Acquisition of reading and written spelling in a transparent orthography: Two non parallel processes?

GIUSEPPE COSSU[1], MARIA GUGLIOTTA[2] and JOHN C. MARSHALL[3]
[1] *Servizio di Neuropsichiatria Infantile, University of Parma, Italy, and Neuropsychology Unit, University Department of Clinical Neurology, Oxford, UK*; [2] *Servizio di Neuropsichiatria Infantile, University of Parma, Italy*; [3] *Neuropsychology Unit, University Department of Clinical Neurology, Oxford, UK*

ABSTRACT: Reading and written spelling skills for words and non-words of varying length and orthographic complexity were investigated in normal Italian first and second graders. The regularity and transparency of the mapping between letters and phonemes make Italian orthography an unlikely candidate for discrepancies between reading and spelling to emerge. This notwithstanding, the results showed that reading accuracy is significantly better than spelling. The difference is particularly striking in first graders, but it is still evident in 2nd graders, though most strongly on non-words. The data show that reading and written spelling are non parallel processes and that the developmental asynchrony reflects a partial structural independence of the two systems.

KEY WORDS: Reading acquisition, Spelling, Transparent orthography

INTRODUCTION

Pure alexia without agraphia (Dejerine 1892) and its converse, pure agraphia without alexia (Gordinier 1903) provide evidence that, in adults, the visual language system is dissociable into independent components. However, it is far from clear whether (and how) such dissociations apply developmentally. At present, there are no compelling grounds to select between two contrasting hypotheses: (a) the acquisition of reading and written spelling is subserved by a unitary (non dissociable) processing system; (b) adult literacy constitutes the final outcome of two computational systems that are (at least partially) independent from the outset. In general, developmental change and mutual interaction among the processes underlying the acquisition of reading and spelling are not well understood.

Notwithstanding these persistent obscurities, in recent years the concept of two developmentally distinct systems (for the acquisition of literacy) has become less implausible than it might have appeared on intuitive grounds. The pioneering work of Read (1971, 1986) showed that some children as young as 3.6 and 4 years of age were able to print messages 'representing English words with the standard alphabet, though employing an orthography of their own invention'. Surprisingly, these children were unable to read back the message they had just printed. Similar findings were also reported by Carol

Reading and Writing: An Interdisciplinary Journal 7: 9–22, 1995.

Chomsky (1971). Likewise in English-speaking children, Bradley & Bryant (1979), Bryant & Bradley (1980) and Bradley (1985) described young pupils who often spelled correctly words they were unable to read. A reversed pattern was reported by Frith (1980, 1983) who documented children with good reading and poor spelling.

It is worth noting that the former dissociation does not apply only to English-speaking subjects; in Spanish-speaking third graders, 31% of a sample of 118 children could spell better than they could read (Carbonell de Grompone 1974). Similarly, in a large sample of German-speaking school children, it was found that the taxonomy of 'literacy disabilities' included two groups who showed predominantly reading problems and predominantly spelling problems, respectively (Valtin, Jung & Scheerer-Neuman 1981). A recent paper on German-speaking first graders (Wimmer & Hummer 1990) showed that 'reading was easier than spelling and real words elicited higher performance than pseudowords'. Compared to English, German orthography is reasonably regular, although it is not as regular and phonologically transparent as Italian.

In a very transparent orthography, namely Italian, Cossu & Marshall (1985) have reported the cases of two mentally retarded children in whom a severe inability to read was in striking contrast with their relatively good spelling ability. These children were able to write correctly 80 out of 212 non-words (38%), but could read correctly only 7 of them (3%). Furthermore, a case recently referred to one of the authors (G.C.), a 7.3 year old Italian girl, with mental retardation, showed the reversed discrepancy. She could read 64 out of 120 words (53%) and non-words, while not one single item was spelled correctly, even when mobile (plastic) letters of the target were provided in scrambled order. Developmental dissociation between reading and spelling thus extends across different orthographies and provides some support for a 'developmental independence hypothesis'.

In the current literature, however, the interpretation of the discrepancy between reading and written spelling is controversial; ad hoc accounts, rather than theoretically constrained hypotheses, are common. Bradley (1985) claims that dissociations between reading and spelling arise because (some) children rely upon a 'rigidity strategy': namely, a visual strategy in reading and a phonological strategy in spelling. This looks suspiciously like a description posing as an explanation. The notion of 'rigidity' does not indicate why these children should 'choose' different strategies for the two tasks. Another account (Waters, Bruck & Seidenberg 1985) claims that 'grade three children use similar processes for reading and spelling'. Dissociations must therefore arise as a consequence of the particular (and in English peculiar) relationship between the spoken word and its orthographic rendition. In this version, 'the ease of spelling a particular word is determined by the number of possible spellings for a given pronunciation, while ease of reading is determined by the number of possible pronunciations for a given spelling pattern' (Waters, Bruck & Seidenberg 1985). This elegant account can reconcile disparities between reading and spelling in a deep orthography (such as English), but not in a highly regular and transparent orthography, like Italian (or Spanish). Yet one might suspect that the above asymmetries, being widespread across contrastive orthographies, could reflect a genuine (albeit partial) independence of the mechanisms that underly reading and writing in the alphabetic systems.

Let us assume that evidence from pathology (acquired or developmental) reflects the underlying structure of the normal system (Shallice 1988). The task of reading and spelling per se might activate distinct processes and place different cognitive requirements upon the beginning reader. As a consequence, we should expect (in both normal and pathological acquisition) that discrepancies between reading and spelling will emerge, though often transitorily, in any orthography. The degree and direction of the dissociation will be determined by the internal structure of each orthographic system and by the child's biological endowment. Furthermore, both the degree and direction of the dissociation might undergo substantial developmental changes.

Within this framework, cross-linguistic studies should enable one to track commonalities and differences in the asymmetrical development of reading and spelling across different orthographies. To investigate the validity of our approach we select a condition where current knowledge of reading and writing acquisition seems to predict no reason for dissociations to occur, at least under normal conditions.

The Italian language and its orthography provide an ideal testing ground. Spoken language has only five vowels (Ferrero, Magno Caldognetto, Vagges & Lavagnoli 1978), while spoken English has a dozen or more (Agard & Di Pietro 1965). Italian has a shallow phonology with little morpho-phonological alternation as compared to English. In addition, though Italian has a mixed stock of syllable types, it has fewer than half those of English (Carlson, Elenius, Granstrom & Hunnicut 1985). Moreover, unlike English, which has a predominantly closed syllable structure (e.g. CVC, CVCC, CCVC, etc.) Italian's most frequent syllabic form by far is the open syllable (e.g. CVCV, CVCCV, CVCVCV, etc.), with relatively few variations (Carlson et al. 1985).

The written rendition of Italian is transparent, characterized by an almost biunivocal correspondence between grapheme and phoneme. Thus, regardless of the context in which they occur, each of the five vowels has only one orthographic rendition in Italian. Consonants have only one graphemic rendition and vice versa, except for a few stop consonants and affricates (i.e. /k/ and /g/; /tʃ/ and /dʒ/). In these cases, the same grapheme followed by different vowels has different phonological renditions. For instance, the letters [g] + [a] are rendered as /ga/, but [g] + [i] as /dʒi/; in order to obtain the voiced velar /gi/, we need to insert the letter h [ghi]. A similar trend applies to the voiceless velar /k/ as well.

In a few cases, the orthographic rendition of the word is phonologically unpredictable: the voiceless velar /k/ followed by the vowel /u/ is rendered in /kuadro/ [picture] as 'quadro', in /kuore/ [heart] as 'cuore' and in /akua/

[water] as 'acqua'. Similarly unpredictable, in rare occasions, is the written spelling of the voiceless palatal /tʃ/, the voiced affricate /dʒ/ and the fricative /ʃ/ before the vowel /e/. The words /tʃeleste/ [light blue] and /tʃelo/ [sky], /dʒelo/ [frost] and /tʃiliedʒe/ [cherries] are rendered in orthography as 'celeste' and 'cielo', 'gelo' and 'ciliegie', respectively. In similar vein, /tʃero/ [candle] and /tʃeco/ [blind], /ʃena/ [scene] and /ʃentsa/ [science] are rendered as 'cero' and 'cieco', 'scena' and 'scienza', respectively.

With these exceptions, Italian orthography has a fairly biunivocal correspondence between phoneme and grapheme. Under such conditions, we would expect any discrepancy between reading and spelling ability to be minimized during the early stages of acquisition. On the contrary, if there are significant discrepancies, the hypothesis of structural independence between reading and spelling sub-systems is strengthened.

METHOD AND SAMPLE

Seventy children from an urban elementary school in Parma (Italy) were examined. Half of them were attending the first grade and had a mean age of 79 months (range 73–86; SD = 4.0), half were from second grade classes and had a mean age of 91 months (range 85–97; SD = 3.5). The sample, which included 40 males and 30 females, was homogeneous in that all the children came from the middle social classes and were attending their grade at the regular age. No child with a known or suspected history of brain or behavioural problems was included in the sample. Otherwise, no attempt to preselect children with reading/spelling disabilities was made.

On the WISC scale, the mean verbal IQ was 96.5 (range 79–130; SD = 13.6) for the first graders and 104.7 (range 74–130; SD = 18.3) for the second graders. All the children were individually tested between the end of January and late March.

Reading and spelling tests. Since no normative data for reading ages are currently available for Italian children, we chose our reading list from books of the corresponding grade, but not in use in the actual classes selected for the study. The reason for this decision was to avoid words that may have been over-practiced in a formal (school) setting, but would nevertheless be common in everyday life. Criteria for the selection of stimuli were as follows: the list contained 30 words which differed in length; fifteen words were 4 to 5 letters long with a CV or CCV sequence, interspersed with an equal number of words 8 to 9 letters long. From these 30 words (listed in Appendix 1), an equivalent list of legal non-words was derived by substituting between 3 and 6 consonants and vowels. The CV sequence of each target word was always preserved in its corresponding non-word. The long words (and non-words) often contained geminates (n = 10) and three consonant letter clusters (n = 9), whereas such complexities are not represented in the short items. These differences undoubtedly add to the complexity of long items and bring about another level of difficulty apart from a mere difference in length.

Procedure. The same list of words and non-words was presented for reading and for writing to dictation. To counterbalance the effect of sequential presentation of tasks, two matched groups were selected within each grade; the first group read the items on the first day and wrote them to dictation on the second; this order of presentation was reversed for the second group. Testing on two consecutive days was employed to avoid tiredness and decreased attention. Reading was tape-recorded for further inspection and checking. In the reading task, each stimulus was printed in lower case on a 15 × 10 cm. white card and presented one at a time; there was no time limit for inspection. In dictation, each word (or non-word) could be repeated once by the examiner if the child so requested. Words and non-words were interspersed in pseudo-random order. The children were allowed to make self corrections if they so wished; the child's final response was the one counted. No child had any articulatory problem when reading; no child displayed any significant motoric problem when writing.

In dictation the doubling had to be represented for the response to be counted as correct; likewise, the relevant phonetic distinction had to be made in reading.

RESULTS

Inspection of correct answers in the total sample (1st and 2nd graders) reveals marked differences between reading and spelling for both words and non-words (Table 1) with written spelling consistently worse than reading. We will

Table 1. Means (and SD) of correct responses for first and second graders (see text)

	Reading		Spelling	
	Short (n = 15)	Long (n = 15)	Short (n = 15)	Long (n = 15)
FIRST GRADE				
Words	14.28 (1.22)	13.91 (1.61)	13.60 (1.71)	8.28 (4.42)
Non-words	12.77 (2.04)	11.77 (3.07)	12.31 (2.75)	6.62 (3.81)
SECOND GRADE				
Words	14.94 (0.23)	14.91 (0.28)	14.65 (0.72)	13.91 (1.93)
Non-words	14.22 (1.16)	13.85 (1.49)	13.82 (1.09)	10.42 (2.45)

consider separately the two grades. In first graders a three-way ANOVA with Task (reading vs. spelling), Lexicality (words vs. non-words) and Length as main factors showed that all main effects were significant. Task: F = 74.0, df = 1, $p < 0.0001$; Lexicality: F = 54.7, df = 1, $p < 0.0001$; Length: F = 151. 9, df = 1, $p < 0.0001$.

In the second grade all three main effects were likewise significant (Task: F = 89.0, df = 1, $p < 0.0001$; Lexicality: F = 69.2, df = 1, $p < 0.0001$; Length: F = 63.5, df = 1, $p < 0.0001$). All three first-order interactions are significant (Task by Lexicality: F = 19.5, df = 1, $p < 0.0001$; Task by Length: F = 54.4, df = 1, $p < 0.0001$; Lexicality by Length: F = 21.7, df = 1, $p < 0.0001$). The interpretation of the results is complicated by a second-order interaction of Task by Lexicality by Length (F = 14.6, df = 1, $p < 0.0001$).

For the first graders the results are unambiguous (see Table 1). Reading is better than spelling; words are better than non-words. The length variable affects written spelling significantly more than reading. Combining responses to word and non-word stimuli, the discrepancy between short/long items is more salient in spelling (t = 12.4, df = 34, $p < 0.0001$) than in reading (t = 3.20, df = 34, $p < 0.003$). Similarly significant is the difference between reading and spelling short stimuli (t = 2.09, df = 34, $p < 0.05$).

The second graders show a somewhat different picture. Their performance is often close to ceiling and the short/long discrepancy hence minimal. Nonetheless, spelling of long non-words (69.5%) is strikingly less good than the spelling of long words (92.7%). Furthermore, the short/long discrepancy is significant in reading (t = 1.98, df = 34, $p < 0.055$) and is still more evident in spelling (t = 8.27, df = 34, $p < 0.001$). Ceiling effects, however, must render the interpretation of these interactions somewhat tentative. Given the ease with which Italian children learn to read and write it is not clear that this putative methodological deficit would be remediable by an alternative choice of materials.

The existence of ceiling-effects recalls the problems raised by Harshman & Krashen (1972) to the measurement of laterality effects; discrepancies between reading and writing can be masked at high levels of accuracy. Therefore, we provide an alternative analysis, an 'unbiased' measure of the reading/spelling coefficient (RSC), that is independent of overall accuracy. Specifically, the RSC value (Marshall, Caplan & Holmes 1975) is a function which, for any particular pair of values of reading correct (Rc) and spelling correct (Sc) gives an RSC which takes into account the mathematically possible range of values of Rc and Sc at each level of accuracy. The RSC index (f) has two values: when the overall accuracy is less than 50%, it is the score on reading minus the score on spelling divided by the total correct responses: (RSC = Rc – Sc / Rc + Sc); at overall levels of accuracy greater than 50%, it is the score on reading minus the score on spelling divided by the total errors: (RSC = Rc – Sc / Re + Se). This RSC for words, non-words shows that for the first graders the f index is significant for both words ($R^2 = 0.364$; $p < 0.001$) and non-words ($R^2 = 0.243$; $p < 0.002$).

Figure 1 shows the relationship between the percentage of words (and non-words) correctly read and spelled by the first graders. The discrepancy in the ratio between reading and spelling is apparent at all levels of performance, since almost all the data-point fall within the area of the lower triangle.

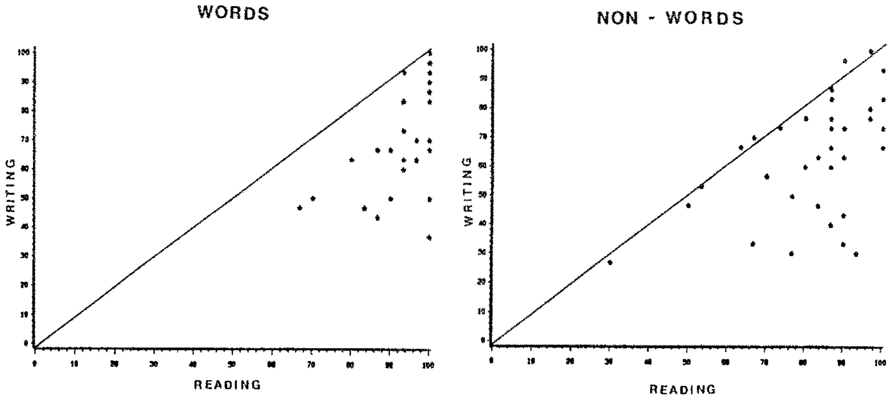

Figure 1. Distribution of correct responses for reading and writing words and non-words in the Grade 1 children.

Reading and spelling errors. The asymmetrical distribution of errors in reading and spelling may reflect qualitative disparities in the functional architecture of the two systems. In order to address this issue, we first examined how (a) consonant/vowel structure and (b) initial/final syllable-position were reflected in the reading and spelling errors. As shown in Table 2, the frequency of errors for consonants and vowels is proportionally similar in both tasks. In reading, the consonant errors correspond to 72% of the total, whereas the vowel errors amount to 28%. In spelling, the picture is replicated: consonant errors correspond to 75% of the total, whereas the vowel errors amount to 25%.

Analysis of the syllable-position effect reveals that the frequency of errors in reading and spelling follows an identical path (Table 3). In reading, the final syllable provokes 71% of the total errors; similarly, in spelling the errors on the final syllable correspond to 76% of the total. The initial syllable, on

Table 2. Frequency of errors for consonants and vowels in reading and spelling of first graders

	Reading		Spelling	
	Consonants	Vowels	Consonants	Vowels
FIRST GRADE				
Words	43	23	224	73
Non-words	132	45	308	105

Table 3. Frequency of reading and spelling errors as a function of syllable position in first graders

	Reading		Spelling	
	Initial	Final	Initial	Final
FIRST GRADE				
Words	17	23	76	176
Non-words	28	87	54	237

the contrary, is far more immune from errors in both tasks: 29% of the total in reading and 24% in spelling.

At the molecular level of orthographic architecture, reading and spelling reveal similar sensitivity to the consonant/vowel and the syllable-position paradigms. And yet, at the word level, the two tasks evoke a remarkable discrepancy in the performance of beginning graders. We therefore next analyzed the effects of the orthographic structure of words and non-words. Our experiment was tailored to investigate the effects of lexicality and length on the acquisition of reading and spelling. Different categories of orthographic complexities were thus mixed in the 'long items'. However, though unequally distributed within the list, we may recognize the following categories of orthographic 'complexity': [a] long regular (words: n = 6; non-words: n = 7); [b] consonant geminate cluster (words: n = 7; non-words: n = 3); [c] two-letter graphemes (words: n = 5; non-words: n = 3); [d] three-consonant letter-clusters (words: n = 4; non-words: n = 3). We will consider first the effects of mere length on reading and spelling, by comparing the errors elicited by the 14 short words (we excluded 'pesce') and the 6 long 'regular' words, which contained a CV, or a CCV sequence (but no geminate, or two-letter grapheme, like [ch]). In the first graders, a two-way Anova with Task (reading and spelling) and Length (short-long) as main factors shows that all main effects and interaction are significant (Task: F = 26.9, df = 1, $p < 0.0001$; Length: F = 15.9, df = 1, $p < 0.0001$; Task by Length: F = 15.3, df = 1, $p < 0.0001$). A separate two-way Anova for the corresponding short/long non-words gives identical results: (Task: F = 30.1, df = 1, $p < 0.0001$; Length: F = 49.9, df = 1, $p < 0.0001$; Task by Length: F = 32.2, df = 1, $p < 0.0001$).

In second graders, analysis of word errors provides a somewhat different picture: Task (F = 14.83, df = 1, $p < 0.0001$) is highly significant, but Length (F = 1.92, df = 1, $p < 0.175$) and the interaction of Task by Length (F = 2.46, df = 1, $p < 0.126$) are not significant. The growth of an orthographic lexicon and a fluent mastery of orthographic skills, removes the effects of an otherwise laborious serial computation. With non-words, where sublexical analysis is mandatory, all the main effects and interaction are significant: Task (F = 28.23, df = 1, $p < 0.0001$), Length (F = 51.81, df = 1, $p < 0.0001$), Task by Length (F = 36.02, df = 1, $p < 0.0001$).

When we move to the four 'complexity' categories, even a cursory glance at the kind of errors provoked by the different categories reveal peculiar asymmetries. In writing the 7 words containing a geminate cluster, for instance, the first graders made 126 deletion errors (76% of the total in that category). In reading the same words, they made 12 deletion errors, which correspond to 38% of the total in the category. In writing the 6 'long regular' words the first graders made 32 deletion errors (50% of the total); in reading, the same words provoked only 2 deletion errors (15% of the total). A two-way Anova was run separately for first and second graders, on long words and non-words: Complexity (long regular, consonant geminate cluster, two-letter grapheme and three-consonant letter-clusters) and Task (reading and spelling) were the two main factors. In the first graders, on long words, all main effects and interaction proved to be significant: Complexity ($F = 22.4$, $df = 3$, $p < 0.0001$), Task ($F = 55.3$, $df = 1$, $p < 0.0001$) and Complexity by Task ($F = 17.7$, $df = 3$, $p < 0.0001$). For the young grader, different complexities have uneven degrees of difficulty and reading and spelling are unequally affected by these complexities. With long non-words, the Task effect was likewise significant (Task: $F = 69.8$, $df = 3$, $p < 0.0001$); however, Complexity ($F = 2.2$, $df = 3$, $p < 0.085$) and the interaction of Complexity by Task ($F = 1.2$, $df = 3$, $p < 0.317$) were not significant. When the orthographic lexicon cannot be used, the length of the target turns all 'complexities' into an almost impossible task in both reading and spelling. In the second graders, on the contrary, the two main factors (and the interaction) were significant both for the word and the non-word list.

DISCUSSION

Unexpectedly, in a transparent orthography (Italian), the discrepancy between reading and spelling persisted throughout the first years of literacy acquisition. Reading is acquired faster and its efficient mastery extends across words and non-words; spelling is much slower and, particularly in the first graders, the discrepancy with reading is remarkably large. Moving from description to explanation, however, is more problematic. Current models of the acquisition of literacy are mostly descriptive and, central to our analysis, they have been derived, in the main, from the analysis of reading and spelling errors in a deep orthography, English (Marsh, Friedman, Welch & Desberg 1980, 1981; Frith 1985). Consequently, though purporting to outline a general theory, these models do not seem suitable to account for the acquisition of other orthographic types; attempts to adapt them to the analysis of (relatively) transparent orthographies has met with considerable difficulty (Wimmer & Hummer 1990).

The crucial point is that the above models of literacy acquisition implicitly assume that, other than 'directional' mapping differences, the two components of the system (reading and spelling) share an isomorphic structure.

As Read (1986) writes: 'There is clearly some relation between spelling and reading. The two have complementary functions based on the same writing systems, and children learn both skills within approximately the same period.' Accordingly, if differences are not to be found inside the system, discrepancies between reading and spelling could arise because children adopt different 'strategies' (Bryant & Bradley 1983), or because they 'are able to apply [orthographic knowledge] in one situation, but not in another' (Frith 1983), or because of discrepant alternations for the phonological renditions of a grapheme and the reverse transcoding (Waters et al. 1985).

Whether or not these accounts are valid for a deep orthography is a matter of experimental testing. What, by contrast, appears undeniable is their inadequacy with respect to transparent orthographies. It is difficult to adopt the 'strategic' account because our subjects are better at reading than spelling words, and are also better at reading non-words than spelling them. The 'discrepant alternatives' account fails because Italian orthography has very little irregularity in phoneme-grapheme correspondences. Discrepancies between reading and spelling, however, extend uniformly across languages and their orthographies. We must therefore concentrate on the commonalities shown by the architecture of different orthographies.

Clearly, children master a sight vocabulary and a 'writing vocabulary' even in an orthography as transparent as Italian. Our data show that performance is better for words than for non-words in both reading and writing (see Table 1). The following descriptive generalizations appear to hold of our data. First, even in a reasonably transparent orthography, children do acquire word-specific input and output orthographic lexicons. In Grade 1, the additional 'reading power' conferred by the development of these orthographic lexicons is about 10% (i.e. the difference between word and non-word reading and spelling). The point of developing such lexicons is to further fast, fluent, 'automatic' reading and spelling by content-addressable lexical-look up.

An alternative account might draw attention to more general asymmetries between recognition and recall. Could the pattern of better reading be interpreted by claiming that reading is a recognition task and writing-to-dictation a recall task? This position is unconvincing when applied to transcoding tasks. Reading words may involve recognition of the printed string, but the appropriate pronunciation must be recalled; writing-to-dictation may involve recognition of the acoustic stimulus, but the correct spelling thereof must be recalled. The reading and writing of non-words has the same logical structure, albeit at the level of individual graphemes and phonemes.

The word-reading and word-spelling discrepancy (of about 13%) suggests that acquisition and deployment of sight vocabulary is (for most children at grade 1) somewhat easier than acquisition of the orthographic output lexicon. That is, the visuo-perceptual coding of word-forms proceeds more efficiently than does the visuo-motor coding of the same forms.

The non-word reading and spelling discrepancy (of equivalent magnitude, about 13%) must clearly have another source. There is little (or no) memory-load at the input and in reading single non-words; the stimulus is available for continuous viewing. There is, however, a memory load at the output end; the phonological sequence must be assembled in working memory.

By contrast, the memory-load in spelling non-words arises at the input end; the child must remember the segmented phonetic-perceptual signal that is input to the phoneme-grapheme correspondence rules. There is no (major) memory load at output; each letter can be written down when its form becomes available from the output of the phoneme-grapheme transcoding process. In Grade 1, then, it would seem that effective short-term storage of phonological information at input is some 13% less efficient than the equivalent storage of the phonological information at output. A similar pattern holds at Grade 2, although overall performance has, of course, improved. This analysis in terms of memory-load in phonological input and output is consistent with the highly significant effects of letter length reported in Table 1.

Further support for a structural asymmetry between reading and spelling stems from the comparison of short stimuli in the two tasks. In the first graders the discrepancy between reading (90.1% correct) and spelling (86.3% correct) is significant ($t = 2.09$, $df = 34$, $p < 0.05$). But even in second graders, where ceiling effects reduce the difference (97.2% correct responses in reading, vs. 94.9% in spelling), the discrepancy still remains significant ($t = 2.76$, $df = 34$, $p < 0.01$). Given the shortness of each target, the differential performance cannot be plausibly attributed to attention or motoric factors. The discrepancies more likely involve mechanisms of phonological analysis (for non-words) and access to the orthographic lexicon for the words.

Inspection of errors provides a complementary perspective on the structural asymmetry between reading and spelling. However, the picture is more complex: as assessed by the distribution of errors, the two tasks reveal a similar sensitivity to some phonological and orthographic paradigms, whereas they diverge radically on others. At the molecular level of orthographic architecture, the asymmetry in error-rate for consonants and vowels follows an identical pattern in both reading and spelling; in each task, consonant errors outstrip vowel errors by some 40%. This discrepancy is revealing in three ways: it suggests that (a) graphemic representations specify an autonomous level for CV structure and letter identity; (b) the CV level has priority and is equivalently specified for both reading and spelling; (c) the asymmetry between consonants and vowels reflects properties of the combinatorial phonology of the language (and the orthographic rendition thereof). Point (c) finds support from cross-language analyses of reading errors: in beginning readers of Serbo-Croatian, consonant errors predominate (Ognjenovic, Lukatela, Feldman & Turvey 1983), whereas the reverse pattern has been documented for American speaking children (Fowler, Liberman & Shankweiler 1977).

Reading and spelling further display a similar sensitivity to syllable position: final syllables are prone to error some 40% more frequently than initial syllables in both reading and spelling. Several concomitant factors may be responsible for this effect in the two tasks: the limited size of the orthographic lexicons, the laboriousness of serial computations and the consequent effects on memory-load.

When we move to the word (and non-word) level, both quantitative and qualitative discrepancies between the two tasks emerge. Geminate features and consonant clusters, for instance, elicit different error-rates in reading and spelling. Furthermore, an asymmetrical distribution of different error-types is also evident. These results support our hypothesis of a structural asymmetry; more specifically they suggest that: (a) reading and spelling are unequally sensitive to the orthographic structure of words (and non-words); (b) orthographic representations do not simply consist of linearly ordered sets of graphemes (Caramazza & Miceli 1989); (c) other concomitant variables besides orthographic structure (length and lexicality, for instance) cooperate in provoking errors.

In summary, previously reported asymmetries in the development of reading and spelling have been taken to reflect (a) the idiosyncratic properties of particular orthographic systems, or (b) the 'volitional' strategies children adopt (perhaps in the face of the character of those orthographic systems). An alternative to both these positions is that distinct functional properties of the information-processing architecture separately govern the development of reading versus (written) spelling.

Position (a) and (b) both predict that asymmetries between reading and writing should not appear in a (fairly) transparent orthography, with regular bidirectional links between grapheme and phoneme. Our results show that: (1) Even in a writing system as transparent as Italian, children engage virtually immediately (i.e. by mid first grade) in the acquisition of word-specific orthographic representations; there is a significant superiority in performance on words versus non-words. Positions (a) and (b) have great difficulties in accounting for such an effect. (2) Input orthographic representations are acquired more readily than output (written) representations; there is a persistent asymmetry between reading and spelling performance on words. Thus, like the word/non-word contrast, the reading/spelling contrast cannot be attributed to either (a) or (b). We conclude that position (c) is supported. The asymmetry of reading and spelling suggests that distinct components of the functional architecture of children's minds are engaged by the two tasks.

ACKNOWLEDGMENTS

This study was supported by the Medical Research Council and the McDonnell-Pew Foundation. We also thank two anonymous reviewers for their helpful suggestions.

APPENDIX: List of stimulus words and non-words

LENGTH VARIABLE							
Short				Long			
	Words		Non-words		Words		Non-words
1	PIPA	1	RIPU	1	OMBRELLO	1	USTRAMPO
2	PERA	2	SEBA	2	BANDIERA	2	MANTIEPA
3	TOPO	3	LIPO	3	TELEFONO	3	COPEFONO
4	VASO	4	MACE	4	OROLOGIO	4	APOTORIO
5	LUNA	5	DUPE	5	OCCHIALI	5	ENTRIALI
6	MANO	6	PITO	6	FINESTRA	6	LIPESTRA
7	SOLE	7	TOBE	7	MARTELLO	7	PARFELLO
8	CANE	8	TUNE	8	CHITARRA	8	CRIBERRA
9	SCALA	9	STIDO	9	FORCHETTA	9	SOLTRECCA
10	RUOTA	10	FIOPI	10	TARTARUGA	10	RANTABUTA
11	LIBRO	11	FIDRO	11	SIGARETTA	11	MEDALINTA
12	SEDIA	12	TAVIA	12	PANTALONI	12	DAMPACONI
13	TRENO	13	CRILO	13	BOTTIGLIA	13	NOSTIGLIA
14	PESCE	14	TISCE	14	BICCHIERE	14	DONCHIABE
15	BARCA	15	GIRBA	15	LAMPADINA	15	ZENTAVIPA

REFERENCES

Agard, F. B. & Di Pietro, R. J. (1965). *The sounds of English and Italian.* Chicago: The University of Chicago Press.

Bradley, L. (1985). Dissociation of reading and spelling behaviour. In: D. D. Duane & C. K. Leong (eds.), *Understanding learning disabilities* (pp. 65–85). New York: Plenum Press.

Bradley, L. & Bryant, P. E. (1979). The independence of reading and spelling in backward and normal readers, *Developmental Medicine and Child Neurology* 21: 504–514.

Bryant, P. E. & Bradley, L. (1980). Why children sometimes write words which they do not read. In: U. Frith (ed.), *Cognitive processes in spelling* (pp. 355–370). London: Academic Press.

Bryant, P. E. & Bradley, L. (1983). Auditory organization and backwardness in reading. In: M. Rutter (ed.), *Developmental neuropsychiatry* (pp. 489–497). New York: Guilford.

Caramazza, A. & Miceli, G. (1989). Orthographic structure, the graphemic buffer and the spelling process. In: C. von Euler, I. Lundberg & G. Lennerstrand (eds.), *Brain and reading* (pp. 257–268). London: The MacMillan Press.

Carbonell de Grompone, M. A. (1974). Children who spell better than they read, *Academic Therapy* 9: 281–286.

Carlson, F., Elenius, K., Granstrom, B. & Hunnicut, S. (1985). Phonetic and orthographic properties of the basic vocabulary of five European languages, *KTH Speech Transmission Laboratory, Quarterly Report* 1: 63–94.

Chomsky, C. (1971). Write first; read later, *Childhood Education* 47: 296–299.

Cossu, G. & Marshall, J. C. (1985). Dissociation between reading and written spelling in two Italian children: Dyslexia without dysgraphia?, *Neuropsychologia* 23: 697–700.

Dejerine, J. (1892). Contribution à l'étude anatomopathologique et clinique des différentes varietés de cécité verbale, *Comptes Rendues de Séances de la Sociéte de Biologie* 4: 61–90.

Ferrero, F. E., Magno-Caldognetto, E., Vagges, K. & Lavagnoli, C. (1978). Some acoustic characteristics of the Italian vowels, *Journal of Italian Linguistics* 3: 87–96.

Fowler, C., Liberman, I. Y. & Shankweiler, D. (1977). On interpreting the error pattern in beginning reading, *Language and Speech* 20: 162–173.

Frith, U. (1980). Unexpected spelling problems. In: U. Frith (ed.), *Cognitive processes in spelling* (pp. 495–515). London: Academic Press.

Frith, U. (1983). The similarities and differences between reading and spelling problems. In: M. Rutter (ed.), *Developmental neuropsychiatry* (pp. 453–472). New York: Guilford.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In: K. E. Patterson, J. C. Marshall & M. Coltheart (eds.), *Surface dyslexia* (pp. 301–330). Hillsdale, NJ: Erlbaum.

Gordinier, H. C. (1903). Arguments in favour of the existence of a separate centre for writing, *American Journal of Medical Science* 126: 490–503.

Harshman, R. & Krashen, S. (1972). An 'unbiased' procedure for comparing degree of lateralization of dichotically presented stimuli, *UCLA, Working Papers in Phonetics* 23: 3–12.

Marsh, G., Friedman, M. P., Welch, V. & Desberg, P. A. (1980). Development of strategies in learning to spell. In: U. Frith (ed.), *Cognitive processes in spelling* (pp. 339–352). New York: Academic Press.

Marsh, G., Friedman, M. P., Welch, V. & Desberg, P. A. (1981). A cognitive developmental theory of reading acquisition. In: T. G. Waller & G. Mckinnon (eds.), *Reading research: Advances in theory and practice*, Vol. 3 (pp. 199–221). New York: Academic Press.

Marshall, J. C., Caplan, D. & Holmes, J. M. (1975). The measure of laterality, *Neuropsychologia* 13: 315–321.

Ognjenovic, V., Lukatela, G., Feldman, L. & Turvey, M. (1983). Misreadings by beginning readers of Serbo-Croatian, *Quarterly Journal of Experimental Psychology* 35: 581–615.

Read, C. (1971). Preschool children's knowledge of English phonology, *Harvard Education Review* 41: 1–34.

Read, C. (1986). *Children's creative spelling*. London: Routledge & Kegan Paul.

Shallice, T. (1988). *From neuropsychology to mental structure*. Cambridge: Cambridge University Press.

Valtin, R., Jung, U. O. H. & Scheerer-Neuman, G. (1981). *Legasthenie in Wissenschaft und Unterricht*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Waters, G. S., Bruck, M. & Seidenberg, M. (1985). Do children use similar processes to read and spell words?, *Journal of Experimental Child Psychology* 39: 511–530.

Wimmer, H. & Hummer, P. (1990). How German-speaking first graders read and spell: Doubts on the importance of the logographic stage, *Applied Psycholinguistics* 11: 349–368.

Address for correspondence: Giuseppe Cossu, Servizio di Neuropsichiatria Infantile, Università di Parma, via Gramsci 14, I-43100 Parma, Italy
Phone: +39 521 991354; Fax: +39 521 290458