Reading and spelling acquisition in two different teaching methods: A test of the independence hypothesis

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ABSTRACT: The development of word reading and word spelling was examined in French speaking children initially instructed either by a phonic or a whole-word method. Second, fourth and sixth graders were administered to reading and spelling tests in which grapho-phonological regularity, frequency, length and lexicality were manipulated. The results showed that in both curricula, reading and spelling acquisition can be characterized by a parallel increase in the use of sub-lexical correspondences and in the reliance on word-specific information. Contrary to a simple view of lexical development according to which the use of analytical knowledge and the use of word-specific knowledge correspond to two different cognitive processes that develop independently from each other, whole-word children did not appear to rely more on whole-word knowledge. On the contrary, and paradoxically, grade 2 whole-word children tended to use analytical correspondences to a greater extent than their peers. In later development, reading matched phonic and whole-word groups did not differ from each other. It is argued that the results support the hypothesis that the acquisition of sub-lexical correspondences constitutes a necessary step in the acquisition of reading and spelling. We conclude that the analytic comparison of different curricula provides a naturalistic tool for the study of the dynamics of development.

KEY WORDS: Reading development, Spelling development, Teaching method

INTRODUCTION

Are there several ways to learn to read and write? And if there are, do the teaching methods influence the course of development, and can they have long-term effects? In this study, we wanted to establish to what extent teaching methods influence the nature of the competencies used in reading and spelling isolated words.

Given the nature of the relation between orthography and pronunciation in alphabetical systems, two kinds of general competencies may be usefully distinguished at the behavioral level to characterize the stable state. The word recognition competence refers to the capacity to retrieve information stored in memory about familiar words, and the decoding competence consists in using knowledge productively or generatively with new forms. A skilled subject must possess both competencies, for not all words can be read or spelled on the basis of general rules, and efficient reading or spelling presupposes the ability to face novel linguistic forms.

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There has been much debate about the nature of the cognitive mechanisms implementing these competencies. The dual-process framework (Coltheart 1978; Patterson & Morton 1985) is based on the assumption that the word recognition and the decoding competence correspond to distinct cognitive processes. For reading, one process, often called addressing, consists in retrieving the phonological code corresponding to the orthographic stimulus from the mental lexicon. The other procedure, called assembling, uses sublexical regularities to derive a phonological form. An analogous framework has been proposed to account for word spelling (see Morton 1980; Ellis 1984). Subjects may retrieve orthographic information stored in the lexicon (the addressing strategy), or they may use sound-to-spelling regularities (the assembling strategy).

In recent years, the dual-process framework has been challenged on several grounds. The strongest attack has come from simulation work. Using a connectionist approach, Seidenberg & McClelland (1989) have shown that a number of empirical findings hitherto interpreted in terms of cooperation and competition between separate processes could be accounted for within a single mechanism based on weighted distributed associations between orthographic and phonological codes. A similar single-process account of spelling performance has been recently proposed by Brown & Loosemore (1994).

It is, however, not clear whether the single-process framework provides a better account of all aspects of human reading and spelling performance. Several authors have pointed out that Seidenberg & McClelland's (1989) model did not succeed in simulating some neuropsychological dissociations (e.g. Coltheart, Curtiss, Atkins & Haller 1993). Similarly, normal subjects have been found to modulate their use of lexical and sublexical information as a function of experimental conditions in ways that suggest some degree of dissociation between the two knowledge sources (Content & Peereman 1992; Monsell, Patterson, Graham, Hughes & Milroy 1992; Peereman & Content 1993).

From a developmental viewpoint, one central question is whether these two competencies develop independently from each other, or alternatively, and whether there are strong constraints on the dynamics of development. Although they are obviously related, the cognitive structure issue and the developmental dynamics issue are only loosely connected. In general, the finding that a given competence constitutes a prerequisite of the acquisition of another skill does not entail the inference that the prerequisite and the consequent abilities are realized at the cognitive level as a single subsystem. For instance, it is conceivable that the prerequisite ability constitutes a transient utility which renders the consequent learnable. Conversely, two behavioral competencies supported by the same cognitive component will probably never be fully independent in their acquisition, but different developmental patterns might be observed, such as monodirectional dependency, synergy, or interference.

One view, attractive for its simplicity, is what we shall call the independence hypothesis, i.e. that each component develops at its own rate, independently of the other. Marshall (1984) has advocated that developmental failures should be interpreted in relation with the functional architecture of the adult system and might closely match the syndromes of acquired dyslexia. As Marshall notes, this choice presupposes that the (gross) architecture of the reading system is pre-wired. But it also denies the possibility that one component B crucially depends on the pre-existence of another component A for its development. Indeed, in that case any defect or delay in the acquisition of A will automatically transfer to B, and some patterns of dissociation (such as B without A), which may be expected if A and B are structurally separate, should never occur in developmental pathology.

By contrast, many theorists (Frith 1985; Marsh, Friedman, Desberg & Welch 1980; Marsh, Friedman, Welch & Desberg 1981; Seymour & MacGregor 1984; Seymour 1986) have assumed the existence of qualitatively distinct and inter-dependent stages in the acquisition of reading and spelling. For example, Frith (1985) and Seymour (Seymour & MacGregor 1984; Seymour 1986, 1987a, b) described reading acquisition as a succession of three stages, characterized by the predominant use of distinct processing strategies. Both authors share the assumption that developmental disorders can best be described as arrests at some point in the sequence, which block the acquisition of subsequent components. A central claim of both Frith's and Seymour's models concerns the dependency between decoding – the alphabetic strategy – and rapid and efficient word identification and production – the orthographic strategy. Similarly, other authors have argued that knowledge of analytical correspondences might facilitate the acquisition of reading and spelling (see Content 1990; Content, Morais, Alegria & Bertelson 1986; Jorm & Share 1983; Stuart & Coltheart 1988).

On empirical grounds, two indirect lines of evidence support this hypothesis. First, numerous studies have shown a strong relationship between phonemic analysis of speech and reading acquisition (see Bradley & Bryant 1983; Content 1984; Lundberg, Frost & Petersen 1988; Morais, Alegria & Content 1987; Wagner & Torgesen 1987). Second, reviews of educational studies indicate that instructional curricula that include systematic teaching of phonics produce higher attainment levels in reading (Adams 1990; Chall 1967, 1979). Both arguments demonstrate that knowledge of sub-lexical correspondences is related to general measures of reading, but they do not directly show that decoding influences or determines the acquisition and use of word-specific knowledge.

One potential counter-argument stems from the claim of behavioral dissociations between the use of decoding and word-specific knowledge. Some researchers (Baron 1979; Baron & Treiman 1980; Bryant & Impey 1986; Treiman 1984) have argued that there is substantial variability in how children read and spell. Among beginning readers of comparable efficiency, some

appear to rely mainly on sub-lexical knowledge (the 'Phoenicians') and others on word-specific knowledge (the 'Chinese'). However, the crucial question is whether all types of reading behaviour lead to similar efficiency at the stable state. Recently, Byrne, Freebody & Gates (1992) examined the evolution of two contrasted groups of second grade poor readers, one with adequate decoding ability and below average skills on irregular words (the Phoenicians) and the other with average sight word recognition ability but poor decoding skills (the Chinese). Relative to each other, the Phoenicians were improving from grade 2 to grade 3, whereas the Chinese were declining in the ability to read both regular and irregular words as well as in reading comprehension.

Furthermore, recent work by Gough and Walsh (1992) challenges the mere existence of extreme 'Chinese-type' readers among normal learners. They examined inter-individual variability in pseudoword and exception word reading and found subjects with high pseudoword reading and low exception word reading, but no children with high exception word reading and low exception word reading. This suggests that pseudoword reading is necessary, but not sufficient, to exception word reading. In addition, the same authors demonstrate that children with good decoding skills learn new irregular words quicker than children poor at decoding, corroborating the notion that knowledge of sublexical correspondences facilitates the acquisition of word-specific information.

Another, naturalistic, way to test the notion of developmental independence consists in examining the effect of teaching methods on how children read and spell. If there is independence, the specific training of one or the other competence should result in the emergence of the trained competence at its asymptotic level even in the absence of the other. So, under the independence hypothesis, one would expect that children instructed by a whole-word method would develop the word recognition competence, whereas those instructed by a phonic method would display decoding capacity.

Several studies, mostly based on the analysis of reading errors, indicate a clear effect of teaching method on early reading (Barr 1975; Biemiller 1970; Seymour & Elder 1986): whole-word instruction leads to reading errors that reflect the influence of semantic and syntactic context, and the responses are often visually similar words belonging to the set of words learned in the classroom (see Seymour & Elder 1986). These observations support the notion that children instructed by a whole-word method acquire the word recognition competence without the decoding capacity. Conversely, when the instruction emphasizes letter-sound correspondences, indications of early decoding competence are observed in reading and spelling (Seymour & Evans 1992).

Other studies demonstrated an influence of teaching method on explicit speech segmentation abilities, which develop more rapidly in the context of phonic instruction (Alegria, Pignot & Morais 1982; Perfetti, Beck & Hughes 1987). For example, Alegria et al. (1982) showed that children instructed by a whole-word method were worse than children instructed by a phonic method

when asked to reverse the phonemes of a monosyllabic word presented orally while the two groups were comparable when the task consisted of reversing syllables.

The long term effects of teaching methods have rarely been investigated. Using a lexical decision task, Johnston and Thompson (1989; see also Thompson & Johnston 1992) found that 8-year-old children instructed with a phonic method in Great Britain made more errors on pseudo-homophones in a lexical decision task than children educated with a whole-word method in New Zealand. However, no difference between the two groups remained in a phonological lexical decision task, in which subjects had to say whether the pseudowords were pronounced like real words or not. Thus, while children instructed by a whole-word method may be less prone to rely on phonology when it is not necessary (as in the standard LD task), they are as able as pupils educated by a phonic method to use analytical correspondences when required. More recently, Masterson, Laxon & Stuart (1992) tested second grade children from schools that put little emphasis on formal phonics instruction, and they also observed indications of decoding ability. Children made more errors on irregular than on regular words in a naming task, and they confused pseudo-homophones (e.g. daze) and words (days) in a word comprehension task.

In summary, while there are clear indications of differences related to the method at the onset of literacy acquisition, little is known about the effect of methods on later development. Our aim was to assess in more detail the development of isolated word naming and spelling as a function of teaching methods.

Rationale and design of the tests

Four reading tests and two spelling tests[1] were administered to groups of second, fourth and sixth grade children recruited in two schools using contrasted (phonic, PH vs whole-word, WW) teaching methods. As previous studies have shown that the ability to analyze speech into segments emerges earlier in the context of phonic instruction (Alegria, Pignot & Morais 1982), a speech segmentation test was introduced in order to validate the difference between the two teaching methods.

The first reading test assessed the effect of regularity. Regular words conform in pronunciation to the most frequent correspondences between letters (or letter groups) and speech sounds. Conversely, the pronunciation of irregular words cannot be obtained on the basis of analytic correspondences because they include spelling patterns that deviate from their most usual pronunciation. Hence, the comparison between regular and irregular words permits to contrast the use of recognition and decoding abilities. If children predominantly use the recognition strategy, no difference between regular and irregular words should come out. Conversely, if the decoding strategy dominates, performance should be better for regular words, and regularisation

errors should occur on irregular words. Regularity effects on naming time and accuracy have been reported both for skilled readers (Content 1991; Seidenberg, Waters, Barnes & Tanenhaus 1984) and beginners (Backman, Bruck, Hebert & Seidenberg 1984), and the effect decreases with reading level, suggesting that whole word recognition gradually becomes predominant.

In the second test, we varied the degree of complexity of the grapho-phonological correspondences and the lexical status of printed stimuli. Simple items, words and pseudowords were made of letters that systematically correspond to one phoneme, independently of the orthographic context. Complex items contained at least one grapheme in which several letters correspond to one phoneme or several pronunciations are permissible depending on the orthographic context. Thus, the test aimed at investigating the contribution of lexical knowledge by comparing performance for very frequent words and pseudowords, and by comparing the effect of complexity on words and pseudowords. Since grapho-phonological complexity affects decoding, the effect should be more limited for words than for pseudowords.

The third test compared high-frequency words, low-frequency words and pseudowords varying in length. It is generally accepted that the presence of a frequency effect indicates a lexical contribution. Similarly, since decoding includes a serial component, a difference in length effects for words and pseudowords would suggest a contribution of lexical knowledge.

In the last reading test, words, homophonic pseudowords and non-homophonic pseudowords were presented to isolate two components of the word/pseudoword difference. The comparison of words and homophonic pseudowords would assess the advantage resulting specifically from the recognition of the orthographic forms, because the two types of stimuli share the same pronunciation. The second contrast (homophonic vs non-homophonic pseudowords) would indicate the advantage resulting from the familiarity of the phonological form obtained through decoding.

The first spelling test consisted of regular words and pseudowords. As in reading, an advantage for words over pseudowords would indicate the contribution of lexical knowledge. We also looked at the influence of the presence of consonantic clusters on spelling performance. The detrimental effect of consonantic clusters on children's spelling performance (Bruck & Treiman 1990) likely results from a greater difficulty in analyzing consonant clusters in the speech stream and would thus constitute an additional indication of reliance on analytical correspondences.

The second spelling test assessed the contribution of lexical orthographic knowledge. Words varying in frequency and orthographic transparency were compared. Ambiguous and exception words cannot be spelled solely on the basis of analytical correspondences. Hence, the evolution of spelling performance on these types of words provides further clues to the development of word specific knowledge (Waters, Bruck & Seidenberg 1985; Waters, Bruck & Malus-Abramowitz 1988).

METHOD AND RESULTS

Subjects. Different teaching methods are used in Belgium and some degree of choice is given to principals and teachers in this regard. It is thus possible to find public schools applying different approaches. The two schools for this study were selected after interviews with the teachers and informal observation in the classrooms. Two types of methods will be considered here. In the phonic school, letter-sounds correspondences were taught progressively and systematically from the beginning of the first year. In the whole-word school, the beginning of learning was based on rote memorisation of written words coming from sentences or texts proposed by the children. The vocabulary was not selected. The letter-sound correspondences were not taught systematically; some of them were given a set of words containing a particular letter-sound relation when it was encountered. The emphasis was on comprehension and communication.

It should be noted that both institutions were public schools and recruited in similar social layers. Parental occupations rated on a three-point scale gave similar distributions for the two schools: 11, 16 and 11 respectively for high, medium and low occupational status in the phonic school, and 13, 15 and 11 for the whole-word school.

Samples of second, fourth and sixth graders were tested. Table 1 provides further details on the characteristics of the groups. A few subjects missed some of the tasks because of extended absence from school, and a few data were lost because of technical failures. This accounts for the slight variations in sample size across tests.

Reading efficiency was assessed with a forced-choice sentence completion test (Lobrot 1973). Five alternatives were provided on each of the 36 sentences. The complexity of the vocabulary increases gradually, so that the test is sensitive to a large range of reading ability. The test was administered collectively in each classroom. Children had to complete as many sentences as they could in five minutes.

A three (Grade) × 2 (Method) ANOVA was carried out on the percentage of correct responses (see Table 1). Performance increased with grade [$F(2,80) = 71.57$; $p < 0.001$]. Overall, the WW groups were slightly better than the PH groups [$F(1,80) = 4.65$; $p < 0.05$], though the interaction was also

Table 1. Characteristics of subjects

	2PH	2WW	4PH	4WW	6PH	6WW
N	16	14	14	16	12	16
Age (years; months)	7;10	7;9	10;1	9;11	12;0	12;0
Reading score (Lobrot)	24.86	13.86	52.48	69.71	67.54	88.25

significant [$F(2,80) = 5.98$; $p < 0.005$], reflecting the fact that, while in grade 2 the PH group was better than the WW group, while the WW group surpassed the PH group from grade 4. This performance pattern was also observed in all reading and spelling tests.

It is interesting to note that the grade 4 WW group and the grade 6 PH group had equivalent reading skill. These two groups thus provide an opportunity to investigate processing differences as a function of teaching methods with a reading level match design. This analysis has been performed for all subsequent tests and will be reported only when significant differences are observed.

Metaphonological tests

Children were asked to produce what remained of a word after deletion of a part specified orally by the experimenter. The task consisted of 40 trials, belonging to three conditions presented successively. In the Syllable condition (8 trials) either the initial or the final syllable had to be stripped out. In the Consonant condition (16 trials) subjects had to delete either the initial or the final consonant from CVC words. In the Consonant-Cluster condition (16 trials), they had to delete either the first or the second consonant from CCV(C) words. Only one example was given (/ʃɔkɔla/ without /la/) before the 40 experimental trials. Feed-back was given at each trial.

Results. A 3 (Grade) by 2 (Method) by 3 (Condition) ANOVA was performed on percentage of correct responses (see Table 2). Performance increased with Grade [$F(2,82) = 24.50$; $p < 0.001$] and the PH groups performed better than the WW groups [$F(1,82) = 12.11$; $p < 0.001$]. The difference between PH and WW groups decreased with grade [$F(2,82) = 4.36$; $p < 0.05$] but the grade 4 and 6 PH groups still outperformed the WW groups for consonant suppression. The effect of Condition was significant [$F(2,164) = 26.48$; $p < 0.001$], and interacted both with grade [$F(4,164) = 15.12$; $p < 0.001$] and with method [$F(2,164) = 6.86$; $p < 0.001$].

A planned comparison between syllable deletion and the two consonant deletion conditions yielded a significant effect [$F(1,82) = 20.44$; $p < 0.001$], which interacted with grade [$F(2,82) = 22.03$; $p < 0.001$] and, more importantly, with method [$F(1,82) = 9.53$; $p < 0.005$]. This indicates that the dif-

Table 2. Mean percentage of correct responses in 3 conditions of segmentation

	2PH	2WW	4PH	4WW	6PH	6WW
N	16	14	14	16	12	16
Syllable	92.2	85.7	84.8	88.3	94.8	93.8
Consonant in CVC	84.0	69.6	94.6	91.8	96.4	91.0
Consonant in CCV	72.3	42.4	85.3	81.3	97.4	86.7

ference between the PH and the WW groups was larger for consonant suppression than for syllable suppression. A second comparison, contrasting the consonant and the consonant-cluster conditions, also proved significant [$F(1,82) = 32.70$; $p < 0.001$] and interacted with grade [$F(2,82) = 8.01$; $p < 0.001$] and method [$F(1,82) = 4.11$; $p < 0.05$], indicating that the difference between the PH and the WW groups was larger for the consonant-cluster condition than for the single consonant condition. Finally, when comparing the two reading level matched groups, the WW group performed less well than the comparable PH group [$F(1,26) = 5.81$; $p < 0.025$].

In summary, Phonic groups outperformed WW groups, and this advantage was particularly marked for the tests involving consonant deletion. Moreover, the effect of method remained present until grade 6. This is particularly striking, given the fact that grades 4 and 6 WW groups were in average better readers than the corresponding PH groups. The findings thus support the existence of differences between the two schools' reading curricula, and corroborate our informal observation in the classrooms. In addition, they show long lasting effects of teaching methods on speech segmentation abilities. Finally, the fact that the difference remains when matched groups are compared indicates that a same level of reading efficiency may be compatible with fluctuations in segmentation skills.

Reading tests

General method. All the reading tests used a common procedure. Words belonging to the oral vocabulary of primary school children were selected based on test-relevant linguistic properties. They were presented in lower case in the middle of an Apple IIe screen and response times were recorded by the microcomputer. Each word was preceded by a warning signal (a central 'plus' sign), which remained on the screen for 300 ms and was followed by a blank screen for 200 ms. Timing and latency measurements were controlled through an Apple Mountain clock card, accurate to the millisecond. The presentation of the word was synchronized on screen-scanning cycles and triggered the clock, which was stopped by a voice-key activated by the response. Erroneous responses were encoded by the experimenter in phonetic notation during the session.

The whole set of reading tests was presented in two sessions with a 20 items training block at the beginning of each session. The first session consisted of the regularity test, the complexity test and the frequency test. The second session consisted of the homophony test only. Subjects were tested individually in a quiet room at school. They were asked to respond as quickly and as accurately as possible.

Mean pronunciation latencies and mean percentage of errors were analyzed for each test. All available subjects were considered in the analyses of errors. For the analysis of RTs, only correct responses were taken into account. Because of the high error rates obtained in some of the tests, RTs would in

some cases be based on very few observations. To eliminate spurious effects due to such unreliable data, we discarded subjects who had less than one third of observations in one or several cells of the experiment. For each test, 3 (grade) × 2 (Method) × (variables specific to each experiment) mixed ANOVAs were run. Since the results of the error and RT analyses were generally similar, they are reported together.

Regularity. Twenty four pairs of words were selected. Each pair included one regular and one irregular word. Word length varied between three and nine letters, and one to three syllables. Both members of each pair had the same number of letters, of syllables and of phonemes, and the same or a very similar phonological onset, in order to avoid voice-key triggering errors in latency measurements. They were matched as closely as possible for frequency of use (Imbs 1971).

Results. Three (Grade) by 2 (Method) by 2 (Regularity) ANOVAs were run on latencies and error rates. As expected, children were more accurate [$F(1,80) = 236.39$; $p < 0.001$] and faster [$F(1,61) = 42.63$; $p < 0.001$] for regular than for irregular words. The interaction between Regularity and Grade was significant both on errors [$F(2,80) = 7.97$; $p = 0.001$) and on latencies [$F(2,61) = 18.06$; $p < 0.001$], indicating that the difference between regular and irregular words decreased. As shown in Table 3, the accuracy for regular words was relatively high from the outset (grade 2) and rapidly reached ceiling level, whereas performance for irregular words was poor in grade 2 and progressively increased until grade 6.

There was also a Regularity by Method interaction, both on errors and on latencies [$F(1,80) = 11.10$ and $F(1,61) = 12.11$ respectively; both p's < 0.001], resulting from the fact that from grade 4 onwards, the effect of regularity was slightly more marked in the PH than in the WW groups. However, the ANOVAs comparing the grade 4 WW and the grade 6 PH groups on accuracy and pronunciations latencies showed no interaction between Regularity and Group, suggesting that the variation of the regularity effect between PH and WW groups might be a consequence of differences in reading level across the two school groups.

Table 3. Mean naming latencies in ms and mean percentage of errors in parenthesis for regular and irregular words

	2PH	2WW	4PH	4WW	6PH	6WW
Number of subjects	7 (15)	3 (13)	14 (14)	16 (16)	11 (12)	16 (16)
Regular	1682 (31.9)	1550 (52.4)	1039 (5.7)	873 (3.7)	801 (4.8)	630 (3.1)
Irregular	1932 (66.6)	2805 (77.3)	1178 (30.8)	954 (22.5)	826 (26.0)	655 (11.6)

A three-way interaction also came out on RTs [$F(2,61) = 10.21$; $p < 0.001$] due to the fact that at grade 2, the regularity effect was larger for the WW group.[2] On errors, the regularity effect was smaller in the WW than in the grade 2 PH group. However, this difference is due to the fact that the grade 2 WW group made much more errors on regular words. Indeed, their performance on irregular words was also worse than in the PH group. Furthermore, the proportion of regularization errors was lower in the WW than in the PH group (34% and 57% out of the total number of errors on irregular words, respectively). Hence, the findings suggest that grade 2 WW subjects tend to use analytical correspondences even though their knowledge of them is poorer and less accurate. Moreover, the very low score on irregular words suggests that their use of word-specific knowledge is extremely limited.

Complexity and lexicality. The materials included 24 words, varying in length between three and seven letters and belonging to the highest classes of frequency (Imbs 1971), and 24 pseudowords derived from the words by single letter substitution. Half of the stimuli consisted of simple graphemes only (words: dur, fée; pseudowords: tur, vée) and the other half included complex correspondences, in which either several letters correspond to a single phoneme (e.g. pour, vour) or several pronunciations are permissible depending on the orthographic context (e.g. gel, gul). The experiment consisted of one block with words and one with pseudowords. In each block, simple and complex strings were randomly mixed.

Results. The test was designed to provide two clues of a lexical contribution to word pronunciation: the effect of lexical status and the interaction between lexical status and complexity. The lexical status effect was significant [RT: $F(1,74) = 27.32$; $p < 0.001$; ER: $F(1,82) = 71.78$; $p < 0.001$] but it did not interact with either grade or method. It thus seems that the lexical status effect has little discriminative power within the range of reading skill studied here.

Overall, simple items were responded faster [$F(1,74) = 14.62$; $p < 0.001$] and more accurately [$F(1,82) = 115.47$; $p < 0.001$] than complex items. As expected, the effect of complexity was quantitatively more important for pseudowords than for words [RT: $F(1,74) = 5.86$; $p < 0.05$; ER: $F(2,82) = 11.31$; $p = 0.001$]. For the word list only, there was an interaction between complexity and grade on errors [$F(2,82) = 3.14$; $p < 0.05$], supporting the notion of increasing use of word-specific knowledge. No difference was found as a function of method.

It can be seen in Table 4 that the complexity effect is numerically larger for pseudowords than for words in all groups except the grade 2 WW group, thus suggesting that decoding is predominantly used for both types of items in this group. This observation is even more striking given that words and pseudowords were presented in different blocks, which could have helped children to adopt different strategies as a function of list composition (Content & Peereman 1992). On the other hand, the same group displayed better per-

Table 4. Mean naming latencies in ms and mean percentage of errors in parenthesis for simple and complex words and pseudowords

	2PH	2WW	4PH	4WW	6PH	6WW
N	14 (16)	8 (14)	14 (14)	16 (16)	12 (12)	16 (16)
Simple words	1533 (18.4)	2327 (36.8)	772 (3.2)	635 (2.2)	666 (3.7)	555 (1.0)
Complex words	1599 (25.7)	2436 (47.6)	895 (8.9)	665 (4.8)	646 (9.9)	558 (3.5)
Simple pseudowords	1669 (22.7)	2313 (46.8)	973 (8.8)	791 (8.8)	806 (5.1)	671 (4.1)
Complex pseudowords	1873 (37.4)	2435 (58.9)	1229 (20.4)	891 (16.4)	889 (13.9)	724 (13.1)

formance for words than for pseudowords. The two putative indicators of decoding thus appear to dissociate in an unexpected fashion. As the following tests bring further evidence on the interpretation of the lexical status effect, we shall return to this issue in the general discussion.

Finally, in the comparison between grade 4 WW and grade 6 PH groups, the only significant effect was the interaction between group and lexical status on error rates [$F(1,26) = 5.20$; $p < 0.05$]. Inspection of Table 4 shows that the grade 4 WW children were slightly better at reading words and worse at reading pseudowords than grade 6 PH subjects. This result lends some support to the view that the Whole-Word method favours the development of word-specific knowledge, whereas the Phonic method enhances the use of sub-lexical correspondences.

Frequency by length. Series of high-frequency and low-frequency words of 4 and 8 letters were selected, and pseudowords were constructed by changing a few letters of each word. Each series consisted of 16 stimuli. The mean frequency per million was 418.5 for high-frequency four-letter words, 165.5 for high-frequency eight-letter words, 3.3 for low-frequency four-letter words, and 2.2 for low-frequency eight-letter words. The 96 stimuli were randomly mixed and divided into two experimental blocks. High-frequency words, low-frequency words and pseudowords were matched on number of syllables, number of phonemes, number of letters and phonological onset.

Results. To assess separately the effect of frequency and the effect of lexical status, two orthogonal contrasts were used. The first compared High Frequency and Low Frequency words (Frequency effect). The second contrast compared both word classes to pseudowords (Lexical status effect). Unfortunately, the data of the grade 2 PH group were lost, due to a technical defect. Thus one set of analyses was run on the data from fourth and sixth graders, and another on the grade 2 WW group.

Table 5. Mean naming latencies in ms and mean percentage of errors in parenthesis for high frequency words, low frequency words and pseudowords

	2WW	4PH	4WW	6PH	6WW
N	4 (14)	13 (14)	15 (16)	11 (12)	14 (16)
High frequency – 4 letters	1883 (42.4)	1036 (3.3)	799 (2.6)	763 (1.5)	648 (1.6)
High frequency – 8 letters	2843 (52.5)	1294 (3.2)	909 (2.2)	868 (3.7)	707 (2.1)
Low frequency – 4 letters	2159 (39.6)	1184 (9.0)	913 (1.4)	835 (4.9)	718 (2.1)
Low frequency – 8 letters	3179 (57.9)	1373 (7.8)	1102 (4.8)	946 (4.9)	808 (3.7)
Pseudowords – 4 letters	2888 (42.4)	1353 (18.9)	1007 (13.0)	927 (14.8)	793 (5.7)
Pseudowords – 8 letters	4247 (72.2)	1951 (16.7)	1601 (25.9)	1424 (28.2)	1118 (29.7)

In grades 4 and 6, there was a frequency effect on both RTs [$F(1,49) = 32.25$; $p < 0.001$] and errors [$F(1,53) = 11.24$; $p < 0.001$], indicating better performance for high frequency words than for low frequency words. The lexical status effect was significant on RTs and errors [respectively, $F(1,49) = 95.46$; $p < 0.001$; $F(1,53) = 100.10$; $p < 0.001$] and interacted with length [RT: $F(1,49) = 56.05$; $p < 0.001$; ER: $F(1,53) = 33.01$; $p < 0.001$], indicating that length affected performance for pseudowords more than for words. No interaction between these factors and grade or method reached significance.

In contrast, in grade 2, there was no effect of word frequency [RT: $F(1,3) = 2.94$; ER: $F(1,13) < 1$]. The lexical status effect came out [RT: $F(1,3) = 6.93$; $p = 0.08$; ER: $F(1,13) = 8.09$; $p < 0.05$] and interacted with length [RT: $F < 1$; ER: $F(1,13) = 5.57$; $p < 0.05$].

The effect of frequency, which is indicative of the use of word-specific knowledge, thus appeared in grades 4 and 6, but not in the grade 2 WW group. This supports the view that the grade 2 WW children mainly rely on decoding, a conclusion further supported by a large length effect on RTs, which was similar in size for words and pseudowords. However, the hypothesis that the grade 2 WW subjects predominantly use analytical correspondences seems to be invalidated by the presence of a lexical status effect in this test and the previous one. The following test examines the lexical status effect in more detail.

Pseudo-homophony and lexicality. Eighteen high-frequency five-letter words and 18 low-frequency five-letter words were selected according to the same criteria as in the previous tests. The mean frequency per million was 260.0

for the high-frequency words and 12.2 for the low-frequency words. For each word, a homophonic pseudoword and a non-homophonic pseudoword were derived. Homophonic pseudowords were created either by deleting one silent letter from the word (word: robot; homophonic pseudoword: robo), or by substituting one letter or digram (e.g. rouge, rouje; frère, fraire). The homophonic and non-homophonic pseudowords shared the same number of letters with the real word (e.g. word: maison; homophonic pw: meizon; non-homophonic pw: moipon).

The three types of stimuli were randomly mixed with the constraint that for one half of the triplets, the word appeared before the homophonic pseudoword. To render the presence of homophonic pseudowords less apparent, 36 high-frequency words were added as fillers. In addition, words and their corresponding homophonic pseudowords were separated by at least ten stimuli. The 144 items were divided into three experimental blocks which were presented in fixed order.

Results. Two contrasts were computed on each set of data. The first contrast (Lexicality) compared words and homophonic pseudowords. On error rates, lexicality yielded a significant effect [$F(1,82) = 12.81$; $p < 0.005$] and interacted with grade [$F(2,82) = 4.70$; $p < 0.05$]. There was no difference between words and homophonic pseudowords in grade 2. From grade 4 onwards, error rates were lower for words than for homophonic pseudowords, indicating the development of word-specific knowledge. This interpretation is further supported by the interaction between lexicality and frequency [$F(1,82) = 7.33$; $p < 0.01$], which shows that the advantage from words over homophonic≥≥ pseudowords was larger for the high frequency set than for low frequency

Table 6. Mean naming latencies in ms and mean percentage of errors in parenthesis for words, homophonic pseudowords and non homophonic pseudowords

	2PH	2WW	4PH	4WW	6PH	6WW
N	14 (16)	8 (14)	14 (14)	16 (16)	11 (12)	16 (16)
Words – high frequency	1774 (21.4)	2959 (45.7)	992 (1.6)	772 (1.4)	757 (1.4)	638 (1.7)
Words – low frequency	1801 (19.4)	2973 (49.1)	1022 (3.2)	806 (3.8)	731 (2.3)	637 (0.7)
Homophonic PW – high frequency	1780 (25.5)	2938 (43.3)	1044 (6.4)	879 (8.8)	820 (8.0)	668 (6.6)
Homophonic PW – low frequency	1774 (19.0)	2881 (45.9)	1044 (3.6)	866 (5.2)	792 (3.3)	669 (4.6)
Non-Homophonic PW – high frequency	2078 (28.9)	3252 (54.9)	1386 (12.5)	961 (15.0)	869 (21.8)	759 (13.9)
Non-Homophonic PW – low frequency	1830 (21.5)	3007 (51.0)	1248 (6.9)	885 (10.9)	855 (9.8)	718 (9.5)

set. None of these effects were significant on RTs and none interacted with method.

The second contrast compared homophonic and non-homophonic pseudowords (Homophony effect). Homophony yielded significant effect on both RTs [$F(1,73) = 26.61$; $p < 0.001$] and errors [$F(1,82) = 43.31$; $p < 0.001$] and interacted with frequency [RT: $F(1,73) = 4.25$, $p < 0.05$; ER: $F(1,82) = 4.96$, $p < 0.05$]. There was no interaction between homophony and grade or method. This indicates that, from the beginning of reading acquisition, children are able to make use of their knowledge of word's phonological forms to obtain the pronunciation of pseudowords.

Spelling tests

Regular word and pseudoword dictation. Twenty-eight words were selected so that half the stimuli contained consonantic clusters and the other half did not. All the words were orthographically regular, i.e. their spelling can be derived through the application of frequent analytic correspondences. The stimuli were matched as closely as possible across the two classes in terms of word frequency, number of letters and number of syllables. Twenty-eight pseudowords were constructed by changing at least one phoneme. The words were dictated in the context of sentences in one session, and the nonwords were dictated in another session. Children were tested collectively in the classrooms.

Because there are very few univocal correspondences in French, several phonologically correct spellings are possible. For instance, many written consonants may be geminated and a final silent E may often be added or deleted (e.g. futur and future, or bal and balle are homophones). To compare word and pseudoword spelling, the score was the number of phonologically accurate spellings. So, an advantage for words over pseudowords would indicate the contribution of lexical information. Conversely, the lack of a difference between words and pseudowords would suggest that subjects rely on sublexical correspondences.

Results. The percentage of phonologically accurate responses (see Table 7) was higher for words than for pseudowords [$F(1,79) = 14.95$; $p < 0.001$]. Although the Lexicality by Grade interaction did not reach statistical significance, it should be noted that in the grade 2 groups, the lexicality effect was almost non existent (< 1%). There was also a main effect of phonological complexity [$F(1,79) = 27.00$; $p < 0.001$], which was larger in grade 2 than in grade 4 and 6 [$F(2,79) = 7.53$; $p < 0.005$]. The interaction between grade, method and phonological complexity was also significant [$F(2,79) = 3.28$; $p < 0.05$]. The effect of phonological complexity was larger in the WW group than in the PH group in grade 2, but affected the PH groups more than the WW groups in the higher grades.

The lack of a lexicality effect, together with a large complexity effect suggests that second graders mainly rely on sound-to-spelling knowledge. The

Table 7. Mean percentage of phonologically accurate responses in spelling regular words and nonwords

	2PH	2WW	4PH	4WW	6PH	6WW
N	16	13	13	16	11	16
Words without clusters	92.9	80.2	97.8	98.2	96.8	99.1
Words with clusters	87.5	65.9	95.1	94.6	95.5	97.8
Pseudowords without clusters	92.0	78.6	93.4	91.5	90.9	98.2
Pseudowords with clusters	84.8	64.8	87.4	91.5	86.4	98.7

lexicality effect observed in older children indicates that lexical information contributes to spelling. From grade 4, the effect of phonological complexity is smaller in WW than in PH groups, suggesting that the use of analytical correspondences develops faster in the WW school. However, there was no differences between the reading-matched groups. Hence, the observed difference in the effect of consonantic clusters is likely to be a consequence of differences in absolute literacy levels between the two schools.

Word dictation. Four types of words varying in frequency and in orthographic transparency were used. The first category consisted of regular words (see above). The items of the morphological category contained a silent final letter (ex. pot, /po/) that can be derived through the pronunciation of morphologically related words (poterie, potier). Words from the two other categories contained at least one segment that can be spelled in several ways. For example, the sound /ɛ̃/ can be spelled in French by *in, ain, en, im, ein, ym, aim*, the first ones being the most frequent (Véronis 1986). In the ambiguous words, phonological segments were always spelled by one of the most frequent spelling patterns (ex. *matin, train*), whereas the exception words included spelling patterns that rarely occur in the French orthography (ex. *thym, faim*).

The stimuli consisted of 108 words divided in two lists: 56 high-frequency and 52 low-frequency words. In each frequency list, the stimuli were equally divided among the four word categories outlined above and were matched as closely as possible in terms of number of letters, number of syllables and word frequency. The mean frequency per million of the regular, morphological, ambiguous and exception words was 80.7, 69.2, 82.0 and 64.0 respectively for the high frequency words and 3.7, 4.9, 4.5 and 3.7 for the low frequency words. Because of limitations of testing time in the classrooms, reduced lists were prepared for the second grade, consisting of 7 words per category. Stimuli were mixed and presented in a fixed random order.

Subjects were tested in the classroom. The experimenter read each word in the context of a sentence and then repeated it in isolation before the children wrote it down. Subjects were given answer sheets on which the carrier sentences were printed and they had to fill the blanks to complete the sentence. The score was the percentage of correctly spelled words.

Results. A 3 (Grade) by 2 (Method) by 4 (Word class) by 2 (Frequency) ANOVA was run on percentage of correct responses (see Table 8). The effect of frequency was significant [$F(1,75) = 195.98$; $p < 0.001$] and increased with grade [$F(2,75) = 30.96$; $p < 0.001$]. As shown in Table 8, the frequency effect did not appear until grade 4. The Frequency by Word class interaction was also significant [$F(3,225) = 33.88$; $p < 0.001$]. Local analyses indicated that there was no frequency effect for the regular words ($F < 1$), whereas significant effects came out for all other word classes ($p < 0.001$ in each case).

There was a significant effect of Word class [$F(3,225) = 231.69$; $p < 0.001$], which varied with grade [$F(6,225) = 12.61$; $p < 0.001$] and with method [$F(3,225) = 3.19$; $p < 0.05$]. Newman-Keuls post hoc tests were computed for each group and word frequency level. In grade 2, performance was highest for regular words, intermediate for ambiguous words and low scores were obtained for morphological and exception words. In grade 4 and 6, different patterns were observed for high and low frequency words. For high frequency items, ambiguous and morphological words were generally spelled as accurately as regular words, and lower scores occurred for exceptions. For low-frequency words, the four categories reached significantly different scores in nearly all cases.

The results thus suggest that the use of sound-spelling, morphological and lexical information varied from grade 2 to grade 6, independently of teaching method. The difference between regular words and other categories and the lack of a frequency effect suggests that Grade 2 children rely on sound-spelling

Table 8. Mean percentage of correct responses in spelling high and low frequency words of different types

		High frequency				Low frequency			
	N	Regular	Ambiguous	Morphol	Exceptions	Regular	Ambiguous	Morphol	Exceptions
2PH	14	67.3	43.9	23.5	25.5	67.3	41.8	25.5	8.2
2WW	12	41.7	31.0	0.0	9.5	61.9	32.1	1.2	1.2
4PH	12	74.4	70.2	71.4	50.0	70.5	52.6	38.5	21.8
4WW	12	85.3	76.8	75.0	73.7	81.3	69.7	46.2	39.9
6PH	11	90.3	86.4	79.9	69.5	79.0	69.2	62.2	38.5
6WW	16	86.2	89.3	89.3	73.7	85.6	76.0	59.6	46.6

Note: the means underlined by a common line are not statistically different at $p = 0.05$.

correspondences, a conclusion in agreement with the absence of a lexicality effect in the previous spelling test. The intermediate performance for the Ambiguous category suggests that when several spelling alternatives exist, beginners apply the most frequent correspondences. Finally, the finding that morphological words are as difficult as exception words shows that children at grade 2 do not make use of morphological information in spelling (see also Leybaert & Alegria 1995).

At grade 4 the pattern of performance radically changes and shows reliance on word-specific and morphological information in addition to the use of sound-spelling knowledge. The use of word-specific information is indicated by the higher performance for high-frequency exception and ambiguous words and by the presence of a large frequency effect for these categories. The fact that the frequency effect does not come out for regular words implies that sound-spelling information is also used. In addition, the performance for morphological words, which was significantly better than for exception words, indicates that morphological knowledge is used at least for high-frequency words.

DISCUSSION

One aim of the study was to characterize acquisition of word reading and spelling in terms of the development of decoding skill and word-specific knowledge. For both reading and spelling, there is a parallel improvement in the efficiency and rapidity of decoding and a progressive increase in reliance on word-specific knowledge. The results further suggest that development proceeds very similarly in the groups taught by a phonic method and in those taught by a whole-word method.

For reading, the main evidence for the development of decoding skill was better performance for regular words (Regularity test), better performance for pseudowords (Complexity, Frequency and Pseudohomophony tests), and a decrease in the effect of grapho-phonological complexity (Complexity test) and of length (Frequency test) on pseudowords. For spelling, evidence for the improvement of the use of analytical correspondences was an increase of phonologically accurate responses to pseudowords, a decrease in the effect of phonological complexity on pseudowords (Words and Pseudowords dictation), and an increase in correct spellings for regular words (Word dictation test).

The principal indications of an evolution in the reliance on word-specific knowledge in reading were an increase in performance for irregular words (Regularity test), smaller effects of complexity and length for words than for pseudowords in grade 4 and 6 (Complexity and Frequency tests), and a difference between words and homophonic pseudowords for the same groups. For spelling, the evidence for lexical contribution was better performance for regular words than for pseudowords at grade 4 and 6 (Regular Words and

Pseudowords spelling test), and the increase of correct spellings for ambiguous as well as exception words (Word spelling test).

One finding that seems to contradict that interpretation is the presence of a lexical status effect in reading at grade 2. Up to now, differences between words and pseudowords have generally been considered to demonstrate the existence and the use of word-specific knowledge. Several aspects of the results are incompatible with this interpretation: the presence of a length effect on latencies, which was identical for words and pseudowords; the lack of any difference between words and homophonic pseudowords; the occurrence of a similar effect of grapho-phonological complexity on words and pseudowords. The word/pseudoword difference may be partly due to differences in the familiarity of the phonological forms. The observation of better performance for homophonic pseudowords (which are phonologically familiar) than for non-homophonic pseudowords supports this interpretation. Thus, one conclusion which can be drawn from the present study is that a word/pseudoword difference is not in itself sufficient to demonstrate the intervention of word-specific orthographic knowledge. Since the comparison of words and homophonic pseudowords equates phonological familiarity, it provides a more accurate measure of lexical contribution to word naming.

Concerning the influence of teaching methods, the most prominent finding was an interaction between grade and method. In all reading and spelling tests, the overall pattern of performance reversed between grade 2 and grade 4. While grade 2 WW children lagged behind their PH peers, the WW groups performed better at grade 4 and 6. This finding might be taken as an indication that in the long term the whole-word method favours a better integration between word-specific knowledge and decoding. However, such a conclusion seems in contradiction with numerous studies indicating that instructional curricula that include systematic phonics lead to higher reading achievements (see Adams 1990 for a review). One potential explanation may be that the two teaching methods examined here are not sufficiently contrasted. Although there were clear differences in classroom activities between the two schools, which resulted in marked differences in segmentation ability, the WW school did not use a radical language-experience program in which little attention is drawn to oral reading and word identification, as described in other studies (Evans & Carr 1985). On the other hand, given the small number of classes used here, the difference might also result from a number of other uncontrolled factors, such as teachers' quality, differences in the two schools' sociocultural and instructional milieus. Furthermore, given the cross-sectional nature of the study, the selection of children between grade 2 and grade 4 might also differ across schools. In any case, given the small scale of the study and the number of uncontrolled factors that may be confounded with reading method, the ascription of the observed advantage to teaching methods per se is of course totally unwarranted.

The main purpose of this study was to examine whether decoding and word-specific skills develop independently of each other by comparing the

performance of children taught by different methods. The independence hypothesis would lead one to suppose that the whole-word method, which favours the storage of associations between printed words and their pronunciation, might enhance the development and use of word-specific knowledge, whereas phonic instruction would accelerate the acquisition of sub-lexical correspondences.

The results consistently indicate that this was not the case. Although there were some hints that WW groups rely more on word-specific knowledge (the effect of regularity was less important than in the PH groups; the effect of was lexicality more marked; the difference between less frequent words and their homophonic pseudowords was significant in the grade 6 WW group), most of these tendencies vanished when matched groups were compared. There is thus no element in the present study to conclude that the nature of instruction induces variability in word naming and word spelling strategies in the long run.

One possible critique would be that the contrast between the two methods was not sufficiently marked to determine developmental differences. The finding that differences in explicit speech segmentation tests remain until grade 6 reinforces our confidence that much less explicit phonic instruction was provided in WW groups. On the other hand, it is possible that some attention to oral reading and to the relation between letters and sound during classroom activities is sufficient to lead most children to explore and discover by themselves the regularities. The fact that the grades 4 and 6 WW children achieved good, if not higher, performance for what concerns decoding, suggests that a systematic teaching of correspondence rules is generally not necessary.

A surprising result, in the face of previous findings with first graders (Seymour & Elder 1986), is that the performance of the grade 2 WW group showed no indication of a greater reliance on word-specific knowledge. On the contrary, and paradoxically, some elements suggested that word-specific knowledge could be less developed, or less used, in the grade 2 WW group. In reading, the error rate for irregular words was higher than in the corresponding PH group, and the effect of grapho-phonological complexity was the same for words and for pseudowords, whereas it tended to be smaller for words than pseudowords in the PH group. Moreover, in spelling tests, the percentage of correct responses for ambiguous and exception words was lower in the grade 2 WW group than in the grade 2 PH group.

How can this paradox be explained? It could be argued that the development of word-specific knowledge is generally slower or starts later than decoding, whatever the teaching method. Because the tests used words that were not selected on the basis of classroom experience, they might be insufficiently sensitive to word-specific knowledge. It is likely that the use of word-specific information would be observed in grade 2 WW children if more familiar words were selected. This argument, however, cannot account for

the finding that word-specific knowledge appears earlier in the PH curriculum. In comparison, the fact that WW children faced with a sample of words well within the vocabulary of their age appear to use a predominant decoding strategy suggests that their knowledge of orthographic forms is less developed.

On the other hand, since the performance related to decoding were weaker in the grade 2 WW group than in the grade 2 PH group, it may be concluded that grade 2 WW children were in general less advanced readers. The pattern of data is consistent with observations by Byrne, Freebody & Gates (1992) and Gough & Walsh (1992) showing a strong relationship between the ability to learn new orthographic forms and decoding skills. So, what remains in our view as the most plausible explanation of the paradox is the notion that the acquisition of analytic knowledge constitutes a necessary step in the construction of the orthographic lexicon which characterizes the skilled reader.

To summarize, the long-term effect of instruction appears to be very limited. It does not seem that the teaching methods determines important differences in the word reading and spelling mechanisms used by children. It must be borne in mind, however, that the present research deals only with the processing of isolated words. Whether teaching method has an influence on access to semantic information, or on higher-level processes such as syntactic integration of information at the sentence level remains to be investigated.

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NOTES

1. Test materials are available upon request to either author.
2. Note however that, because of numerous errors on irregular words in the grade 2 groups, the RT data are based on only 7 (2PH) and 3 (2WW) subjects.

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