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Analogy without priming in early spelling development

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Abstract. This article reports three experiments investigating the use of analogies in spelling acquisition. French children spelled pseudowords to dictation, some of which were phonological neighbours of words with uncommon endings (e.g., /daby/ derived from "début" /deby/). A more frequent use of these uncommon graphemes in neighbour pseudowords than in control pseudowords was taken as evidence for spelling by analogy. In Experiment 1, an analogy effect was observed in Grades 3 to 5. Younger children did not use analogies, but they were also unable to spell most reference words. Experiments 2 and 3 introduced a reference word learning phase prior to the pseudoword dictation task. An analogy effect was found in second graders (Experiment 2) and even in first graders (Experiment 3) when children knew how to spell most reference words. Comparable use of analogies was observed in children with comparable lexical knowledge independently of their grade level or alphabetic skills. The results suggest that children establish specific orthographic knowledge from the beginning of literacy acquisition and use this knowledge to generate new word spellings as soon as it is available.

Keywords: Acquisition, Analogy, Children, French, Learning, Neighbourhood, Nonword, Pseudoword, Spelling, Writing

Introduction

Traditional stage models of spelling development assume progression through a number of discrete stages in which different sources of knowledge are used (Brown, 1990; Ehri, 1986; Frith, 1985; Gentry, 1982; Marsh, Friedman, Welch & Desberg, 1980; Nunes, Bryant & Bindman, 1997; Templeton & Bear, 1992). For example, Frith (1985) described literacy development as a strict succession of qualitatively different stages, which are not adopted simultaneously in reading and spelling. During the first stage, called logographic, spelling is restricted to a few rote words without knowledge of the links between sounds and letters. This stage is followed by an alphabetic stage during which children rely on phoneme–grapheme conversion rules to spell new words. After extensive literacy experience, their reading becomes orthographic, with words being read through the evocation of their memorised orthographic form. Orthographic spelling comes later, when orthographic representations become more precise. According to this

view, it is only during this last stage that children can reliably spell words with irregular or ambiguous phoneme–grapheme mappings (e.g., *phone*, *two*, or *read*, which might have been spelled *fone*, *tu* or *reed* during the alphabetic stage). Spelling new words by analogy to previously learned words can only happen at the final orthographic stage when lexical representations are fully specified (Perfetti, 1992; Stuart & Coltheart, 1988). Accordingly, lexical analogies should only be observed in more experienced spellers who are able to switch from a strictly sublexical strategy to a strategy based on orthographic knowledge. For example, a new word such as /ˈʃʊbəʳ/ might then be spelled *subar* (by analogy to the stored spelling *sugar*) rather than *shuber*.

Contrary to the stage view, several authors have proposed that spelling development is a continuous process during which children can use a variety of sources of knowledge from a very early age (Goswami, 1988; Lennox & Siegel, 1994; Nation & Hulme, 1996, 1998; Rittle-Johnson & Siegler, 1999; Share, 1999; Snowling, 1994; Treiman, 1998; Varnhagen, McCallum & Burstow, 1997). This suggests that children might start spelling new words by analogy to memorised words very early on. In this study, we will present empirical evidence in support of an early emergence of spelling by analogy.

Several studies have been conducted to determine when children start spelling new words by analogy to known words. Marsh et al. (1980) asked children to spell pseudowords, a few of which were phonologically close to irregularly spelled words (e.g., "jation" derived from *nation*). Ten-year-old children did use analogies but seven-year-old children did not. Using a lexical priming task, in which children had to spell pseudowords intermixed with real words, Campbell (1985) showed that pseudoword spelling was influenced by the spelling of previously heard words. For example, /fri:t/ was more often spelled *freat* following "neat" and *freet* following "feet". However, this priming effect only held for children with a reading age of at least 11 years. Dixon and Kaminska (1994) replicated this experiment and added an associative lexical priming condition. They found a significant effect of both direct and associative priming for nine-year-old children. Younger children were not tested.

These findings might suggest that novice spellers do not make use of lexical knowledge when asked to spell novel words. However, a problem is that these experiments did not establish that younger children could spell the prime words accurately. Without such data, it is difficult to interpret the absence of analogy effects. Using Campbell's paradigm, Nation and Hulme (1996, 1998) observed a significant priming effect in second graders who were selected on their ability to spell at least 50% of the prime words

correctly, suggesting an earlier use of analogies in spelling than previously reported.

Other studies have shown an early use of analogies when children were provided with the basis for analogy (Goswami, 1988; Deavers & Brown, 1997). For example, Goswami (1988) found that even first graders can spell new words by analogy when clue words are shown simultaneously and when children are told that using them might be helpful. However, these results do not say much about children's potential to use analogies spontaneously when spelling new words based on their own lexical knowledge. Indeed, Nation and Hulme (1996, 1998), replicating Goswami's (1988) paradigm, found that children with different spelling ages demonstrated similar rates of analogy spellings when using the clue word technique (see Deavers & Brown, 1997, Experiment 2a, for similar findings). In addition, Deavers and Brown (1997) showed that spelling strategies vary as a function of the task. In one task, pseudowords were dictated in isolation, and in another the same pseudowords were preceded by a neighbour word as in Goswami's paradigm. Seven-year-old children exhibited considerable task-dependence, using more analogies in pseudoword spelling when the reference word was salient.

In summary, spelling by analogy has only been observed in beginning spellers when priming or clue word paradigms are used. As argued by Muter, Snowling and Taylor (1994) with respect to reading, a stronger case for the use of analogy in early spelling development would be made by demonstrating reliable analogy effects in tasks where no real word is provided to encourage the use of lexical analogies. The present series of experiments was designed for this purpose. French children ranging from 6 to 11 years of age (grades 1 to 5) were tested in a spelling to dictation task in which only pseudowords were presented. They did not hear or see any real words and they were encouraged to spell pseudowords as spontaneously as possible. This design should promote the use of frequent sublexical phoneme–grapheme correspondences and discourage any deliberate strategic use of lexical knowledge.

Deavers and Brown (1997, Experiment 1) did report spelling by analogy in children with a mean spelling age of eight years four months in the absence of prompts. However, the experimental pseudowords were presented in blocks and were derived from words with consistent endings, which might have led to an overestimation of the use of analogies. In the present series of experiments, less than 20% of the dictated pseudowords were close phonological neighbours of real words; these were mixed with other pseudowords and were never dictated successively. All neighbour pseudowords were derived from high frequency words (hereafter *reference words*) whose final grapheme did not correspond to the most frequent phoneme–grapheme mapping in

French (e.g., /bəti/ derived from /pəti/ *petit* [small], where "it" is less frequent than "i" to spell a final /i/). This choice of stimuli allowed us to distinguish between spellings based on sublexical phoneme–grapheme correspondences (the most frequent mapping would then be expected) from spellings produced by analogy to the reference words. A higher use of target spellings in the context of neighbour pseudowords (e.g., /bəti/ spelled *betit* rather than *beti*) than in the context of control pseudowords with identical endings but no close neighbour would provide strong evidence for a spontaneous use of analogies. Since no analogy effect should be expected without knowledge of the reference words, the ability of children to spell reference words was systematically assessed.

Experiment 1

Method

Participants

Five groups of 29 children from all five grades of a French primary school were randomly chosen from pupils who were native French speakers, had never repeated a grade, and were not identified by their teachers as suffering from dyslexia or dysgraphia. Participants in each group came from two or three different classes. At the beginning of the experiment, in April, their mean chronological age was 6 years and 10 months (range: 6;3–7;2) for 1st graders, 7 years and 8 months (range: 7;3–8;3) for 2nd graders, 8 years and 8 months (range: 8;3–9;2) for 3rd graders, 9 years and 9 months (range: 8;9–10;6) for 4th graders, and 10 years and 8 months (range: 10;3–11;2) for 5th graders. Most French children start learning to read after the age of 6, so the first graders were novice readers who had received only 6 months of formal literacy acquisition at the time of testing. In France, systematic spelling instruction begins in the second year, between 7 and 8, and remains the focus of teaching for several years.

Materials

A set of 76 disyllabic pseudowords was designed, comprising 42 experimental pseudowords and 34 fillers. The experimental pseudowords (see Appendix A) comprised 14 neighbour pseudowords, and two sets of control stimuli: 14 "phoneme" control pseudowords and 14 "syllable" control pseudowords (see below).

The 14 *neighbour pseudowords* were derived from 14 disyllabic words with irregular endings. For instance, the neighbour pseudoword /daby/ was derived from the reference word /deby/-début (beginning). The reference words were selected in the BRULEX French lexical database (Content,

Mousty & Radeau, 1990) on the basis of their high frequency (mean: 21,922 per 100 million, range 642–147,638). Because of their high frequency, it was assumed that most children would be familiar with these words. All reference words ended with an inconsistent phoneme corresponding to at least 5 different graphemes in French. The phoneme–grapheme correspondences used in the reference words were never the most frequent ones in French (see Appendix B). For instance, the word *crapaud* (toad) was selected as a reference word but not *chapeau* (hat), because the grapheme *aud* is infrequently used to spell /o/ in final position whereas *eau* is the most frequent option. Final graphemes were chosen as critical targets because this is where most of the spelling ambiguities occur in French (e.g., final /o/ can be spelled o, eau, au, aut, ot, aud, os, op, etc., whereas initial or medial /o/ is mostly spelled o or au). Most of the selected graphemes (12/14) ended with a silent consonant, as is common in French (59% of all words ending with the phonemes /i/, /a/, /y/, /u/, /o/, /ɛ̃/ or /ã/ end with a silent consonant). The 14 "neighbour" pseudowords were constructed by substituting a single phoneme in the initial syllable of the reference words leaving the second syllable intact, with the constraint that the pseudowords would have no close neighbours other than the reference words. Because of this constraint, the phoneme substituted was the initial consonant in 9 pseudowords and the first vowel in the 5 remaining pseudowords.

Two control pseudowords that were at least two phonemes away from the reference words were constructed for each neighbour pseudoword. None of the controls had any close phonological word neighbour (i.e., they were at least two phonemes away from any real word). The 14 *phoneme control pseudowords* shared their final phoneme with the corresponding neighbour pseudowords (and reference words). For example, the pseudoword /laʃy/, that only shares its final phoneme with the reference word *début* (/deby/), was the phoneme control pseudoword for the neighbour pseudoword /daby/ derived from *début* (/deby/). A higher use of target final graphemes in neighbour pseudowords than in phoneme control pseudowords would provide evidence for an analogy effect. However, it has been suggested that phoneme–grapheme mappings used in spelling new words could be sensitive to syllabic context (Pacton, Fayol & Perruchet, 2001). That is, some endings may be "irregular" if one considers all words of the language (as in Appendix B) but may actually be very common following some specific phonemes or letters. For example, the mapping /i/ -> IL which is considerably less frequent than /i/ -> I overall, might be more frequent in the context of the syllable /ti/ as in "gentil" (although this seems unlikely in this instance). In the absence of adequate norms, we controlled for this possibility by constructing a set of *14 "syllable" control pseudowords*. The final syllable of the "syllable"

controls was identical to the final syllable of the neighbour pseudowords and of the reference words. For example, /faby/, was the syllable control for the neighbour pseudoword /daby/ derived from the real word *début* (/deby/). A higher use of target graphemes in syllable controls than in phoneme controls will suggest that orthographic choices were influenced by syllabic context. Crucially, a higher use of target graphemes in neighbour pseudowords as compared to syllable control pseudowords will support an analogy effect over and above any effect of context.

The spelling list also comprised *34 filler pseudowords* that were included to vary the final phonemes and to reduce the proportion of target items. All fillers were disyllabic and ended by /õ/, /e/, /ø/ or a consonant. They had no phonological neighbours.

The 76 experimental and filler pseudowords were divided into 4 lists of 19 items in order to minimise carry-over effects across conditions and to be of an appropriate length for the youngest children. Each list contained only one member of each pseudoword triplet. Pseudowords with identical final syllables never occurred in the same list, and pseudowords ending with the same phoneme were always separated by at least five items. Thus, each list contained only three or four neighbour pseudowords (near 20%). Lists always began with three filler items.

Procedure

The pseudoword lists were dictated by teachers in the classroom. This was the most ecologically valid situation since the experimental task was proposed amongst other daily activities without any special emphasis. The experimenter checked that each teacher pronounced the pseudowords according to the phonetic transcription provided. Teachers were not informed of the aim of the study, or of the particularity of some of the stimuli. They told the children that the exercise was made to find out how nonsense words could be spelled. An example of a pseudoword was given and teachers explained that a pseudoword could have several correct spellings. However, the children were not told that pseudowords could be spelled by analogy to real words, and no mention of the reference words was made. Teachers asked children to write each dictated pseudoword on a separate page of a notebook, using the first spelling that came to mind. Each pseudoword was repeated twice, or more on request. Children were tested during four collective sessions spread across a two-week period. They were assessed under examination conditions (i.e., they were unable to see each other's work or talk to each other). The four lists were presented in random order. At the end of the fourth session, the children were asked to spell the 14 reference words to dictation.

Table 1. Experiment 1: Mean number (and standard deviations) of pseudowords spelled with the target final grapheme and mean number (and standard deviations) of correct spellings of the entire reference words (N = 14 in each column).

Grade and mean age	Pseudoword type			Reference words
	Neighbour	Syllable control	Phoneme control	
1 (6;10)	0.37 (0.86)	0.20 (0.49)	0.20 (0.41)	1.96 (2.29)
2 (7;8)	1.03 (1.20)	0.55 (0.90)	0.48 (0.87)	4.24 (2.71)
3 (8;8)	2.34 (1.71)*	0.96 (1.20)	0.79 (0.77)	9.37 (3.41)
4 (9;9)	3.89 (1.79)*	1.96 (1.59)	1.10 (1.11)	11.14 (2.51)
5 (10;8)	5.06 (1.88)*	1.48 (0.91)	1.20 (1.01)	12.00 (1.88)

*Significant neighbourhood effect.

Results

The analysis was restricted to the final grapheme of experimental pseudowords. Final graphemes were spelled in a phonologically plausible way most of the time (from 96% of the time in grade 1 to 98% in grade 5). None of the children ever produced a reference word instead of a neighbour pseudoword. Not surprisingly, children of all grades preferentially used common phoneme–grapheme mappings. In 1st grade, 51% of final phonemes were transcribed using the most frequent corresponding grapheme. This rate was 48% in 2nd grade, and progressively decreased to 31% in 5th grade. Note that apart from the target grapheme (e.g., it for /i/ as in *petit*) and the highest frequency grapheme (i for /i/), a number of other spellings were usually possible (e.g., ie, is, il, ys, y or ît for /i/). The use of these alternative graphemes increased with age.

In order to assess analogy effects, the number of times children used the final grapheme of the reference words was calculated for each category of pseudowords and each group of children (see Table 1). This constituted the dependent variable. The distribution of this variable required the use of non-parametric tests since it was not normal and presented variance heterogeneity. Between-subject effects were tested with the Kruskal–Wallis ANOVA (H statistic) or Mann–Whitney test (z) and within-subject effects were tested with the Friedman ANOVA (Q statistic) or the Wilcoxon signed ranks test (Z). By-items analyses always followed by-subjects analyses.

First, the number of target graphemes varied across school grades for neighbour pseudowords ($H(4, N = 145) = 85.86$; $Q(4, N = 14) = 36.95$, both $P < 0.0001$), syllable controls ($H(4, N = 145) = 41.89$; $Q(4, N = 14) = 26.18$,

both $P < 0.0001$) and phoneme controls ($H(4, N = 145) = 25.20$, $P < 0.0001$; $Q(4, N = 14) = 13.47$, $P < 0.01$). Actually, production of target graphemes increased with grade (Jonckheere test: $J(145) = 7005$, 5812, 5525 for neighbours, syllable controls and phoneme controls respectively, all $P < 0.001$). Moreover, more target spellings were produced for neighbour pseudowords than for either syllable controls ($Z_1(145) = 7.38$, $P < 0.0001$; $Z_2(14) = 3.18$, $P < 0.01$) or phoneme controls (Z_1 $(145) = 8.09$, $P < 0.0001$; $Z_2(14) = 3.04$, $P < 0.01$). Syllable and phoneme control pseudowords differed in the by-subjects analysis (Z_1 $(145) = 2.53$, $P < 0.05$) suggesting that syllabic context affects the probability of producing target graphemes, but this effect did not generalise across items ($Z_2(14) < 1$).

In order to test the interaction between school grade and pseudoword type with nonparametric statistics, a score of analogy was calculated for each subject and each item. This score corresponds to the ratio of the number of target graphemes used in neighbour pseudowords over the number of target graphemes used in the syllable control pseudowords plus a constant (to avoid impossible calculations when no target graphemes occurred in control pseudoword spellings).[1] This analogy score varied ($H(4, N = 145) = 54.78$; $Q(4, N = 14) = 22.61$, all $P < 0.001$) and actually increased significantly with school grade (Jonckheere test, $J(145) = 6294$, $P < 0.001$).

More specific analyses were run to assess the presence of an analogy effect at each level of grade by comparing the number of target graphemes in neighbour pseudowords and in syllable control pseudowords (the most conservative comparison). The analogy effect was significant from grades 3 to 5 (Z_1 (29) $= 3.53$, 3.81, and 4.62, all $P < 0.001$; Z_2 $(14) = 2.67$, 2.8 and 3.18, all P < 0.01) but not in grades 1 and 2 (Z_1 $(29) = 0.77$ and 1.63, both $P > 0.10$; Z_2 $(14) = 1.48$, $P > 0.10$ and 1.99, $P < 0.05$). This might be interpreted as showing that children under 8 years of age cannot use analogies in spelling. However, first and second graders failed to spell most of the reference words accurately (see Table 1). Their very weak dictation scores suggest that the absence of a neighbourhood effect in younger children might be due to their poor knowledge of the spelling of the reference words. This hypothesis is supported by the fact that older children who do show a neighbourhood effect in pseudoword spelling are also far more accurate in their spellings of the reference words. Discussion

Experiment 1 suggests that the orthography of specific words can be activated and can influence pseudoword spelling even in a task that biases towards using sublexical sound-spelling correspondences. Consistent with earlier studies, the analogy effect was only present in children aged eight and over. A common interpretation of this finding is that younger children cannot spell by analogy, because they have not reached the spelling stage at

which this becomes possible (Campbell, 1985; Dixon & Kaminska, 1994). However, we also found that younger participants lacked specific knowledge about the spelling of reference words. This is an important factor that has not always been taken into account in previous experiments. In this situation, no clear conclusion can be drawn from the results of the younger children, since pseudowords could not possibly be spelled by analogy to word spellings that are not known. To clarify this issue, Experiment 2 replicated Experiment 1 with a group of children who were taught the spellings of the reference words.

Experiment 2

Method

Participants

Four classes of 1st grade children and four classes of 2nd grade children took part in this experiment. The classes were from two primary schools located near the school that participated in Experiment 1 and children in the different schools had similar socio-economic backgrounds. The methods of reading and spelling instruction used in the classes that participated in Experiment 1 and 2 were also equivalent. For each grade, two groups of 29 participants were selected according to the same criteria as in Experiment 1. Participants' mean chronological age was 6 years and 11 months (range 5;9–8;3) for the 1st grade and 7 years and 10 months (range 7;2–8;3) for the 2nd grade. The two control groups were the first and second graders tested in Experiment 1.

Learning phase

In the previous experiment, 1st and 2nd graders misspelled most of the 14 reference words. In Experiment 2, teachers introduced these words in their classroom. The reference word list was given to them in November. The objective was for most children to have a good knowledge of these words' spelling at the end of April, prior to the administration of the experimental task. Posters of the words were displayed in classrooms. Each teacher was in charge of developing other materials to enhance learning. Two teachers of each grade introduced the reference words in reading and in spelling tasks, while the two other teachers were asked to introduce the words in reading tasks only. This was done to examine whether training would generalise across tasks. The reference words were introduced during ordinary literacy training sessions. Other words' spellings were learned during the same period under similar conditions so that the reference word learning was not particularly emphasised. Teachers were not informed of the link between the words and some of the pseudowords. They were told that the aim of the study was to

Table 2. Experiment 2: Mean number (and standard deviations) of pseudowords spelled with the target final grapheme and mean number (and standard deviations) of correct spellings of the entire reference words (N = 14 in each column).

Grade	Learning task	Pseudoword type			Reference words
		Neighbour	Syllable control	Phoneme control	
1	Read.	0.27 (0.70)	0.13 (0.44)	0.10 (0.30)	4.58 (4.04)
	Read. & spell.	0.20 (0.41)	0.27 (0.59)	0.13 (0.35)	2.31 (2.55)
	None	0.37 (0.86)	0.20 (0.49)	0.20 (0.41)	1.96 (2.29)
2	Read.	2.68 (2.39)*	1.03 (1.29)	0.48 (0.57)	8.24 (3.47)
	Read. & spell.	3.20 (2.19)*	1.27 (1.25)	0.48 (0.68)	11.66 (2.30)
	None	1.03 (1.20)	0.55 (0.90)	0.48 (0.87)	4.24 (2.71)

*Significant neighbourhood effect.

determine the impact of reading and writing on spelling acquisition and the possible improvement of spelling production in general, as evaluated by the pseudoword dictation task.

Procedure

At the end of the learning phase, the posters were removed from the classrooms. The experimental phase began after a two week holiday period and at the same period of the year as in Experiment 1. The lists of pseudowords dictated by teachers were the same as in Experiment 1. The procedure was also identical. No link was explicitly established between the 14 words previously learned and the pseudoword dictation task.

Results

As in Experiment 1, most final graphemes were transcribed in a phonologically plausible way (89% in 1st grade, 96% in 2nd grade) and no error consisted in writing the reference word instead of the dictated pseudoword. Furthermore, children most commonly used the highest frequency graphemic option in French to translate the target phonemes (47% in 1st grade, 42% in 2nd grade). Table 2 shows the mean number of pseudowords spelled with the target grapheme in each condition. By-subjects and by-items analyses, successively presented, used the same non-parametric tests as in Experiment 1.

Second graders produced more target spellings overall than first graders in neighbour pseudowords ($z(174) = 7.36$, $P < 0.0001$; $Z(14) = 3.3$, $P < 0.001$), syllable controls ($z(174) = 4.24$, $p < 0.0001$; $Z(14) = 2.67$, $P < 0.01$) and

phoneme controls ($z(174) = 2.96$, $P < 0.01$; $Z(14) = 1.99$, $P < 0.05$). The main result is that the second graders of Experiment 2 (who were trained on the spelling of the reference words) did produce more target graphemes in neighbour pseudowords than in both syllable or phoneme controls. This was true for the group that was trained in reading only (neighbours vs. syllable: $Z_1(29) = 3.86$, $P < 0.001$, $Z_2(14) = 2.76$, $P < 0.01$; neighbours vs. phoneme: $Z_1(29) = 4$, $P < 0.0001$, $Z_2(14) = 3.06$, $P < 0.01$) and for the group that was trained in reading plus spelling (neighbours vs. syllable: $Z_1(29) = 3.91$, $P < 0.0001$, $Z_2(14) = 2.62$, $P < 0.01$; neighbours vs. phoneme: Z_1 $(29) = 4.36$, $P < 0.0001$, $Z_2(14) = 3.14$, $P < 0.01$). However, there was no effect of pseudoword type in first graders, who, despite training, produce a similar pattern of response as the first graders tested in Experiment 1.

In order to compare the rate of use of analogies as a function of learning condition using non-parametric tests, we computed a score of analogy for each subject and each item. As in Experiment 1, this score corresponds to the ratio of the number of target graphemes produced in the neighbour pseudoword condition over the number of target graphemes produced in the syllable control condition. There was an overall effect of learning condition in 2nd grade ($H(2, N = 87) = 10.18$, $P < 0.01$; $Q(2, N = 14) = 8$, $P < 0.05$). The reading only condition and reading plus spelling learning condition did not differ from each other ($z(58) < 1.0$; $Z(14) < 1$), indicating that they both lead to a similar increase in analogies as compared to the no learning condition. In 1st grade, there was no difference in the rate of analogies produced in the three groups ($H(2, N = 87) < 1$; $Q(2, N = 14) = 3.93$, $P = 0.14$), showing that training failed to increase the rate of analogies in the youngest children.

Crucially, results of the post-test dictation task (see Table 2) showed that knowledge of the reference words' spelling improved in 2nd grade following both learning procedure ($z(58) = 6.13$ for the reading plus spelling learning procedure; $z(58) = 4.15$ for the reading only procedure, all $P < 0.001$). In grade 1, the spelling of the reference words only improved significantly following the reading only learning procedure ($z(58) = 2.65$, $P < 0.01$), and this effect was relatively small. On average, only 4.58 reference words were spelled correctly so that an analogy effect could not really be expected. As in Experiment 1, only the groups of children who demonstrated good knowledge of the reference word spellings also showed a neighbourhood effect in pseudoword spelling.

Discussion

Results from Experiment 2 show that second graders can use analogies to spell new words provided that they know the spelling of phonologically similar words. No analogy effect was observed in grade 1, but these children

remained unable to spell most of the reference words despite the learning phase. Thus, we cannot conclude about the ability of first graders to spell new words by analogy to known words.

Teachers gave possible explanations of the learning phase inefficiency in the 1st grade. On the whole, they thought that the learning was hard work for them and not adapted to the spelling level of the children. In Experiment 3, we provided teachers with extensive material support specifically designed for collective and individual teaching of the reference words in 1st grade classes.

Experiment 3

Method

Participants

Two classes of 1st grade children participated in Experiment 3, one year after Experiment 2 was conducted. The study involved the same school and the same teachers as in Experiment 2. A group of 29 participants (mean age: 6 years 11 months; range: 6;4–7;3) was selected according to the same criteria as in Experiments 1 and 2. The control group was taken from Experiment 2 (grade 1, reading plus spelling group).

Learning phase

In Experiment 3, extensive support material was constructed to help teachers during the learning phase. For each reference word, this material consisted of posters of the word and a corresponding image for bill posting in class together with 11 individual exercises of word recognition, reading and spelling, where words were presented in isolation or embedded in short sentences. The material and exercise types were similar to those normally used by teachers. The learning phase lasted approximately as long as in Experiment 2 (from November to April). Teachers introduced one word per week, for 14 weeks. They read each word when it was posted on the classroom wall, as usually done for all posted words. They were also read a few times when presenting the exercises. The children then worked on the exercises individually without the help of teachers.

Procedure

Following the learning phase, the experimental phase began after a two week holiday period, at the end of April. The lists of pseudowords dictated by teachers were the same as in Experiments 1 and 2. The procedure was also identical. As before, posters of the reference words were removed during the holiday period that preceded testing.

Table 3. Experiment 3: Mean number (and standard deviations) of pseudowords spelled with the target final grapheme and mean number (and standard deviations) of correct spellings of the entire reference words in first graders ($N = 14$ in each column).

Group	Pseudoword type			Reference words
	Neighbour	Syllable control	Phoneme control	
Experimental	1.96 (2.24)*	0.55 (0.78)	0.37 (0.49)	11.96 (1.95)
Control	0.20 (0.41)	0.27 (0.59	0.13 (0.35)	2.31 (2.55)

*Significant neighbourhood effect.

Results

As in Experiments 1 and 2, most target phonemes were spelled in a phonologically plausible way (98%) and children never produced a reference word instead of a pseudoword. As before, children preferentially used the most frequent phoneme–grapheme correspondences (51%). The number of target graphemes produced (see Table 3) were analysed using the same by-subjects and by-items non-parametric tests as in previous experiments.

Children who were taught the spelling of the reference words using the improved teaching method produced more target spellings for neighbour pseudowords than for either phoneme control ($Z1(29) = 3.38$, $P < 0.001$; $Z2(14) = 2.93$, $P < 0.01$) or syllable control pseudowords ($Z1(29) = 3.24$; $Z2(14) = 2.8$, both $P < 0.01$). In order to compare the rate of analogies between groups, we used the same ratio score as in earlier experiments. This confirmed that the rate of analogies was higher in the group of children who received the new training ($z(58) = 3.35$, $P < 0.001$; $Z(14) = 2.98$, $P < 0.01$).

Crucially, results from the reference word dictation task revealed that the new learning procedure was successful. Children in this group accurately spelled 12/14 reference words on average as opposed to 2.3/14 in the control group.

Discussion

Experiment 3 shows that even 1st grade children can spell new words by analogy to known words provided that they know how to spell the reference words. This is consistent with the pattern of results obtained in Experiments 1 and 2 and confirms that knowledge of the reference words is a critical determinant in the production of analogies.

Table 4. Mean analogy scores[a] (and SD) as a function of grade and word spelling scores.

Grade	Reference word spelling scores				
	0–2	3–7	8–11	12–14	Total
1st	$N = 54$	$N = 24$	$N = 17$	$N = 21$	$N = 116$
	0.16 (0.49)	0.50 (0.79)	1.43 (1.80)	2.26 (2.90)	0.80 (1.67)
2nd	$N = 9$	$N = 32$	$N = 20$	$N = 26$	$N = 87$
	0.33 (0.70)	1.62 (1.63)	2.08 (1.66)	2.86 (1.98)	1.96 (1.82)
From 3rd to 5th	$N = 1$	$N = 9$	$N = 30$	$N = 42$	$N = 82$
	0.50	2.36 (2.04)	2.25 (1.41)	3.04 (2.60)	2.64 (2.18)
Total	$N = 64$	$N = 65$	$N = 67$	$N = 89$	
	0.19 (0.52)	1.31 (1.58)	1.99 (1.61)	2.80 (2.51)	

[a]The analogy score corresponds to the number of target graphemes produced in neighbour pseudowords divided by the number of target graphemes produced in syllable control pseudowords.

Post hoc analyses

Two post-hoc analyses were conducted on the overall results from all three experiments to examine the extent to which the production of analogies was related to: (a) level of lexical knowledge and/or (b) sound-to-spelling conversion abilities.

Relationship between lexical knowledge level and the rate of analogies

In the first analysis, an analogy score was calculated for each subject as in the previous experiments. Subjects were classified according to school grade (3 levels: grade 1, grade 2 and grades 3–5) and according to their lexical knowledge, as estimated from their score on the reference word spelling task (4 levels: from 0 to 2, 3 to 7, 8 to 11and 12 to 14). The mean analogy scores of each group are presented in Table 4.

Subjects with a lexical score of 0 to 2 were discarded from the analysis because their distribution did not allow a cross-level comparison. Kruskal-Wallis test revealed an effect of lexical knowledge in Grade 1 ($H(2, N = 62) = 6.74$, $P < 0.05$) and Grade 2 ($H(2, N = 78) = 7.42$, $P < 0.05$). This shows that lexical knowledge influenced the production of analogies in young children's pseudoword spelling even when the influence of grade was neutralised. The effect was not significant in Grades 3–5 ($H(2, N = 81) < 1$), which might be due to a ceiling effect on lexical knowledge in that group. There was an effect of school grade at the second level of lexical knowledge ($H(2, N = 65) = 12.05$, $P < 0.01$) but not at the third and fourth levels ($H(2, N = 67) =$

Table 5. Mean (and SD) of the score estimating alphabetic abilities (sound-to-spelling Correspondences) as a function of grades and experiments (max = 20).

Experiment	Grade				
	1	2	3	4	5
1	6.73 (3.63)	10 (2.48)	14.33 (2.29)	13.34 (2.12)	14.52 (2.23)
2	6.48 (3.75)	10.25 (3.49)			
3	7.24 (2.85)				

4.85, $P = 0.09$ and H(2, $N = 89$) = 3.07, $P = 0.21$). In addition, the analogy scores of second and third-to-fifth graders did not differ at any of the lexical knowledge levels (all z($N = 41$, 50 and 68) < 1). Thus, for the same level of lexical knowledge, second graders produced as many analogies as older children did. In addition, first and second graders did not differ in their use of analogies except at the lower lexical knowledge level (level 3–7: z(56) = 2.87, $P < 0.01$; level 8–11: z(37) = 1.49, $P = 0.13$; level 12–14: z(47) = 1.43, $P = 0.15$). Moreover, the scores of first and third-to-fifth graders who had the best lexical knowledge did not differ (level 3–7: z(33) = 2.54, $P < 0.05$; level 8–11: z(47) = 2.09, $P < 0.05$; level 12–14: z(63) = 1.65, p = 0.10). This suggests that with a high level of lexical knowledge, first graders can spell by analogy as much as older children.

Relationship between alphabetic abilities and the rate of analogies

According to stage theories (Frith, 1985), children progress to the orthographic spelling stage (at which analogies can be used) once they have reached a sufficient mastery of the alphabetic level. Although this may not entail that children need to have perfect alphabetic skills before they can move on to the next stage, a relationship should be expected between alphabetic skills and the production of analogies, especially in younger children. This question was studied in a second post-hoc analysis in which knowledge of sound-to-spelling correspondences was estimated for each participant and compared between the different grades. Accuracy in pseudoword spelling was taken as an indicator of sound-to-spelling knowledge. The scores presented in Table 5 are based on a subset of 20 pseudowords used in Experiments 1 to 3 (14 fillers and 6 controls) that contained either a consonant cluster or a context-sensitive grapheme, in order to avoid ceiling effect. Spellings were scored as accurate if they were phonologically plausible, that is, if they could be pronounced as the auditory stimulus.

First, there was a wide range in pseudoword spelling accuracy across grades (from 35% in Grade 1 to about 75% in Grade 5). Second, sound-

to-spelling knowledge was less established in the second graders tested in Experiment 2 than in 4th and 5th graders [$F(1,114) = 45.46$, MSe = 8.60, $P < 0.0001$]; nevertheless these 2nd grade children produced as many analogies as older ones (see post hoc analysis 1). Third, the first graders tested in Experiments 2 and 3 did not differ in their alphabetic ability [$F(1,56) = 2.41$, MSe = 9.24, $P = 0.125$] although only children tested in Experiment 3 showed an analogy effect.

Discussion

Post-hoc analyses confirmed that analogy production was primarily determined by the children's lexical knowledge. Provided they had a high knowledge of the reference words, first and second graders produced as many analogies as older children did. Moreover, the analogy rate was not systematically related to alphabetic skills.

General discussion

In summary, the purpose of this series of experiments was to demonstrate that children use analogies in naturalistic situations of learning to spell from the beginning of literacy acquisition. In Experiment 1, an analogy effect was obtained for children of grades 3 to 5 but not for younger children. However, we could not conclude that younger children are not capable of spelling by analogy because they were unable to spell most of the reference words accurately. In Experiments 2 and 3, the spelling of reference words was taught in the months preceding the experimental spelling to dictation task, with a gap of two weeks between the two phases. These words were introduced as part of everyday literacy lessons and were interspersed with many other words that form part of the regular curriculum. We are therefore confident that our method was naturalistic. When the spelling of the reference words was effectively learned prior to the experiments, significant analogy effects were obtained in second and even in first graders, who had received only six months of formal literacy training. Furthermore, spelling by analogy occurred in conditions that discouraged any overt strategy, since no clue words or lexical primes were used as prompts and since only 20% of the pseudowords were close to real words. The present findings therefore suggest that children of all ages can perform analogies in naturalistic situations of learning to spell.

Our study also revealed that the rate of analogical spellings is dependent upon knowledge of the reference words but not on children's alphabetic skills. With regards to alphabetic skills, 1st grade children who demonstrated an analogy effect in Experiment 3 had a similar mastery of phoneme–grapheme

correspondences to 1st graders in Experiments 1 and 2 who did not show any analogy effect. With regards to orthographic knowledge, the use of analogies by 2nd graders in Experiment 2 was comparable to that of older children with the same level accuracy on reference word spelling (even though the older children had better alphabetic skills as shown in Table 6). Overall, the use of analogical spellings seems independent of the children's alphabetic skills but crucially related to reference word knowledge.

Several studies have concluded that younger children do not spell by analogy to the same extent as older ones (Campbell, 1985; Marsh et al., 1980; Deavers & Brown, 1997). Our findings contradict this view, as third to fifth graders did not produce more analogies than either second graders or first graders who had a good knowledge of the reference words. This demonstrates that children from different grades show similar use of analogy as far as they have similar levels of lexical knowledge. We therefore conclude that earlier failures to demonstrate analogy effects in beginning spellers were probably due to the fact that younger children (with more limited lexical knowledge) did not know the reference words, rather than to the fact that children of different ages employ fundamentally different spelling strategies.

The present findings also suggest that it is inappropriate to view spelling acquisition as stage-like, with new processes emerging at different points during development. According to a strict version of stage-based theory, lexical analogies are used only in later stages of literacy acquisition once alphabetic skills are sufficiently well established. In other words, novice spellers should only be able to generate new word spellings by using a sublexical phoneme–grapheme conversion process. Contrary to this hypothesis, we observed that children within the first 6 months of literacy training can successfully learn inconsistent word spellings and use this knowledge to produce analogies, which demonstrates an ability to use an orthographic strategy from the very beginning of spelling acquisition (see Varnhagen, Boechler & Steffler, 1999, for similar results on English vowel spelling). Thus, our results are more compatible with theories positing that children of all ages use multiple processes to spell words (Siegler, 1995; Rittle-Johnson & Siegler, 1999). In addition, our study shows that the frequency with which a particular process is used to spell new words can be experimentally modified. First graders who demonstrated almost no use of analogy in Experiment 1 showed reliable effects in Experiment 3 when the familiarity of the reference words was increased, providing a basis for analogies to occur.

This analogy by familiarity account supports an item-based perspective of spelling acquisition similar to that proposed by Share (1995, 1999) with respect to reading. In this perspective, the occurrence of analogies will depend primarily on the frequency with which a child has been exposed to a partic-

ular word together with the similarity between this word and the target item. Our data suggest that relatively few exposures are necessary to acquire word specific orthographic information that will form the basis for analogy spelling. Indeed, earlier studies have shown that after only a few exposures to new words, children can name them more quickly, identify them more successfully and reproduce them more accurately (Erhi & Saltmarsh, 1995; Manis, 1985; Reitsma, 1983; Share, 1999). Similarly, very young children exposed a few times to a novel grapheme within a single word will use this grapheme in spelling new words (Bernstein and Treiman, 2001). Therefore, there is converging evidence suggesting that children establish specific orthographic knowledge rapidly, and that they use this knowledge to generate new word spellings as soon as it is available.

It would go beyond the scope of this article to give a detailed interpretation of the pattern of results we obtained in terms of specific theories of spelling. However, our results are globally consistent with at least two possible views of the spelling process: (a) a single-route connectionist account, in which spelling is always the result of an analogy process or (b) a dual-route account, in which the lexical and sublexical processes would interact at an output level, therefore allowing for a lexical influence on pseudoword spelling.

The functioning of purely analogical (single-route) connectionist models of spelling is by definition item-based since connection weights vary according to the words the network is exposed to. In this general framework, spelling could be conceptualised as a multiple-trace memory process of the kind proposed for reading by Ans, Carbonnel, and Valdois (1998; see also Brown & Loosemore, 1994 or Plaut, McClelland, Seidenberg & Patterson, 1996). Such models predict that the rate of analogy responses will be a function of lexical knowledge and primarily determined by the size of the vocabulary over which the analogy process may operate.

In fact, within the connectionist framework, spelling is primarily viewed as an analogy process. Orthographic sequences are generated based on the activation of all known words and as a function of their phonological similarity with the input. Spelling of pseudowords having only one close phonological neighbour should be influenced by this lexical neighbour according to its relative frequency in the lexical database. It is only when the reference word is among the lexical words that have the highest activation level during the experimental phase that its neighbour pseudo-word is likely to be spelled with the final target grapheme. However, the proportion of spellings obviously resulting from an analogy process (because of the production of low probability target graphemes) does not say much about the real frequency of analogical spellings in novice spellers. When reference words are not sufficiently familiar to the children, many phonological words weakly activated

by the input will contribute to the spelling output. Therefore, the graphemes most frequently associated in the lexical database to each of the pseudowords' constituent phonemes will be activated. The spelling output will then result in a sequence of graphemes most frequently associated to the input phonemes, suggesting the use of phoneme–grapheme conversion rules. Because rule-like spellings would actually derive from analogical processing, they would become more accurate as the lexical database is extended and diversified. Since the probability of knowing reference words also increases with the amount of lexical knowledge, rule-like spellings should develop in parallel with obvious analogical spellings.

As mentioned earlier, our results are also consistent with "dual-route" models of spelling, if some degree of interaction between lexical (stored whole-word orthography) and sublexical (phonology to orthography correspondence) processes exists. In the literature on adult spelling, several authors (e.g., Barry, 1988; Kreiner, 1992) have made the general suggestion that lexical and sublexical processes, although not directly influencing each other, may interact at an output level. Subsequently, more specific proposals for a mechanism of lexical-sublexical integration have been put forward (Houghton & Zorzi, in press; Rapp, Epstein & Tainturier, 2002; Tainturier & Rapp, 2001; Tainturier, Bosse, Valdois & Rapp, 2000). The suggestion is that spelling is the result of the activation of a single layer of output graphemic units (i.e., letters and/or graphemes) that are activated jointly by lexical orthographic knowledge and by sublexical phonology to orthography conversion processes. This proposal reduces the degree of autonomy of lexical and sublexical processes because both processes would activate a common level of representation. As a result, the spelling of either words or pseudowords would be under the combined influence of lexical and sublexical processes. The selection of a letter string for output would result from the integration (e.g., through summation of activation values) of these two sources of activation and would be a function of their respective strength. This general proposal can in principle account for analogy effects in pseudoword spelling. This is because the likelihood of a given grapheme (e.g., *il* for /i/) being selected for output would depend not only on the overall frequency of use of this mapping relative to other mappings (e.g., *i*, *is*, *it* for /i/), but also on the degree to which this grapheme is activated by lexical orthographic units at any given time. As in purely analogical models, the influence of lexical neighbours on the spelling of pseudowords should be stronger when neighbours are of higher frequency and when they are phonologically close to target pseudowords (as shown in adults by Tainturier et al., 2000). Since there is no reason to assume that the lexical and sublexical processes cannot develop in parallel during spelling acquisition (contrary to what is implied in

some stage models), this interactive dual-route framework can also account for our findings of a lexical influence on pseudoword spelling in beginning spellers.

In conclusion, we have provided evidence that children can spell nonwords by analogy to real words from the beginning of formal spelling instruction, provided that they can spell the reference words used in the experimental tasks designed to assess analogy effects. This finding does not support a strict version of stage models in which analogical processing emerges later on in spelling acquisition, once alphabetic knowledge is fully established. Rather, our data suggest that children's early spelling reflects the use of a lexical database in constant evolution. Whether this influence of real word knowledge on the spelling of new words is best accounted for in purely analogical models or in interactive dual-route models is a matter for future research, and more computationally explicit theories are needed before this issue can be resolved.

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Appendix A

List of the reference words (target graphemes underlined) and of the three types of matched pseudowords used in Experiments 1, 2 and 3.

Reference word	Neighbour pseudoword	Syllable control pseudoword	Phoneme control pseudoword
Sold<u>at</u> /ʃɔlda/ (soldier)	/ʃɔlda/	/nɛlda/	/pilga/
Déb<u>ut</u> /deby/ (beginning)	/daby/	/faby/	/laʃy/
Beauc<u>oup</u> /boku/ (a lot)	/loku/	/laku/	/tãpu/
Moy<u>en</u> /mwajɛ̃/ (medium)	/nwajɛ̃/	/dɥijɛ̃/	/fwalɛ̃/
Print*<u>emps</u>* /prɛ̃tã/ (spring)	/brɛ̃tã/	/klytã/	/drofã/
Gent<u>il</u> /ʒãti/ (kind)	/ɛuti/	/myti/	/byli/
Tab<u>ac</u> /taba/ (tobacco)	/toba/	/ɛiba/	/ʒyna/
Déf<u>aut</u> /defo/ (fault)	/tefo/	/ryfo/	/nedo/
Parf<u>um</u> /parfœ̃/ (perfume)	/barfœ̃/	/sirfœ̃/	/virsœ̃/

Reference word	Neighbour pseudoword	Syllable control pseudoword	Phoneme control pseudoword
Petit /pəti/ (small)	/bəti/	/lõti/	/tãʒi/
Crapaud /krapo/ (toad)	/krəpo/	/frəpo/	/gliro/
Tuyau /tɥijo/ (pipe)	/nɥijo/	/ʃujo/	/rwalo/
Repas /rəpa/ (meal)	/repa/	/lypa/	/tida/
Sirop /siro/ (syrup)	/ʃiro/	/vøro/	/mevo/

Appendix B

Frequency of use (in percentages) of the most frequent graphemes and of the target graphemes for each final phoneme used in the experimental list.

Phonemes	Most frequent graphemes	%	Target graphemes	%
/a/	a	34.5	at	29.8
			as	3.6
			ac	1
/i/	i	49.5	it	18.2
			il	0.8
/o/	eau	48.7	aut	2.5
			au	1.2
			aud	1.1
			op	0.3
/ɛ̃/ or /õ/*	in	41.1	en	19.4
			um	0.6
/y/	u	73.6	ut	5.2
/u/	out	37.9	oup	36.2
/ã/	ent	56.7	emps	1.4

*Indicates two phonemes that were indistinguishable due to regional accent.

Note

1. Results with a score using phoneme control pseudowords are not presented but always provided equivalent or higher significance.

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