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Causal connections in the acquisition of an orthographic rule: a test of Uta Frith's developmental hypothesis

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Background: In a longitudinal study we tested Frith's causal hypothesis that children first gain orthographic knowledge through reading and then later, as a consequence, through spelling. **Method:** Children from Years 2 and 3 were tested three times over two years on their reading and spelling of pseudo-words which conformed to the conditional orthographic rule, the 'final –e' or 'split-digraph' rule. **Results:** Cross-lagged panel correlation analyses suggested that the children's success in reading split-digraph words was a causal determinant of their learning to use split-digraphs in spelling, in the 7- to 8-year period and, with one year-group but not with the other, in the 8- to 9-year period. In the 9- to 10-year period children's success in reading no longer seemed to affect their spelling. **Conclusions:** These results strongly support Frith's causal hypothesis about the development of orthographic knowledge. **Keywords:** Reading development, spelling development, orthographic knowledge, conditional rules.

Literacy involves reading and writing. These two activities may be strongly related to each other, but the time-course of their development is certainly not identical. Children, and many adults too, find it hard to spell some words which they read easily. Also, children sometimes spell words correctly which they do not read (Bryant & Bradley, 1980; Gough, Juel, & Griffith, 1992). Thus, the connection between learning to read and to spell is not a simple one.

Only one theory about learning to read and write makes a coherent statement about this connection. Uta Frith (1985) claimed that there are qualitative differences in the time-course of children's reading and spelling, and also that there are *causal* links between these two activities. Early on in the process of becoming literate, according to her theory, children learn about the alphabetic code through spelling and then transfer this new knowledge to reading. After that, however, reading becomes the pacemaker: children learn to recognise orthographic patterns and rules first in reading and then later on apply this new orthographic knowledge to their spelling as well. Thus, in this model, the experiences that children have in spelling promote their use of letter–sound relations in reading, and, a year or two afterwards, their reading experiences provide the impetus for adopting orthographic principles in spelling later on. This theory is important educationally because it implies that the most effective way to foster children's learning of orthographic regularities is to ensure that they have the appropriate experiences of these regularities through reading rather than through spelling practice.

Although Frith's theory has been immensely influential, and justly so, its causal claims have never been tested properly. No one yet has produced any evidence for or against the idea that children initially acquire their orthographic knowledge through reading and then transfer this knowledge to spelling. The claim is an ambitious one because the term 'orthographic knowledge', as Frith herself uses it, comprises several different achievements. One is the knowledge of word-specific spellings which allows us, for example, to tell homophones like 'son' and 'sun' apart and to know that the word 'fight' is spelled that way and not as 'fite'. Another, also mentioned by Frith, is the learning of word-general conditional spelling rules like the split-digraph or final 'e' rule (e.g., 'hop' vs. 'hope', 'hat' vs. 'hate'). A third is the understanding that spelling is based on morphology as well as on phonology, so that, for example, even though the vowel sounds in 'heal' and 'health' are different, they are nevertheless spelled in the same way because they share the same root morpheme.

If Frith's hypothesis is correct, children learn about these regularities in reading first and then, as a consequence, in spelling later. Our paper reports a study which examines this causal hypothesis in relation to the split-digraph rule. Initially children represent vowel sounds with single letters. This works reasonably well with short vowel sounds, as in 'hat', but not with long vowel sounds, as in 'wait', 'fate', 'coat' and 'wrote' because these are usually represented not by single letters but by a digraph, such as 'ai', or by the split-digraph, such as 'a-e'. The first conditional spelling rule that children are taught at school is this split-digraph rule.

The rule seems like a highly general one, but children may master split-digraphs by learning a set of specific letter-sequence correspondences, like '-ame' in 'blame' and 'fame' and '-ope' in 'rope' and 'hope'. Existing research does not show how general or specific children's learning about split-digraphs

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is, but it does establish that children take several years to use split-digraphs effectively in reading and spelling (Marsh et al., 1982; Marsh, Friedman, Desberg, & Saterdahl, 1981; Varnhagen, McCallum, & Burstow, 1997). This research does not, however, deal in any systematic way with the connection between learning to read split-digraphs and learning to spell them, and therefore, does not test Frith's causal hypothesis.

Our aim was to provide this test. Such a test must satisfy several requirements. First, children should be asked to read and spell the same sort of words: this makes it possible to compare the development of these two activities directly. Second, at least some of these words should be pseudo-words: otherwise one cannot rule out the possibility that the children's successes might be due to specific learning about particular words. Third, the study should be longitudinal, which makes a direct test of the causal relations between reading and spelling possible.

Our study satisfied all three criteria, which gave us the chance to test three clear predictions from Frith's hypothesis about learning to use the split-digraph rule in reading and in spelling.

First, the hypothesis states that children learn simple letter–sound relationships before conditional spelling rules. Therefore, initially, children should find it harder both to read and to spell entirely unfamiliar words (pseudo-words) which conform to the conditional split-digraph rule (i.e., CVCe words like 'krite') than words which conform to simple letter–sound rules (i.e., CVC). Second, the hypothesis claims that children learn orthographic rules in reading earlier than in spelling. It predicts, therefore, that children should improve in reading CVCe words before they improve in spelling them. Third, the hypothesis makes the causal claim that the earlier improvement in reading leads to the later improvement in spelling. It follows that children's early successes in reading CVCe words should predict their success in a later session in spelling such words much more strongly than their early spelling successes with these words predict how well they read them later on.

Method

Participants

There were 74 children in the study to start with (39 girls and 35 boys) who were in Year-groups 2 and 3 at the initial testing session (Session 1). The project lasted for two years and the children were seen three times over this period. The second session (Session 2) came one year after Session 1, when 72 of the children were tested again. Two children were absent from Session 2 because one had moved abroad and the other child had had long and sustained absences from school and was unavailable for testing. The same 72 children were tested again one year later in the final session (Session 3).

Table 1 gives the mean ages of the children in the two year-groups at each of the three sessions. Also given in Table 1 are the mean scores from the WORD standardised spelling test, which each child was given at the beginning of Session 1. They show that the mean standardised score for each year-group was moderately above 100. A one-way analysis of variance produced no significant difference between the groups' scores ($F(1,71) = .207$, $p > .05$).

The children were drawn from one primary school in Oxford and three primary state schools on the Isle of Wight. All four schools contain pupils from lower to middle income backgrounds. The participants were native speakers of English.

Stimuli

The Spelling Task. In all three sessions the children were asked to spell 16 pseudo-words (pseudo-word spelling task) which are presented in the Appendix and which provide the spelling data (for Sessions 1 and 2) of this study. The pseudo-words comprised eight long and eight short vowel correspondences usually associated with the primary vowel letters a, i, o and u.

In Sessions 1 and 2, two short vowel consonant–vowel–consonant (CVC) pseudo-words were constructed for each of the vowel phonemes a, o, i, u and two long vowel consonant–vowel–consonant (referred to as CVCe) pseudo-words for each of these vowels (Pseudo-words for the long and short vowel correspondences to e were not included because the e-e spelling pattern rarely lengthens this vowel.) The long and short vowel pseudo-words were randomly arranged into short sentences. For example, the words/wib/,/zute/,/bam/ and/fud/were put in the following sentence: 'On the planet/wib/, a/zute/has two legs, a/bam/has four, and a/fud/has far too many.' The sentences were put into written format with underscored blank spaces indicating the missing test pseudo-words.

In the second session ceiling effects were found for the short vowel spelling scores for the CVC pseudo-words. Consequently, in Session 3 these monosyllabic words were replaced with more difficult polysyllabic ones. Ceiling effects had not occurred with the CVCe pseudo-words and so these remained unchanged in all three sessions. More difficult CVC pseudo-words were

Table 1 The children's ages in each session and their standardised spelling scores (WORD) in Session 1

		Session					
		1		2		3	
Year-group	WORD	*n*	Age	*n*	Age	*n*	Age
2							
M	105.9	38	7 y 1 m	37	8 y 1 m	37	9 y 1 m
SD	14.9		3.6		3.6		3.6
3							
M	104	36	8 y	35	9 y	35	10 y
SD	12.8		3.8		3.8		3.8
Total sample		74		72		72	

Note. Mean ages are given in years (y) and months (m), and standard deviations for ages are given in months.

constructed by adding extra syllables to the originals. For example, the pseudo-word/**gat**/, constructed for Sessions 1 and 2, was changed to/bli**gat**/in Session 3. Thus, the CVC sequences remained the same in all three sessions, but in Session 3 they constituted either the initial syllable (e.g.,/**bam**swik/,/**pog**sted/) or the final syllable (e.g.,/bli**gat**/,/slos**tog**/) and were always in stressed syllables.

The Reading Task. To compare performance in spelling and reading the children were asked to carry out a pseudo-word reading task comprising the same type and number of pseudo-words as the spelling task. These words involved the same primary vowel spellings a, i, o and u that code for long (when marked by a final –e) and for alternate short vowel correspondences (without the marker). The CVC and CVCe pseudo-words were randomised and listed as single words down the centre of pages, approximately five words per page, and printed in a large font.

As with spelling, reading performance was high across all short vowel words in Session 2. Consequently, the CVC words were changed in Session 3 (CVCe pseudo-words remained unchanged in all three sessions). Again, new polysyllabic pseudo-words were constructed by using the original CVC stimuli, so that 'fav' became 'favnik'. As in Sessions 1 and 2, the CVC and CVCe pattern pseudo-words were randomised and put in the form of a written list.

Procedure

The children were tested individually. The order of the spelling and reading tasks was counterbalanced. Before the first task each child was familiarised with the concept of pseudo-words, as follows: 'I'm going to ask you to read and spell some nonsense words. Nonsense words are words which are not real and are made-up, but they can still be spelled. For example, if there really was an insect called a glip, how do you think this nonsense word would be spelled?' When the child was able to verbally spell the pseudo-word unaided, the first task began. No child needed more than two practice pseudo-words.

At the beginning of the Spelling Task the child was given the written sentences with the underlined blank spaces and asked to spell the missing nonsense words. The sentences were read aloud one at a time and the child spelled the missing words in the appropriate blank spaces before the examiner continued with the next sentence. The child was asked to spell the nonsense words the way s/he thought they would be spelled if they were real. No practice words were given and no feedback during the task was given either.

In the Reading Task the child was given the list of written pseudo-words and asked to read aloud each word in the way s/he thought it would be read if it was real. No practice words were given. The child's responses were phonetically transcribed by the interviewer.

Scoring

We will present only the scores for the children's spelling and reading of the vowel sounds. In the Spelling Task we recorded whether they used an appropriate diagraph or split-digraph spelling to lengthen vowels, and whether they used an appropriate single vowel to shorten them. In the Reading Task we noted whether they gave the appropriate short and long vowel pronunciations to the vowel graphemes.

Results

The results are presented in four sections. The first validates the pseudo-word tasks. The second gives a preliminary analysis of the children's long vowel spelling scores. The third examines their reading and spelling scores for long and short vowels. In the final section we investigate Frith's claim that reading causes the development of orthographic spelling.

Part A: Validating the pseudo-word tasks

One of the reasons for testing the children on the WORD standardised spelling test was to validate the pseudo-word reading and spelling tasks. WORD measures children's orthographic knowledge and it is this type of knowledge that is required to deal with long vowels with an orthographic marker in reading and spelling. We looked at the relations between each group's pseudo-word scores in Sessions 1, 2 and 3 and the WORD scores in Session 1. We predicted that the correlations should be high for long vowel scores. This is what we found. The correlations with WORD were moderately low for short vowel spellings (ranging from .15 to .53), but were consistently high and significant for long vowel spellings (from .36 to .62, all $p < .01$).

We also found that the long vowel pseudo-word tasks were reliable. We found good reliability; alphas for these scores ranged from .8 to .9.

Part B: Preliminary analysis of long vowel spellings

Although our interest was primarily in the use of the split-digraph, the children could, and often did, legitimately spell long vowels with digraphs, such as 'oa' for 'poad'. So, our first question concerned the relative development of the use of digraphs and of split-digraphs to represent long vowels. To test Frith's developmental model of spelling, we argued that it would be most appropriate to look at orthographic spelling which is undergoing developmental change in the children being studied. The purpose of this analysis was to see whether the use of digraphs and of split-digraphs changes developmentally over the period being studied.

The mean scores for these two ways of spelling long vowels are presented in Table 2. The children's digraph spellings for long vowels did not increase as the children grew older, but their split-digraph spellings did. This was the case in both the younger and older year-groups.

Table 2 The children's mean scores (out of 8 words) for digraph and split-digraph spellings of long vowels, and single letter spelling of short vowels, in pseudo-words in each session

		Session		
Year-group	Spelling	1	2	3
Year 2	Single vowel letter for short vowels			
	M	6.8	7.4	7.2
	SD	2.3	1.1	1.3
	Split-digraph for long vowels			
	M	2.00	2.59	3.89
	SD	2.3	2.5	2.4
	Digraph for long vowels			
	M	1.14	1.27	1.05
	SD	1.1	1.2	1.2
Year 3	Single vowel letter for short vowels			
	M	7.3	7.5	7.5
	SD	1.3	1.0	0.7
	Split-digraph for long vowels			
	M	3.83	4.63	5.74
	SD	2.5	1.8	1.9
	Digraph for long vowels			
	M	1.34	1.34	1.20
	SD	0.9	1.1	1.1

We carried out separate analyses of variance of the use of digraph and of split-digraph spellings to code long vowels. We analysed these two variables separately because they were not independent of each other: the more the child used digraph spellings, the less likely s/he would be to use split-digraphs, and vice versa.

In the analysis of digraph spellings, there was one within-subjects factor, Session (1, 2 and 3) and one between-subject factor, Year-group (2 and 3). No main effects, nor any interaction, were found. Thus, there was no developmental change in the use of digraphs to represent long vowels.

The analysis of the split-digraph scores involved the same factors. The significant main effects of Session ($F(2,140) = 30.845$, $p < .001$) and Year-group ($F(1,70) = 18.131$, $p < .001$) confirmed that the use of the split-digraph as a method of lengthening vowels increases with age, both with year-group and with session. Post-tests of pairwise comparisons of the Session effect indicated a significant difference between Sessions 1 and 2 ($p = .02$), Sessions 2 and 3 ($p < .001$) and Sessions 1 and 3 ($p < .001$). There was no interaction between Year-group and Session ($F(2,140) = .106$, $p > .05$).

These analyses show definite developmental changes in the children's use of split-digraphs to represent long vowels, but none in their use of digraphs. We shall therefore confine our analysis of spelling, as well as of reading, to their use of the split-digraph as a way of representing long vowels in English words.

Part C: The development of the use of the split-digraph in reading and spelling

From the start of the study, both groups' scores for the correct reading and spelling of short vowel pseudo-words were at ceiling levels and preliminary analyses established no significant longitudinal or cross-sectional developmental differences at all in the children's performance with these words. However, as we have already seen, the children made many mistakes with long vowel pseudo-words and there were sharp age differences in the use of the split-digraph. Our next step, therefore, was to find out whether children begin to use the split-digraph rule in reading before they do so in spelling.

Figure 1 gives the reading and spelling scores for both groups in all three sessions. In this figure the X-axis is the mean age of the groups at time of testing. The only scores for age 7 years are those of Year-group 2 in Session 1, and the only scores for age 10 years are those for Year-group 3 in Session 3. Both groups produce scores at 8 and 9 years (Sessions 2 and 3 for Year-group 2 and Sessions 1 and 2 for Year-group 3). Year-group 3 children

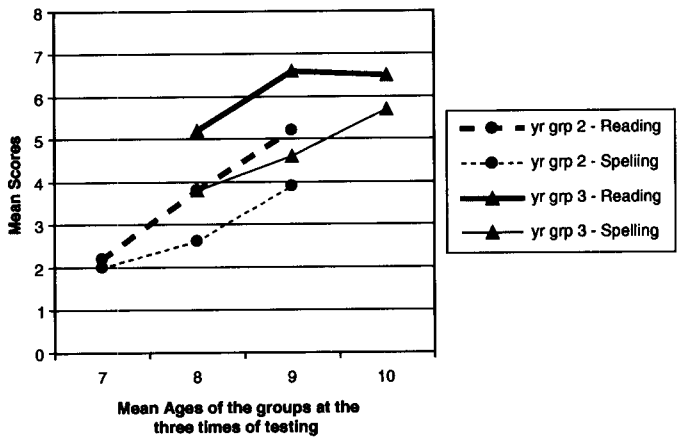

Figure 1 The mean scores for the correct use of split-digraphs (out of 8) to spell long vowels in the three sessions (Year-group 2 – broken lines, Year-group 3 – continuous lines)

achieved higher scores than Year-group 2 children at 8 and 9 years. This was an unexpected difference for which we have no explanation, since the children in the two groups came from the same schools. Practice effects would have led to the opposite pattern of results.

Figure 1 shows that between the ages of 7 and 8 years (Year-group 2) there was a steeper rise in the children's use of the split-digraph in reading than in spelling. From 8 to 9 years (Year-groups 2 & 3), on the other hand, the rate of developmental increase in the use of the rule was roughly the same in spelling as in reading for both year-groups. From 9 to 10 years (Year-group 3) there was a continued increase in the use of this rule in spelling, but not in reading.

This pattern suggests that children do indeed learn about split-digraphs in reading before spelling, as Frith's model claims. At first the improvement is stronger in reading than in spelling. Later on, between the ages of 9 and 10, there is no change in the use of split-digraphs in reading, but a continued increase in its use in spelling.

A by-subjects analysis of variance was performed on the long vowel word scores, in which the main terms were Year-group (2, 3), Task (Reading, Spelling) and Session (1, 2, 3). By-items analyses could not be run because different items were used in the reading and spelling tasks.

All three main terms (Year-group ($F(1,70) = 25.688$, $p < .001$), Session ($F(2,140) = 57.493$, $p < .001$) and Task ($F(1,70) = 70.838$ $p < .001$) were significant. The Year-group by Session interaction ($F(2,140) = 3.319$, $p = .039$) was also significant, but this was qualified by a significant interaction between Year-group, Session and Task ($F(2,140) = 3.719$, $p = .029$).

T-tests established that this interaction was due to the fact that in Year-group 2 there was a significant improvement in the reading scores from Time 1 to Time 2 ($t(36) = -4.508$, $p < .001$) and also from Time 2 to Time 3 ($t(36) = -5.288$, $p < .001$). There was no significant change in their spelling scores from Time 1 to Time 2 ($t(36) = -1.766$, $p > .05$), but these scores did improve from Time 2 to Time 3 ($t(36) = -3.770$, $p = .001$).

The pattern in Year-group 3 was different. Although their reading scores improved from Time 1 to Time 2 ($t(34) = -3.464$, $p = .001$), there was no sign of a change in their reading scores from Time 2 to Time 3 ($t(34) = .190$, $p > .05$). This group's spelling scores did not improve significantly from Time 1 to Time 2 ($t(34) = -2.171$, $p = .037$) but they did from Time 2 to Time 3 ($t(34) = -4.310$, $p < .001$).

The analysis supports our claim that improvements in the correct use of the split-digraph came first in reading and then in spelling, with one small inconsistency. The post-hoc analysis of the three-way interaction establishes that the younger children's use of split-digraphs improved in reading, from 7 to 8 years, before it did so in spelling, from 8 to 9 years. It also establishes that the use of the split-digraphs by the older children in spelling went on increasing at a time, from 9 to 10 years, when it had already levelled off in reading. The only inconsistency concerned the reading scores in the 8- to 9-year period. Both year-groups' use of the split-digraph improved in reading from 8 to 9 years. However, this change was significant for Year-group 2 (Time 2 to Time 3) but not for Year-group 3 (Time 1 to Time 2). Since, as we have noted, Year-group 3 produced more advanced reading and spelling scores than Year-group 2 at 8 and 9 years, the lack of a significant improvement in reading at these ages in Year-group 3 was probably due to the reading scores levelling out sooner among these children than among the children in Year-group 2.

Thus, these analyses show that improvements in the use of the split-digraph come first in reading and then in spelling. This developmental pattern is entirely consistent with Frith's hypothesis.

Part D: Cross-lagged correlations between spelling and reading

We come now to the third prediction, which is that children's successful experience of using of the split-digraph rule in reading eventually leads to them using the rule in spelling as well. This causal prediction was tested with cross-lagged correlation analyses.

Cross-lagged analyses deal with longitudinal correlations between two variables (A and B) that are measured simultaneously on more than one occasion. The logic of a cross-lagged analysis is simple. If A determines B, and B does not determine A, then the correlation between the children's A scores at Time 1 and their B scores at Time 2 (A^1,B^2) should be greater than the correlation between their B scores at Time 1 and their A scores at Time 2 (B^1,A^2). Cross-lagged analyses tell us whether a difference between the cross-lag correlations is significant. The cross-lagged differential establishes whether there is a significant difference in the size of the two cross-lag correlations. If the causal prediction that we are testing is right, this differential should be significant in a comparison of the correlation between early reading and later spelling and the correlation between early spelling and later reading.

Because our data were collected at three time points, we could look at these relationships over two periods, from Sessions 1 to 2 and from Sessions 2 to 3. Because the two year-groups were at different ages during these two periods and, as already noted, the groups' levels of performance at comparable ages (from 8 to 9 years) were different, we analysed the groups separately.

We applied a stringent test of the hypothesis in which the cross-lag correlations were partial correlations that controlled for age differences and also for

the outcome measure at Time 1. So, the correlation between reading at Time 1 and spelling at Time 2 controlled for differences in spelling at Time 1 and for age differences. By controlling for spelling at Time 1, we ensured that the Time1–Time 2 correlation measured the increase in the relation between reading and spelling during the Time 1–Time 2 period, and not any relationship established before that period. Similarly, and for the same reasons, the correlation between spelling at Time 1 and reading at Time 2 controlled for differences in reading at Time 1 as well as for age differences.

Figures 2 and 3 present the results of the analyses for each age group. Figure 2 shows the results for the younger children. From Time 1 to Time 2, and also from Time 2 to Time 3, the correlation between reading at the beginning of the period and spelling at the end was stronger than the correlation for spelling at the beginning and reading at the end. In both cases the cross-lagged differential was significant ($p = .002$ for Time 1 to Time 2: $p = .03$ for Time 2 to Time 3).

Figure 3 presents the results for the older children. The older group's ages in the Time 1–Time 2 period were the same as the younger group's in the Time 2–Time 3 period. For these children, too, the correlation between early reading and later spelling was higher than the correlation between early spelling and later reading in the first period. However, in this case the differential was not significant ($p \geq .05$), even though the pattern went in the same direction as it did with the younger group. This group difference is probably due to the effects of reading beginning to level out earlier in Year-group 3 than in Year-group 2, since Year-group 3 was at a relatively advanced stage in its use of the split-digraph in this age period.

The older group's figures for the 9- to 10-years period suggest a sharp change in the causal relations between the two variables. The correlation between early spelling and later reading was now actually higher than the other cross-lag correlation. The differential for the cross-lag correlations was not significant for this period ($p \geq .05$), and so it is only safe to conclude that at this later age, from 9 to 10 years, the extent of children's success with deciphering split-digraphs no longer determines how well they use these digraphs in spelling.

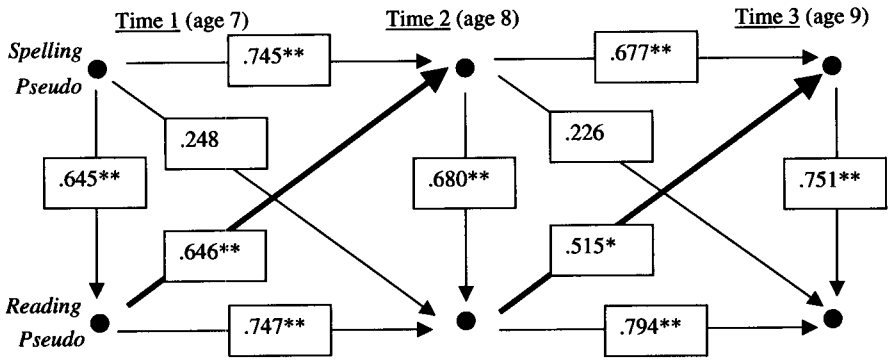

Figure 2 Cross-lagged partial correlations (controlling for age and outcome measure) between the reading and spelling of split-digraphs in Year-group 2. In Figures 2 and 3 the lines shown in bold denote a significant cross-lagged differential and the direction of this influence. *Note*: partial correlations are significant at $^{**}p < .001$, $^{*}p < .01$

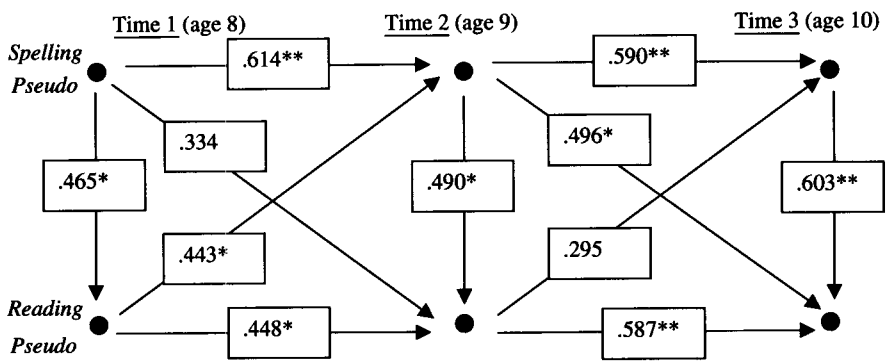

Figure 3 Cross-lagged partial correlations (controlling for age and outcome measure) between the reading and spelling of split-digraphs in Year-group 3

Summary of results

At the age of 7 years the Year-group 2 children's use of split-digraphs was low both in reading and in spelling.

From 7 to 8 years the Year-group 2 children improved reading split-digraph words. There was no equivalent improvement in spelling.

From the age of 8 to 9 years both groups improved in their use of split-digraphs in reading and also in spelling, but this improvement was not significant in the case of the Year-group 3 children whose reading performance was relatively advanced for its age.

From the age of 9 to 10 years the Year-group 3 children's use of digraphs in spelling continued to improve, while there was no change when it came to reading.

The cross-lagged correlation analyses suggested that children's success in reading split-digraph words is a causal determinant of their learning to use split-digraphs in spelling both in the 7- to 8-year period and in the 8- to 9-year period. After that there was no sign that children's success in reading continues to affect their spelling.

Discussion

We set out to test three predictions from Frith's hypothesis about the beginnings of orthographic knowledge. The results strongly supported all three predictions, and also produced one new and quite unexpected discovery about the development of children's orthographic strategies.

The first of the three predictions was that children are initially better at reading and spelling short vowel monosyllabic words which conform to simple letter-sound rules than long vowel words which involve a conditional, and therefore an orthographic, spelling rule. This was true. From the age of 7 years the children in our study had little difficulty in reading or spelling the short vowel CVC words. Yet they made many mistakes with the long vowel words both in reading and in spelling. In reading they often failed to pronounce the CVCe words correctly, and in spelling they just as frequently failed to use either a digraph or a split-digraph to represent the vowels in the long vowel words that they were asked to write.

The second prediction was about changes over time: according to this prediction the children's performance with the difficult long vowel words should improve in reading first and in spelling later on. Again our results supported this prediction. Between the ages of 7 and 8 years there was a greater improvement in children's reading than in their spelling of long vowel words. From 8 to 9 years, in contrast, the improvement in spelling gathered pace and almost equalled the equivalent improvement in the reading scores. From 9 to 10 years the spelling scores continued to improve but the reading scores levelled off. This pattern clearly suggests that children learn to use the orthographic rule first in reading and then in spelling.

The third prediction was that the knowledge of the orthographic rule that the children acquire through reading causes them to learn to use the rule in spelling as well. The pattern of our longitudinal correlations certainly supported this idea. The reading scores for the long vowel words at 7 years predicted their spelling of these words at 8 years significantly better than their 7-year spelling scores predicted their 8-year reading scores. The reading scores for the long vowel words at 8 years also predicted their spelling of these words at 9 years better than their 8-year spelling scores predicted their 9-year reading scores, although the differential was only significant for Year-group 2. The differential probably did not reach significance with Year-group 3 because the effects of reading on spelling were probably beginning to diminish in those children who were relatively advanced in their knowledge of the split-digraph rule.

As well as finding experimental support for Frith's speculative model, we also discovered a significant and quite unexpected pattern. This was the lack of developmental change in the children's appropriate use of (non-split) digraphs. Our data showed that children as young as 7 years old use this particular spelling strategy, but they do not use it extensively. Nor do the children in the older age groups. In British schools children are generally taught digraph spellings in Year 1 when they are also taught the split-digraph rule for long vowels. Therefore, all the children in our study, even the youngest in Year 2 (at 7 years of age), should have received explicit instruction in both methods.

This lack of developmental change may be because digraphs are not the most common spelling pattern for encoding long vowels in English monosyllabic words. In fact split-digraphs are the most frequent way of representing long vowels, at least for the vowel phonemes/a/,/i/and/o/(Barry & Seymour, 1988). Learning about the less frequent digraphs may be more gradual, but we need to study children's reading, as well as their spelling, of digraphs to be sure about this.

The development that we have charted in the correct use of the split-digraph is plainly an orthographic one, and we have shown that it conforms impressively well to the predictions about orthographic development made in Frith's hypothesis. Our results therefore support one clear educational implication of this hypothesis, which is that teachers should enhance children's reading experiences in order to help them learn about this particular orthographic rule, and probably other orthographic rules as well. The possible educational value of Frith's hypothesis should encourage further research to see whether other aspects of orthographic development also fit as well with her hypothesis. The

hypothesis deals not only with children's acquisition of conditional spelling rules of the type that we ourselves studied, but also with their learning about letter sequences and about morphologically based spelling rules. We suggest that longitudinal studies, like our own, should test Frith's predictions about these other aspects of orthography as well.

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Appendix

Appendix 1 Reading and spelling pseudo-words Sessions 1–3

	Primary vowel letters			
Pseudo-words	*a*	*i*	*o*	*u*
Pseudo-word Spelling Task test words				
Long vowel				
Sessions 1–3	/gakẽ	d̃ibẽ	p̃odẽ	žute/
	/jave/	/zitẽ	m̃oke/	/gluke/
Short vowel				
Sessions 1–2	/gat/	/wib/	/pog/	/fud/
	/bam/	/nin/	/tog/	pug/
Session 3	/bli**gat**/	/stan**wib**/	/**pog**sted/	/**fud**nik/
	/**bam**swik/	/**nin**raz/	/slos**tog**/	/mo**pug**/
Pseudo-word Reading Task test words				
Long vowel	fave	dite	dobe	lube
Sessions 1–3	gabe	bipe	moge	wuze
Short vowel				
Sessions 1–2	gab	bip	mog	wuz
	fav	dit	dob	lub
Session 3	bal**gab**	**bip**thirm	**mog**womp	**wuz**glot
	favnik	mols**dit**	kos**dob**	cham**lub**