory, a participant must know that a particular sequence is distinctive. Supporting the idea that degree of graphotactic knowledge is important, the 9-year-olds in Experiment 1 of Pacton et al. (2013) showed good memory for spellings with a doublet in word-initial position whereas the 6-year-olds tested by Wright and Ehri (2007), who were less knowledgeable about this graphotactic property, showed poor learning of spellings containing initial doublets.

Although Pacton et al.'s (2013) finding that children were better at learning spellings with an initial doublet than spellings that included a doublet after a single consonant can be explained on the basis of degree of graphotactic knowledge, there is an alternative explanation. This alternative explanation is based on the idea that letter sequences at the beginnings of words are easier to learn and remember than those in the middle. Indeed, studies show that adults and children often remember the initial letters of words better than the subsequent letters (e.g., Jensen, 1962; Kooi, Schutz, & Baker, 1965; Treiman, Berch, & Weatherston, 1993). There is also evidence that letters at the edges of words, especially the initial letter, play a special role in reading for both children and adults (e.g., Ehri & Saltmarsh, 1995; Rayner, White, Johnson, & Liversedge, 2006; White, Johnson, Liversedge, & Rayner, 2008). For example, Rayner et al. (2006) showed that, compared to a control condition in which words were spelled correctly, reading speed decreased more when a letter at the beginning of a word was switched with its neighbor (e.g., *oculd* for *could*) than when a letter in the middle or at the end of a word was switched (e.g., *cuold or coudl for could*).

The results of Pacton et al. (2013) do not allow us to dissociate the contributions of graphotactic knowledge and doublet position to orthographic learning because these two factors were confounded: children's performance was better for items including doublets in word-initial position than for items including doublets in internal position in the graphotactic judgment task and children were better at recalling spellings including doublets in the word-initial position than spellings including doublets in the internal position in the orthographic learning task. One aim of the present study was to disentangle these two factors. In Experiment 1, we examined how university students, who are expected to perform almost perfectly on a graphotactic judgment task comparing items such as *apprulir* (legitimate) and *aprrulir* (illegitimate), learned spellings that deviate from and spellings that conform to the pattern that doublets cannot occur after single consonants. Experiment 1 used the same procedure and items as the experiment we have described with 9-year-olds, Experiment 2 of Pacton et al. (2013). It differed from the earlier study only in that the participants were university students. If degree of knowledge about doublet regularities at a given position is a crucial factor, as Pacton et al. (2013) hypothesized, participants who have a strong knowledge that spellings like *guprrane* are illegitimate would pay special attention to these spellings when reading. Hence, they would remember these spellings well and would make few transposition errors. In contrast, if the crucial factor is position per se (i.e., that the illegitimate part of *guprrane* is in the middle), then even university students who always choose the correct spellings when presented with pairs like *apprulir – aprrulir* would not pay special attention to patterns like *prr* in *guprrane* when reading such items. Therefore, they would show poor memory for items with illegitimate medial doublets such as *guprrane* and would make transposition errors such as *gupprane*.

Another question that motivated the present study was whether the level of performance and pattern of errors on legitimate and illegitimate spellings is influenced by the conditions under which participants encounter the spellings. Experiment 1 examined the case in which novel spellings are embedded in texts that participants read for meaning, an implicit learning situation. Experiment 2 compared an implicit learning situation that involved presentation of single items to an explicit learning situation in which participants were asked to remember the items' spellings. We predicted that the overall level of performance would be higher in the explicit condition than in the implicit condition, in line with previous studies (Ormrod, 1986). Experiment 3 used a different task, one in which participants copied the items after they were presented but were not told that their memory for the items would later be tested. Previous studies suggest that writing words leads to better learning of their spellings than does reading them (e.g., Bosman & van Orden, 1997; Shahar-Yames & Share, 2008; Van Leerdam, Bosman, & Van Orden, 1998), perhaps because writing forces people to process every letter. We thus predicted that participants in Experiment 3 would perform better than the participants in the implicit condition of Experiment 2, perhaps as well as participants in the explicit condition of that experiment.

When orthographic learning is assessed well after the presentation of the items, as in Experiments 1 and 2, it is not possible to determine when and how the processes that led to transposition errors took place. By using a copy task in the study phase of Experiment 3, and by comparing the spellings produced in the copy phase and the final recall test, we could investigate yet another issue, the time course of these errors. One possibility is that graphotactic knowledge influences initial processing of spellings, such that people sometimes miscopy *guprrane* as *gupprane*. Instead, or in addition, graphotactic knowledge may influence orthographic learning through reconstructive processes that occur when people recall the spellings on the final recall test.

Experiment 1

In this study, university students were tested with the same graphotactic judgment task and nonword learning task as in Pacton et al.'s (2013, Experiment 2) study with 9-year-olds. We expected university students to be very knowledgeable that doublets cannot occur after single consonants. If, because of this strong knowledge, their attention is captured by illegitimate internal patterns like *prr*, then they may recall illegitimate ABB spellings such as *guprrane* as well as or even better than legitimate AB and AAB spellings such as *guprane* and

gupprane. Transposition errors should be rare, and no more common for ABB than AAB items. Another possibility is that, even though university students know that doublets cannot occur after single consonants, their attention is not captured by illegitimate patterns like *prr* in the middles of words. In this case, university students should recall legitimate AAB spellings better than illegitimate ABB spellings and should commit transposition errors primarily on ABB items, showing the same pattern of results as children.

Method

Participants The participants were 24 students (19 females) from Université Paris Descartes, France. They were native speakers of French between 19 and 24 years old, with a mean age of 20 years, 1 month.

Stimuli

Word spelling task In order to ensure that the participants in our three experiments were similar in spelling ability, we developed a recognition task that involved 15 correctly spelled words (e.g., *haleine*, 'breath') and 15 phonologically plausible but incorrect spellings (e.g., *planette* instead of *planète*, 'planet', see Appendix). The latter were selected by choosing words with phonemes that can be spelled in multiple ways in French. The 30 spellings were arranged in a random order and written on a sheet of paper using lowercase letters.

Nonword learning task The items were based on six phonologically legitimate bisyllabic nonwords with a consonant cluster at the beginning of the second syllable: /dyflin/, /gypran/, /mifrʒ/, /nokril/, /toplir/, and /viklar/. Considered individually, all of the letters of the clusters (*f*, *l*, *p*, *r*, *c*) may double in the internal position of French words. Among the 46,146 bisyllabic words of the Lexique database (New, Pallier, Brysbaert & Ferrand, 2004), the number of words including *ff*, *ll*, *pp*, *rr*, and *cc* is 648, 2,226, 409, 758, and 152, respectively. The frequencies of the six legitimate orthographic clusters were 87, 43, 95, 36, 20, and 3 for *ffl*, *ppr*, *ffr*, *ccr*, *ppl*, and *ccl*, respectively. We created AB, AAB, and ABB spellings of each nonword, as in *guprane* (AB), *gupprane* (AAB), and *guprrane* (ABB).We also created three stories which had an average of 157 words. Two nonwords were embedded in one of these three stories, with the constraint that two nonwords of the same type (i.e., AB, AAB, or ABB) were not included in the same story. The nonwords served as nouns, for example the name of a type of fruit. Each nonword occurred five times in each story. Thus, each participant read three stories; each story included two nonwords of different types which each occurred five times; across the three stories, each participant was exposed to two AB spellings (e.g., *dufline* and *guprane*), two AAB spellings (e.g., *muffrine* and *noccrile*) and two ABB spellings (e.g., *topllire* and *vicllare*); and each spelling variation of a given nonword (e.g., *guprane*, *gupprane* and guprrane for /gypran/) was presented to eight participants. Four questions were prepared about each story. The first required participants to select an appropriate title for the story from a list of three. The next three questions were true/false questions about the content. The order of the stories and the nonwords embedded in them were randomized across subjects.

Graphotactic judgment task This test included 18 pairs of nonwords. In the six pairs used to assess knowledge that consonants cannot double in word-initial position, one nonword included a medial doublet and the other an initial doublet, as in *nummar – nnumar*. The two doublets were formed with consonants that often double in French. In the six pairs used to assess knowledge that consonants cannot double before a consonant, one nonword included a doublet before a single consonant and the other a doublet after a single consonant, as in *apprulir – aprrulir*. The two doublets were formed with consonants that can double in French. In the six pairs used to assess knowledge that only some consonants can double, one nonword included a frequent doublet in word-medial position and the other a doublet formed with a consonant that never doubles in French, also in word-medial position, as in *onnave - ojjave*. For each type of pair, legitimate nonwords were on the right in half of the trials and on the left in the other half. The pairs were written on sheets of paper that were arranged in a random order and stapled together in order to make a booklet. The booklet started with three practice pairs in which only one item could be a French word.

Procedure Participants were tested individually in a sound-attenuated room. The session started with the nonword learning task. The experimenter told them that he needed help in calibrating texts that would be used to assess the comprehension skills of fifth graders. Participants were told that they would receive booklets that included stories along with questions about each. Participants had to orally read one story and move to the next page to answer questions about it, without rereading the story, then go the next story, and so on. After this, participants performed a letter cancellation task for 10 minutes. Then the experimenter pronounced each of the six nonwords and asked participants to spell them as written in the texts they read. After this, participants performed the graphotactic judgment task. They were told that the experimenter had made up new words that no one had ever seen or heard and that they would have to circle the made-up word that is more like words they know. Participants received feedback for the practice items. They then went on to the test items, and here they were not told whether their responses were correct or incorrect. Finally, the word spelling task was given. Participants were asked to cross out the misspelled words and were not given information regarding the

proportion of correct and incorrect spellings or about whether their responses were correct or incorrect.

Results

Word spelling task The mean percentage of correct responses was 71.53 (*SD* = 7.48).

Nonword learning task When reading the stories aloud, the participants always pronounced the target consonants in the same way whether the target consonant was single or double. They performed at ceiling on the questions assessing understanding of the texts.

For each participant, we counted the number of spellings that contained only single consonants (AB spellings), the number of spellings that contained a doublet before a single consonant (ABB spellings), and the number of spellings that contained a doublet after a single consonant (ABB spellings) for the three types of spellings on the memory test. Table 1 shows the mean values for the 24 participants, transformed into percentages. Here, as in the other experiments, the percentages of spellings of different types do not always sum to 100 because participants occasionally doubled a consonant that did not belong to the critical cluster (e.g., *gupprane* misspelled as *gupranne*) or produced a phonologically incorrect spelling (e.g., *grupane* for *guprane*). Also here, as in the other experiments, we defined correct spellings as those in which both target consonants were spelled as in the story (e.g., *pr* for the AB item *guprane*, *ppr* for the AAB item *gupprane*, and *prr* for the ABB item *guprrane*). Correct spellings were more common for AB items (77.1 %) than for items with a doublet, and among these items, correct spellings were more common for AAB (legitimate) than for ABB (illegitimate) items (45.8 % and 10.4 %, respectively). The number of correct spellings was submitted to analyses of variances (ANOVAs) using subjects (F_1) and items (F_2) as random variables. The main effect of item type was significant ($F_1(2, 46) = 33.56$, $p < .001$, $\eta_p^2 = .59$; $F_2(2, 10) = 23.02$, $p < .001$, $\eta_p^2 = .82$). Planned comparisons revealed significantly more correct spellings for AB items than for AAB and ABB items ($F_1(1, 23) = 57.28$, $p < .001$, $\eta_p^2 = .71$; $F_2(1, 5) = 74.13$, $p < .001$, $\eta_p^2 = .93$) and significantly more correct spellings for AAB than for ABB items ($F_1(1, 23) = 16.33$, $p < .001$, $\eta_p^2 = .41$; $F_2(1, 5) = 8.35$, $p = .03$, $\eta_p^2 = .62$).

Table 1 Percentage of different types of spellings produced in Experiment 1. Correct spellings are in bold and transposition errors in italics; standard deviations are in parentheses

Type of spelling produced	*AB* items presented	*AAB* items presented	*ABB* items presented
AB	**77.08 (25.45)**	45.83 (38.78)	47.92 (34.51)
AAB	18.75 (24.73)	**45.83 (38.78)**	*35.42 (31.20)*
ABB	0.00 (0.00)	*4.17 (14.21)*	**10.42 (20.74)**

Omission errors were those in which a doublet consonant in an AAB or ABB item was spelled with a singleton (e.g., *gupprane* or *guprrane* misspelled as *guprane*). Transposition errors involved movement of the doubling feature to the wrong target consonant: the first instead of the second consonant of the cluster for ABB items (e.g., *guprrane* misspelled as *gupprane*) and the second instead of the first consonant of the cluster for AAB items (e.g., *gupprane* misspelled as *guprrane*). Whereas omission errors were as frequent for AAB as for ABB items (45.8 % and 47.9 %), transposition errors were almost restricted to ABB items (35.4 % compared to 4.2 % for AAB items). *T* tests using subjects (t_1) and items (t_2) as random variables confirmed that, while omission errors did not differ significantly in frequency for AAB and ABB items (ps > .83), transposition errors were more common for ABB than AAB items ($t_1(23) = 3.98$, $p < .001$; $t_2(5) = 3.27$, $p = .022$).

The prevalence of transposition errors on ABB items did not reflect a general trend to use AAB spellings irrespective of the type of item that had been presented, because AAB spellings were used for AAB items (45.83 % correct) more often than for ABB items (35.42 % transposition errors) and AB items (18.75 % addition errors). An ANOVA on the number of AAB spellings with the variable of item type (AB, AAB, and ABB) revealed, on the by-participant analysis, a main effect of item type ($F_1(2, 46) = 5.02$, $p = .01$, $\eta_p^2 = .41$; $F_2(2, 10) = 3.03$, $p = .094$, $\eta_p^2 = .38$), with more AAB spellings used for AAB items than ABB and AB items ($F_1(1, 23) = 5.31$, $p = .03$, $\eta_p^2 = .19$; $F_2(1, 5) = 2.81$, $p = .15$, $\eta_p^2 = .17$) and more AAB spellings used for ABB than AB items ($F_1(1, 23) = 4.60$, $p = .042$, $\eta_p^2 = .17$; $F_2(1, 5) = 3.48$, $p = .12$, $\eta_p^2 = .17$).

Graphotactic judgment task Participants showed very good knowledge of the three properties of the use of double letters that were assessed, selecting the correct answer at rates of 100 % for items with a doublet in the medial rather than in the initial position (e.g., *nummar* rather than *nnumar*), 93.06 % (SD = 14.68 %) for items with a frequent rather than a nonexistent doublet (e.g., *onnave* rather than *ojjave*), and 95.14 % (SD = 7.74 %) for items with a doublet before, rather than after, a single consonant (e.g., *apprulir* rather than *aprrulir*). *T* tests using subjects (t_1) and items (t_2) as random variables confirmed that the selection rate of legitimate items was significantly above chance (50 %) in all three cases (ts > 13.67, ps < .001).

Discussion

Our university student participants had a strong knowledge that double consonants cannot occur after single consonants. They almost always chose the graphotactically correct item

when they were presented with pairs like *apprulir – aprrulir* in the graphotactic judgment task, whereas the 9-year-old children studied by Pacton et al. (2013, Experiment 2) scored above chance, but far from perfectly. Despite their better performance in the nonword judgment task, the university students showed the same pattern of results in the nonword learning task as the 9-year-olds. Like the children, they were better at recalling spellings with only singletons (e.g., *guprane*) than spellings with doublets. Among items with doublets, they better recalled those with a doublet before a single consonant, which is legitimate in French (e.g., *gupprane*), than those with a doublet after a single consonant, which is illegitimate (e.g., *guprrane*). Omission errors were the most frequent errors for the two types of spellings containing doublets, and their frequency of occurrence did not differ significantly according to whether the doublets were in a legitimate (AAB items) or an illegitimate position (ABB items). The adults also made some transposition errors, which were almost restricted to ABB items (17 out of the 19 transposition errors).

The results speak to the first question that we raised in the introduction: Do participants who have strong knowledge about the illegitimacy of a certain spelling pattern tend to show good memory for items with that spelling pattern after having been exposed to them while reading? When the illegitimate spelling pattern is located in the middle of a word, as it was in the present experiment, the answer to this question appears to be "no." That is, adults' strong knowledge that consonants cannot double after single consonants did not make illegitimate patterns such as *prr* in *guprrane* sufficiently salient to be precisely remembered. Adults made even more transposition errors on ABB items than did children (35 % vs. 25 %), suggesting that they were even more likely to use their knowledge about the orthographic patterns of their writing system to reconstruct spellings.

Would graphotactic legitimacy show less influence on memory when participants are told to attend to how words are spelled? In Experiment 1, as in some previous studies (Pacton et al., 2014; 2013), participants read nonwords in texts without instruction to learn their spellings. In Experiment 2, we asked what happens when participants are explicitly asked to learn the items' spellings. With such instructions, participants might perform an exhaustive analysis of the letters in the nonwords. If so, they may learn spellings like *guprrane* well and may not make transposition errors like *gupprane*.

Experiment 2

We used the same nonwords in Experiment 2 as in Experiment 1, asking whether level of performance and pattern of performance differ when participants are explicitly instructed to learn nonwords' spellings and when they are not. Each nonword was presented five times, the same number of exposures in Experiment 1, but in isolation instead of in text. In the explicit condition, participants were asked to read aloud the nonwords and memorize their spellings. In the implicit condition, participants were asked to read aloud the nonwords but were not asked to memorize their spellings.

Method

Participants The participants were 48 students (34 females) from Université Paris Descartes, France. They were native speakers of French between 20 and 40 years old, with a mean age of 24 years, 11 months. Twenty-four participants were randomly assigned to each of the explicit and implicit conditions.

Stimuli

Nonword learning task We used the same nonwords as in Experiment 1.

Word spelling task We used the same task as in Experiment 1.

Procedure The participants were tested individually in a sound-attenuated room. The nonwords were displayed on the 13-in screen of an Apple Macbook in Chicago font, size 24, for 1 s. Each nonword occurred once in each of five blocks of trials, which were presented in succession. The nonwords were pseudorandomly ordered for each participant within each block, with the constraint that a given nonword was never both the last trial of a block and the first trial of the following block. Participants were informed that the experimenter had made up new words. They were asked to press the space key after each trial in order to display the next new word. In the implicit condition, the participants were asked to read aloud the nonwords. In the explicit condition, the participants were asked to read aloud the nonwords and try to memorize their spellings. After the study phase, participants performed a letter cancellation task for 10 minutes. Then the experimenter pronounced each of the six nonwords and asked participants to spell them as they had been written on the screen. Finally, the word spelling task was given.

Results

Word spelling task The percentage of correct responses was 68.60 (SD = 9.20) for participants in the implicit condition and 67.50 (SD = 9.37) for participants in the explicit condition. These values are not significantly different from one another or from the value for participants in Experiment 1 ($ps > .26$).

Nonword learning task In both conditions, participants always pronounced the nonwords correctly. Table 2 provides

Table 2 Percentage of different types of spellings produced in Experiment 2. Correct spellings are in bold and transposition errors in italics; standard deviations are in parentheses

Type of spelling produced	Implicit instruction			Explicit instruction		
	AB items presented	AAB items presented	ABB items presented	AB items presented	AAB items presented	ABB items presented
AB	**79.17 (32.69)**	25.00 (25.54)	22.92 (32.90)	**89.58 (20.74)**	4.17 (14.12)	6.25 (16.89)
AAB	10.42 (25.45)	**60.42 (25.45)**	*41.67 (31.85)*	6.25 (16.89)	**83.33 (35.10)**	*35.42 (37.53)*
ABB	2.08 (10.21)	*6.25 (16.89)*	**33.33 (38.07)**	2.08 (10.21)	*8.33 (19.03)*	**54.17 (35.86)**

information about participants' performance in the recall test. ANOVAs on the number of correct spellings with the variables condition (implicit or explicit) and item type (AB, AAB, or ABB) revealed main effects of condition, with correct spellings more common in the explicit condition than the implicit condition (75.7 % vs. 57.6 %, $F1(1, 46) = 10.46$, $p < .01$, ηp2 = .18 ; $F2(2, 5) = 17.68$, $p < .01$, ηp2 = .78) and item type ($F1(2, 46) = 21.47$, $p < .001$, ηp2 = .31 ; $F2(2, 10) = 43.43$, $p < .001$, ηp2 = .89) and did not show an interaction (*p*s > .57). Planned comparisons revealed significantly more correct spellings for AB items than for AAB and ABB items (84.4 %, 71.9 %, and 43.8 %, respectively, $F_1(1, 46) = 26.44$, $p < .001$, $\eta_p^2 = .36$; $F_2(1, 5) = 47.74$, $p = .001$, $\eta_p^2 = .91$) and significantly more correct spellings for AAB than ABB items ($F_1(1, 46) = 17.56$, $p < .001$, $\eta_p^2 = .28$; $F_2(1, 5) = 42.45$, $p = .001$, $\eta_p^2 = .89$).

ANOVAs on transposition errors with the variables condition (implicit or explicit) and item type (AAB or ABB) revealed that transposition errors were far more common for ABB items than for AAB items (38.54 % vs. 7.29 %, $F_1(1, 46) = 32.04$, $p < .001$, $\eta_p^2 = .41$; $F_2(1, 5) = 19.89$, $p = .007$, $\eta_p^2 = .80$). There was no effect of condition (24.0 % and 21.9 % transposition errors, in the implicit and explicit conditions, respectively) and no interaction (*p*s > .45).

Although transposition errors were more common for ABB than AAB items, omission errors were equally common for AAB and ABB items (14.58 % in both conditions). Omission errors were also more common in the implicit than in the explicit condition (23.96 % vs. 5.21 %). ANOVAs on omission errors with the variables condition (implicit or explicit) and item type (AAB, or ABB) revealed a condition effect on the by-participant analysis ($F_1(1, 46) = 16.41$, $p < .001$, $\eta_p^2 = .26$; $F_2(1, 5) = 3.28$, $p = .13$, $\eta_p^2 = .40$) but no effect of item type and no interaction (*p*s > .42).

The prevalence of transposition errors on ABB items did not reflect a general trend to use AAB spellings irrespective of the type of item that had been presented, because AAB spellings were used for AAB items (71.88 % correct) more often than for ABB items (38.54 % transposition errors) and AB items (8.33 % addition errors). An ANOVA on the use of AAB spellings with the variables condition (implicit or explicit) and item type (AB, AAB, and ABB) revealed a main effect of item type ($F_1(2, 92) = 56.95$, $p < .001$, $\eta_p^2 = .55$; $F_2(2, 10) = 79.45$, $p < .001$, $\eta_p^2 = .91$) and an interaction which reached significance only in the by-participants analysis ($F_1(2, 92) = 3.73$, $p = .028$, $\eta_p^2 = .08$; $F_2(2, 10) = 2.78$, $p = .11$, $\eta_p^2 = .36$). In both conditions, AAB spellings were more often produced for AAB items than for AB and ABB items (*F*s > 17.50, *p*s < .001) but this difference was larger in the explicit than in the implicit condition (62.50 % vs. 34.38 %). AAB spellings were more often produced for ABB than AB items ($F_1(1, 23) = 13.58$, $p < .001$, $\eta_p^2 = .37$; $F_2(1, 5) = 24.10$, $p = .004$, $\eta_p^2 = .83$ for the explicit instruction and $F_1(1, 23) = 18.55$, $p < .001$, $\eta_p^2 = .45$; $F_2(1, 5) = 4.65$, $p = .083$, $\eta_p^2 = .48$ for the implicit instruction), and this difference was similar in size in the implicit and explicit conditions (31.25 % vs. 29.17 %).

Discussion

Despite the fact that nonwords were presented in isolation in Experiment 2, as compared to in texts in Experiment 1, the pattern of results was the same. Specifically, spellings with only singletons were better recalled than spellings with doublets. Among items that included a doublet, those with a doublet before a single consonant (legitimate AAB items) were better recalled than those with a doublet after a single consonant (illegitimate ABB items). Omission errors were as common for items with a doublet in a legitimate position (AAB items) as for items with a doublet in illegitimate position (ABB items), but transposition errors were almost restricted to ABB items. This pattern of results was found both for participants who were explicitly asked to memorize nonwords' spellings and for participants who were not explicitly asked to do so.

Although instruction type did not affect the pattern of results, it did affect the overall level of correct responses. Confirming previous findings (Ormrod, 1986), participants who received explicit instructions to remember the spellings recalled more correct spellings than participants who did not. Participants who received explicit instruction made fewer omission errors but no fewer transposition errors than the participants in the implicit instruction condition. Thus, participants who were explicitly asked to learn the nonwords'

spellings may have paid more attention to the presence of doublets in specific items than the participants in the implicit condition but graphotactic knowledge still influenced their encoding or retrieval of spelling patterns.

Together, the results of Experiments 1 and 2 suggest that memory for illegitimate ABB spellings is poor in a variety of conditions, even among participants who show strong knowledge that these spellings are illegitimate. In Experiment 3, we asked whether similar results are found when participants copy the spellings during the study phase of the experiment. Copying forces attention to each letter of an item, meaning that memory for illegitimate ABB spellings might be as good as memory for legitimate AAB spellings. The use of a copying task during the study phase allows us to ask not only whether participants make transposition errors on ABB items but also when such errors occur. One possibility is that the errors occur during the initial encoding of the items. Participants may expect novel words to contain familiar patterns, so when presented with an item like *guprrane* they may encode it as *gupprane*. Another possibility is that participants correctly encode both the presence of a doublet and its position but lose positional information somewhere between the item's exposure and the final recall test.

Experiment 3

This experiment used a copy task in which the nonwords of Experiments 1 and 2 were presented in isolation on a computer screen for 1 s, as in Experiment 2, and participants had to write down the spelling of each nonword after it disappeared from the screen. Orthographic learning was subsequently assessed as in Experiment 2.

Method

Participants The participants were 24 students (19 females) from Université Paris Descartes, France. They were native speakers of French between 17 and 26 years old, with a mean age of 20 years, 5 months.

Stimuli

Nonword learning task We used the same nonwords as in Experiments 1 and 2.

Word spelling task This was the same as in Experiments 1 and 2.

Procedure The procedure was as for that of the implicit condition of Experiment 2 except that, after a nonword had been displayed for 1 s and had disappeared from the screen, participants were asked to write its spelling on a piece of paper and give it to the experimenter.

Results

Word spelling task The mean percentage of correct responses on the spelling task was 64.60 (SD = 11.87), not significantly different from the values for participants in Experiments 1 and 2 (*p*s > .10).

Nonword learning task Table 3 provides information about participants' performance in the copy phase and the final recall test. Given that the participants in Experiment 3 did not differ from those in Experiment 2 in spelling ability, as assessed by our word spelling task, we compared the level of orthographic learning in the copy condition of Experiment 3 to that in the implicit and explicit instruction conditions of Experiment 2. ANOVAs on the number of correct spellings with the variables condition (implicit, explicit, or copy) and item type (AB, AAB, or ABB) revealed main effects of condition ($F1(2, 69) = 11.43$, $p < .01$, $\eta p2 = .25$; $F2(2, 10) = 32.35$, $p < .001$, $\eta p2 = .87$) and item type ($F1(2, 138) = 24.25$, $p < .001$, $\eta p2 = .26$; $F2(2, 10) = 27.75$, $p < .001$, $\eta p2 = .85$) and no interaction (*p*s > .11). Planned comparisons revealed significantly more correct spellings in the explicit and copy conditions than in the implicit condition ($F_1(1, 69) = 21.20$, $p < .001$, $\eta_p^2 = .24$; $F_2(1, 5) = 55.58$, $p < .001$, $\eta_p^2 = .92$). However, the numerical advantage of the copy task was not significant when compared to the explicit condition (*p*s > .20).

As Table 3 shows, correct spellings were less common for ABB items than for AB and AAB items in the copy phase. ANOVAs on the number of correct spellings produced during the copy phase with the variable item type (AB, AAB, or ABB) revealed a main effect of item type ($F_1(1, 46) = 15.58$, $p < .001$, $\eta_p^2 = .40$; $F_2(2, 10) = 12.66$, $p = .002$, $\eta_p^2 = .72$), with correct spellings less common for ABB than AB and AAB items ($F_1(1, 46) = 18.68$, $p < .001$, $\eta_p^2 = .45$; $F_2(1, 5) = 14.67$, $p = .01$, $\eta_p^2 = .75$) and no significant difference between AB and AAB items (*p*s > .46).

Transposition errors were observed on ABB items in both the copy phase and the final recall test but never on AAB items. As in Experiments 1 and 2, the occurrence of transposition errors on ABB items did not reflect a general trend to use AAB spellings irrespective of the type of item that had been presented, because AAB spellings were used for AAB items (99.17 % correct in the copy phase and 83.33 % correct in the final recall test) more often than for ABB items (16.25 % transposition errors in the copy phase and 18.75 % transposition errors in the final recall test) and AB items (0.42 % addition errors in the copy phase and no addition errors in the final recall test).

We explored the relationship between how a given ABB item was copied during the copy phase and how it was recalled in the final test. Among the 48 ABB items (two items × 24 participants), which were each copied five times, 25 were

Table 3 Percentage of different types of spellings produced in copy phase and recall task of Experiment 3. Correct spellings are in bold and transposition errors in italics; standard deviations are in parentheses

Type of spelling produced	Copy			Recall		
	AB items presented	*AAB* items presented	*ABB* items presented	*AB* items presented	*AAB* items presented	*ABB* items presented
AB	**97.50 (10.94)**	0.42 (4.56)	1.67 (9.01)	**93.75 (16.89)**	16.67 (31.85)	10.42 (25.45)
AAB	0.42 (4.56)	**99.17 (6.43)**	*16.25 (27.62)*	0.00 (0.00)	**83.33 (31.85)**	*18.75 (28.79)*
ABB	0.00 (0.00)	*0.00 (0.00)*	**80.00 (29.28)**	2.08 (10.21)	*0.00 (0.00)*	**70.83 (35.86)**

miscopied at least once during the five trials. In contrast, only two AB items and two AAB items were miscopied at least once. Among the 25 AAB items that were misspelled, six were spelled with an omission error and the 19 others with a transposition error (see Table 4, lines 2, 3, and 4). Of these 19 ABB items misspelled with a transposition error, three were spelled AAB on all five trials of the copy phase and also in the final recall test (second line of Table 4). Six others were spelled AAB in the first trials of the study phase but correctly in the fourth and fifth trials and also the final recall test (third line of Table 4). (The ten other ABB items miscopied with a transposition error showed a variety of less clear patterns.) These results suggest that some ABB items were encoded and memorized as AAB spellings from the first presentation onward whereas others, also initially encoded as AAB, were subsequently encoded and memorized correctly. Among the 29 ABB items that were never miscopied as AAB during the copy phase, only three were spelled with a transposition error in the final recall test. Thus, it appears that reconstructive processes occurring well after the presentation of the items were relatively uncommon.

Discussion

The results of Experiments 1 and 2 showed that participants sometimes learned that a specific item included a doublet but did not remember its location. In such cases, they sometimes made transposition errors like *gupprane* instead of *guprrane*. The results of the final recall task of Experiment 3 confirm this finding: Participants committed transposition errors and they did so only for ABB items. Copying, even though it forces attention on letters, did not eliminate transposition errors. Copying did benefit memory, however. In fact, participants in Experiment 3 reached similar levels of orthographic learning to those in the explicit condition of Experiment 2, even though they did not know that their memory would be tested.

With regard to the issue of when knowledge about the legitimate position of doublets influences orthographic learning, cases of items written with a transposition error in the copy task were far more common than cases of items always written correctly in the copy task but incorrectly in the recall test. This result suggests that most transposition errors reflect processes that occur soon after the presentation of an item. Cases of ABB spellings correctly encoded but reconstructed as AAB spellings some time after their presentation did exist but were rather rare.

Table 4 Number of correct spellings, transposition errors, and omission errors for ABB items in recall test of Experiment 3 as a function of the pattern of transposition errors during copy task

Transposition errors during the copy task	N	N with ABB (correct) in recall test	N with AAB (transposition) in recall test	AB (omission) in recall test
No error	29	25	3	1
Errors on all five trials	3	0	3	0
Error on first trial but not in the fourth and fifth trials	6	6	0	0
Other	10	3	3	4

General discussion

In this series of experiments, we investigated whether and how the degree to which a novel spelling fits the graphotactic patterns of the language influenced university students' memory for it. The same nonwords, whose spellings varied in conformity to French graphotactic patterns, were presented in different learning conditions across three experiments. The spellings included frequent patterns (AB items that contained only single consonants, such as *guprane*, and AAB items that contained a doublet before a single consonant, such as *gupprane*) or illegitimate patterns (ABB items that contained a doublet after a single consonant, such as *guprrane*). In Experiment 1, the nonwords were embedded in texts that participants read for meaning, without being asked to learn their spelling. In Experiment 2, the nonwords were presented in isolation and participants read them, with or without instruction to memorize their spelling. In Experiment 3, nonwords were also presented in isolation and participants copied them before later recalling them. Orthographic learning was

assessed with the same recall test across the three experiments. In this test, the nonwords were dictated to participants and they were asked to spell them as written in the study phase.

Although the mode of presentation of the nonwords and the instructions given to participants differed greatly across experiments, the pattern of results in the final recall test was strikingly similar. AB spellings, which contained only singletons, and AAB spellings with a doublet in a legitimate position were better recalled than ABB spellings with a doublet in an illegitimate position. Omission errors (e.g., spelling *guprane* instead of *gupprane* or *guprrane*) were frequent and as common for ABB as for AAB items. However, transposition errors were almost restricted to ABB items. That is, participants sometimes spelled *gupprane* instead of *guprrane* but rarely spelled *guprrane* instead of *gupprane*.

The results speak to the questions that we raised in the introduction. Our first question was whether university students, who show a strong knowledge that spellings like *guprrane* are illegitimate, would pay special attention to these spellings and remember them better than legitimate spellings. Our results provide a negative answer to this question. The university students were much more knowledgeable than the 9-year-olds tested by Pacton et al. (2013) about the fact that doublets cannot occur after single consonants, but they also showed poorer memory for items with illegitimate than legitimate sequences in the middle of words. Evidently, the illegitimate pattern did not capture adults' attention to the extent that they encoded and remembered the exact and particular spellings. Rather, the adults appeared to restructure the illegitimate spellings during encoding or retrieval to conform to graphotactic regularities. It is possible that different results would be found with illegitimate patterns that are even more salient than the ones used here. Indeed, one study obtained a different pattern of results when graphotactically illegitimate patterns were located at the beginning of words and when participants were highly knowledgeable about the illegitimacy. In that study, 9-year-olds showed good memory for illegitimate spellings such as *mmupile* and almost never committed transposition errors like *muppile* (Pacton et al., 2013, Experiment 1). The blatantly illegitimate spelling in the initial position of *mmupile* appeared to capture the 9-year-olds' attention when they read it, and they remembered the spelling well. This pattern of results may in part reflect the position of the illegitimacy: Patterns located at the beginnings of words may in general be coded more precisely than patterns located in internal positions. Another contributor to the different pattern of results on French initial and medial doublets may be that, in the initial position, all doublets are illegitimate. In the internal position, in contrast, detection of a consonant doublet's illegitimacy requires identification of whether the doublet occurs after a vowel (legitimate) or a consonant (illegitimate). For instance, *r* and *p* never double in the internal position after another consonant but do frequently double after vowels like *a* or *u*. Further research will be required to examine these possibilities.

The results so far suggest that good memory for unusual patterns depends on both the degree of knowledge that participants have about the unusual nature of the pattern and the context in which it occurs. In Wright and Ehri's (2007) study with US 6-year-olds, children's attention may not have been captured by the presence of a doublet, even in a salient position, because they were not very knowledgeable that doublets are illegitimate in this position. In our study, participants' attention may not have been captured by items that contained illegitimate patterns like *prr* because the illegitimacy of the patterns was less salient in the internal-word position.

The second question that motivated the present study was about how participants' recall of spellings is affected by the conditions under which they are exposed to them. We found differences in level of performance between the implicit and explicit conditions of Experiment 2, in accordance with previous studies (Ormrod, 1986). Although participants in the explicit instruction condition made fewer omission errors than participants in the implicit instruction condition, the two groups showed similar proportions of transposition errors. Thus, asking participants to memorize spellings helped them to remember that a specific item included a doublet but did not necessarily help them to remember which letter was doubled.

The participants in Experiment 3, who copied the nonwords during the study phase without any instruction to learn their spellings, recalled correct spellings better than the participants of Experiment 2, who were not explicitly asked to learn the spellings of the nonwords. These results are consistent with those of previous studies showing that writing words leads to better memory for their spelling than does reading them (e.g., Bosman & van Orden, 1997; Shahar-Yames & Share, 2008; Van Leerdam, Bosman, & Van Orden, 1998). When writing a word, people must process every letter. When reading, they often do not need to do so (Holmes & Carruthers, 1998). The more thorough processing of letters in spelling may produce representations that are more complete and more lasting than those established through reading alone (Conrad, 2008). However, the participants who copied the nonwords did not recall spellings significantly better than the participants of Experiment 2 who were explicitly asked to learn the spellings. This result suggests that intention to learn modified the nature of the processes engaged during the learning phase, leading to more efficient orthographic encoding. Independently of any shift in the processes, intention to learn per se could also account for the benefit caused by explicit instruction to learn in Experiment 2. Although this second possibility cannot be ruled out, there is evidence that the nature of the processing may be more critical than the intention to learn (Hyde & Jenkins, 1973; Perruchet & Pacton, 2004).

The third question that motivated the present study was about when graphotactic knowledge influences orthographic learning. When orthographic learning is assessed with a recall task that is given some time after the presentation of an item, it is not possible to determine whether errors reflect reconstructive processes that take place when participants recall the spellings or processes that take place earlier. In Experiment 3, analysis of the spellings produced during the copy task and the final recall test allowed us to shed light on this issue. If an ABB item which is never miscopied with a transposition error during the copy phase is subsequently misspelled as AAB in the final recall test, reconstructive processes must have taken place some time after the presentation of the item. In contrast, if an ABB item is miscopied with a transposition error during the copy phase, graphotactic knowledge must have had an early influence. We found many more errors of the latter sort than the former sort, suggesting that most transposition errors did not result from belated reconstructive processes of memory. Further research will be required to address the issue of whether these errors resulted from inefficient coding or early reconstructive processes.

Although questions remain, the present results clearly show that adults' knowledge about double letters influences their learning of spelling. The key finding that participants made some transposition errors biased in the direction of replacing illegitimate with legitimate orthographic pattern confirms previous findings (Pacton et al., in press; 2013; Wright & Ehri, 2007) and extends them in three important ways. First, this phenomenon is found even among university students who are very knowledgeable about the legitimacy of a graphotactic pattern. Second, this phenomenon is observed whether nonwords are presented in isolation or embedded in texts and whether participants are asked to learn spellings, copy them, or read them aloud. Third, transposition errors result not so much from reconstructive processes that occur at the time of recall but from reconstructive processes or inefficient encoding at earlier points in time.

Acknowledgments This work was supported by grants from Université Paris Descartes, Institut Universitaire de France, and Agence Nationale pour la Recherche (grant Ortholearn).

Appendix: Items for word spelling task

Correct: *abri*, *antenne*, *balistique*, *étayage*, *fourrager*, *haleine*, *hameau*, *hublot*, *impotente*, *layette*, *occurrence*, *parcimonie*, *sollicitude*, *susurrer*, *vacciner*

Incorrect: *allouette*, *baffouer*, *barraque*, *carrie*, *collis*, *dégraffer*, *épous*, *esquimeau*, *facination*, *hirondèle*, *pantain*, *paquebeau*, *planette*, *poulin*, *remou*

References

Bosman, A. M. T., & Van Orden, G. C. (1997). Why spelling is more difficult than reading. In C. A. Perfetti, M. Fayol, & L. Rieben (Eds.), *Learning to spell: Research, theory, and practice across languages* (pp. 173–194). Hillsdale, NJ: Erlbaum.

Brusnighan, S. M., & Folk, J. R. (2012). Combining contextual and morphemic cues is beneficial during incidental vocabulary acquisition: Semantic transparency in novel compound word processing. *Reading Research Quarterly, 47,* 172–190.

Burt, J. S., & Fury, M. B. (2000). Spelling in adults: The role of reading skills and experience. *Reading and Writing: An Interdisciplinary Journal, 13,* 1–30.

Cassar, M., & Treiman, R. (1997). The beginnings of orthographic knowledge: Children's knowledge of double letters in words. *Journal of Educational Psychology, 89,* 631–644.

Conrad, N. J. (2008). From reading to spelling and spelling to reading: Transfer goes both ways. *Journal of Educational Psychology, 100,* 869–878.

Deacon, S. H., Conrad, N., & Pacton, S. (2008). A statistical learning perspective on children's learning about graphotactic and morphological regularities in spelling. *Canadian Psychology/ Psychologie Canadienne, 49,* 118–124.

Ehri, L. C., & Saltmarsh, J. (1995). Beginning readers outperform older disabled readers in learning to read words by sight. *Reading and Writing: An Interdisciplinary Journal, 7,* 295–326.

Hanna, R. R., Hanna, J. S., Hodges, R. E., & Rudorf, E. H. (1966). *Phoneme–grapheme correspondences as cues to spelling improvement.* Washington, DC: Department of Health, Education, and Welfare, Office of Education.

Holmes, V. M., & Carruthers, J. (1998). The relation between reading and spelling in skilled adult readers. *Journal of Memory and Language, 39,* 264–289.

Hunt, R. R., & Worthen, J. B. (2006). (Eds.) *Distinctiveness and memory.* New York: Oxford University Press.

Hyde, T. S., & Jenkins, J. J. (1973). Recall for words as a function of semantic, graphic, and syntactic orienting tasks. *Journal of Verbal Learning and Verbal Behavior, 12,* 471–480.

Jensen, A. R. (1962). Spelling errors and the serial-position effect. *Journal of Educational Psychology, 53,* 105–109.

Kooi, B. Y., Schutz, R. E., & Baker, R. L. (1965). Spelling errors and the serial-position effect. *Journal of Educational Psychology, 56,* 334–336.

Manesse, D., Chervel, A., & Cogis, D. (2007). *Orthographe: A qui la faute ? [Spelling: Whose fault is it?].* Paris, France: ESF.

Nation, K., Angell, P., & Castles, A. (2007). Orthographic learning via self-teaching in children learning to read English: Effects of exposure, durability, and context. *Journal of Experimental Child Psychology, 96,* 71–84.

New, B., Pallier, C., Brysbaert, M., & Ferrand, L. (2004). Lexique 2: A new French lexical database. *Behavior Research Methods, Instruments, & Computers, 36,* 516–524.

Nicolas, S., & Marchal, A. (1998). Implicit memory, explicit memory and the picture bizarreness effect. *Acta Psychologica, 99,* 43–58.

Ormrod, J. E. (1986). Learning to spell while reading: A follow-up study. *Perceptual and Motor Skills, 63,* 652–654.

Pacton, S., Borchardt, G., Treiman, R., Lété, B., & Fayol, M. (2014). Learning to spell from reading: General knowledge about spelling patterns can distort memory for specific words. *Quarterly Journal of Experimental Psychology, 67*, 1019–1036.

Pacton, S., Perruchet, P., Fayol, M., & Cleeremans, A. (2001). Implicit learning in real world context: The case of orthographic regularities. *Journal of Experimental Psychology: General, 130,* 401–426.

Pacton, S., Sobaco, A., Fayol, M., & Treiman, R. (2013). How does graphotactic knowledge influence children's learning of new spellings? *Frontiers in Psychology, 4,* 701.

Peereman, R., Lété, B., & Sprenger-Charolles, L. (2007). Manulex-Infra: Distributional characteristics of grapheme- phoneme mappings, infra-lexical and lexical units in child-directed written material. *Behavior Research Methods, 39,* 579–589.

Perruchet, P., & Pacton, S. (2004). Qu'apportent à la pédagogie les travaux de laboratoire sur l'apprentissage implicite? [What do implicit learning studies bring to pedagogy?]. *L'Année Psychologique, 104,* 121–146.

Rayner, K., White, S., Johnson, R. L., & Liversedge, S. (2006). Raeding wrods with jubmled lettres: There is a cost. *Psychological Science, 17,* 192–193.

Seymour, P. H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94,* 143–174.

Shahar-Yames, D., & Share, D. L. (2008). Spelling as a self-teaching mechanism in orthographic learning. *Journal of Research in Reading, 31,* 22–39.

Share, D. L. (2004). Orthographic learning at a glance: On the time course and developmental onset of self-teaching. *Journal of Experimental Child Psychology, 87,* 267–298.

Sprenger-Charolles, L. (2003). Linguistic processes in reading and spelling. The case of alphabetic writing systems: English, French, German and Spanish. In T. Nunes & P. Bryant (Eds.), *Handbook of children's literacy* (pp. 43–65). Dordrecht, the Netherlands: Kluwer.

Treiman, R., Berch, D., & Weatherston, S. (1993). Children's use of phoneme–grapheme correspondences in spelling: Roles of position and stress. *Journal of Educational Psychology, 85,* 466–477.

Treiman, R., Kessler, B., & Bick, S. (2002). Context sensitivity in the spelling of English vowels. *Journal of Memory and Language, 47,* 448–468.

Van Leerdam, M., Bosman, A. M. T., & Van Orden, G. C. (1998). The ecology of spelling instruction: Effective training in first grade. In P. Reitsma & L. Verhoeven (Eds.), *Problems and interventions in literacy development* (pp. 307–320). Dordrecht, the Netherlands: Kluwer.

White, S., Johnson, R. L., Liversedge, S., & Rayner, K. (2008). Eye movements when reading transposed text: The importance of word beginning letters. *Journal of Experimental Psychology: Human Perception and Performance, 34,* 1261–1276.

Wright, D. M., & Ehri, L. C. (2007). Beginners remember orthography when they learn to read words: The case of double letters. *Applied Psycholinguistics, 28,* 115–133.

Zechmeister, E. B. (1972). Orthographic distinctiveness as a variable in word recognition. *American Journal of Psychology, 85,* 425–430.