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Learning correspondences between letters and phonemes without explicit instruction

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ABSTRACT
Three studies examined the sources of learning by which children, very early in learning to read, formed correspondences between letters and phonemes when these were not explicitly taught in the whole language instruction they received. There were three classes of predicted knowledge sources: (a) induced sublexical relations (i.e., induction of orthographic–phonological relations from the experience of print words), (b) acrophones from letter names, and (c) transfer from spelling experience. The results of Study 1 indicated that children used both sources (a) and (b). Study 2 results showed that source (a) dominated when the letters were initial components of pseudowords rather than isolated items. The transfer from phoneme-to-grapheme correspondences of the children's spelling was examined in Study 3. The results were not consistent with the use of source (c). The findings of these studies have implications for the question of how early in learning to read children are able to use knowledge from their experience of print words as a source for phonological recoding.

Knowledge of letter–phoneme correspondences has been considered by several theorists (Ehri, 1992; Frith, 1985; Marsh, Friedman, Welch, & Desberg, 1981) to be a critical prerequisite for the child's development of word identification skills in reading. This tradition of research has examined the effect of explicit teaching about letter–phoneme correspondences on the child's overall reading progress (Bond & Dykstra, 1967; Chall, 1967; Foorman, Francis, Novy, & Liberman, 1991). However, when individual letter–phoneme correspondences are not explicitly taught, as in some versions of the whole language approach to reading (e.g., Goodman, 1986; Slaughter, 1988), then understanding the other sources of the child's letter–phoneme knowledge is important in practical as well as theoretical domains. This series of studies was conducted to obtain evi-

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dence about such alternative sources of learning for 5-year-olds' knowledge of letter–phoneme correspondences during the first year of instruction. The general aim has a parallel in the work of Read (1975, 1986), which was conducted to determine the sources of knowledge that young children use in self-taught attempts at spelling.

In learning to read, what are the possible sources of letter–phoneme correspondence knowledge other than the stimulus–response associations that are directly taught? Sources involving the child's self-discovery of the correspondences may be used. In parallel with Read's (1975, 1986) findings on sources of knowledge for self-taught spelling attempts, letter names may provide a source through their component sounds (Mason, 1984; Venezky, 1975). For example, the name of the letter *d* has as its initial component sound the phoneme which usually corresponds to that letter. However, this source is inconsistent for a number of letters. The expected effects of these inconsistencies have been demonstrated for the letters *y* and *w* (Treiman, Weatherston, & Berch, 1994, Study 3).

As another source, beginning readers may acquire letter–phoneme correspondence knowledge by induction from their accumulated experience of letters and corresponding phonemes that are common to several print words. For example, *do*, *day*, *dog*, *duck* and their phonological forms would enable induction of the sublexical relation *d-* → /*d*/-, which is common to these words (Thompson, Cottrell, & Fletcher-Flinn, 1996; Thompson & Fletcher-Flinn, 1993).

Frith (1985) and Seymour and MacGregor (1984) proposed that knowledge of letter–phoneme correspondences for reading can be acquired from early experience with spelling. In support of this claim, these authors cited the findings of Bradley and Bryant (1979) and Bryant and Bradley (1980), which purported to show that 6-year-olds were able to make phoneme-to-letter correspondences for the purpose of spelling before demonstrating knowledge of letter–phoneme correspondences in reading. It was supposed that knowledge of correspondences for spelling would transfer to knowledge of correspondences for reading. If this were the case, then self-taught spelling experience (Bissex, 1980; Read, 1975, 1986) could provide yet another possible source of letter–phoneme knowledge.

Studies 1 and 2 were designed to obtain evidence about letter names and induction from print lexical experience as sources of knowledge for learning the letter–phoneme correspondences of reading. In Study 1, all letters of the English alphabet were presented to 5-year-old children to name and, later, to give the letter sound. Responses to letters for which the initial sound of the letter name provides the standard letter sound were compared with responses to letters for which the initial sound does not. Induced sublexical relations (ISRs) were considered as another source of the children's responses. As this source would derive from the children's print lexical experience, an examination was made of the relationship between their responses and the frequency of occurrence of each letter–phoneme correspondence among the words they experienced in their reading books. Study 2 was designed to manipulate the competing influences of the letter name and ISR sources for selected letters by comparing the children's responses to the letters in isolation with their responses to the letters as components of pseudowords. It was expected that the latter condition would enhance

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the children's use of ISRs as a source of knowledge. In Study 3, a test was made of the alternative possibility that the children's spelling experience was the source of their knowledge of letter–phoneme correspondences. The children in all the studies were at the very early levels of learning to read. They attended schools that provided a version of the whole language approach to reading which did not include explicit instruction on individual letter–phoneme correspondences.

STUDY 1

Acrophonic letter name principle. One purpose of Study 1 was to examine the children's use of the acrophonic principle in English orthography (Venezky, 1975) as a means of deriving the phoneme corresponding to a presented letter from their knowledge of letter names. According to this principle, the initial pronunciation element in the spoken name of the letter is taken as the corresponding phoneme for the letter. For example, the name of the letter *b* has the initial pronunciation element /b/, which the child would take as the phoneme corresponding to the presented letter. Although the acrophonic principle yields the standard phonic response for the letter *b*, it does not for others (e.g., a response with an initial /w/ for the letter *y*).

The standard phonic response is the most typical phoneme corresponding to the letter among the vocabulary of print words experienced by the child. These include the vowel sounds of *at* for the letter *a*, *egg* for *e*, *it* for *i*, *cot* for *o*, and *up* for *u*, as well as the initial consonant sound of *bat* for the letter *b*, *cat* for *c*, etc. (accepting the child's particular accent or dialect of English). These were confirmed as the most typical correspondences in vocabulary counts of the books used in the first year of reading instruction of the children in this study. These are the standard phonic responses traditionally introduced early in phonic teaching programs, although the children in this study had not received any such program.

The vowel of the letter name is a long vowel, which is different from the short central vowel in the standard phonic response to consonant letters. Successful use of the acrophonic principle requires substituting the short vowel phoneme of the corresponding response for the long vowel of the letter name. This requires cognitive access to, and manipulation of, phonological segments at least as small as the phoneme in two-phoneme items. Such skills are demonstrated in tasks that require an awareness of phoneme segments. If children have knowledge of the relevant letter names, demonstrate sufficient sensitivity to phoneme segments for self-generated use of the acrophonic principle, and have inferred and use this principle, then they would be expected to show a very high level of standard phonic responses to letters with names that are compatible with the successful use of the principle: *b, d, j, k, p, t, v, z.* Other letters have names that preclude successful use of the acrophonic principle: *c, g, f, h, l, m, n, s, u, w, x, y.* For example, the initial pronunciation element in the name of the letter *c* is /s/ – not the standard phonic response, /k/. For these letters, few standard phonic responses would be expected, but evidence of the use of the

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acrophonic principle would be predicted in the responses: for example, an /s/ response as the sound for the letter *c;* /ʤ/ (initial phoneme of *jam*) for *g;* and the initial phoneme of *egg* for *f.*

Induced sublexical relations. Letter names, however, may not be the child's only source of knowledge of individual letter–phoneme correspondences when these are not explicitly taught. Another possible source is ISRs. These comprise the child's acquisition of orthographic–phonological correspondences by induction from accumulated print word experience and, of particular interest here, acquisition formed on the letter as an initial-position grapheme common to several words. Researchers have found that knowledge of initial-position letters is acquired more quickly than that of orthographic components in other positions within the print word at the early reading level (Stuart & Coltheart, 1988). If a high incidence of appropriate print lexical experience were available to the children using the ISR source, then a high level of standard phonic responses would be expected. Letters for which appropriate print lexical experience was of low incidence would be expected to yield a low level of standard phonic responses unless such letters had names that were compatible with the use of the acrophonic principle; if that were the case, then letter names would provide a source of appropriate letter–phoneme correspondence knowledge.

Interference between sources. If the children did use both sources of knowledge, then when the acrophonic letter name source was incompatible with the ISR source some competition and interference between the sources would be expected. However, the extent of such interference may vary among the letters that are incompatible with the acrophonic letter name source. For example, for the letters *f, l, m, n,* and *x,* this source would result in the same response (the vowel of *egg*). If children did expect letter sounds to distinguish letters, then they would not expect more than one letter to have the same sound. After they had made the same response to more than one letter, such responses to other letters would likely be inhibited, thus weakening the interference of the acrophonic letter name source. Data was not obtained here to examine whether such factors contribute to the variability of the interference between the two sources of knowledge.

Rather, we predicted that if children did use the ISR source, its influence would be strong enough to be determined in spite of any other confounding factors. The influence of the ISR source would be seen among letters with standard phonic responses that are incompatible with the acrophonic letter name source. The level of standard phonic responses would vary according to the frequency with which the letter as an initial-position grapheme corresponded to the appropriate phoneme in the words of the children's print experience. However, for letters with standard phonic responses that are compatible with the acrophonic principle, no interference would occur, and the child's use of the principle was expected to result in a uniform, high level of standard phonic responses.

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The accent of English. The participants in this study heard and spoke New Zealand English (NZE) (Bauer, 1986; Gordon & Deverson, 1985). In the range of pronunciation varieties which comprise NZE, the letter names for the vowels *a*, *i*, and *o* are closing diphthong sounds, which involve a starting point that is different from the end point of pronunciation; the end point is a more closed ("higher") pronunciation than the starting point. For these letters, the children could use the acrophonic principle by taking the short vowel in their phonological system that is near, but not more closed than, the pronunciation element, which is the starting point of the diphthongal letter name, and use that as their phonic response to the letter. (As these letter names are closing diphthongs, pronunciations that are near, but more closed than, the starting point – that is, in the direction of the diphthongal shift – would be perceived as part of this shift rather than distinguished as near the starting point of pronunciation.) Among the letters with names composed of a vowel phoneme, *o* is the only letter for which the acrophonic principle would be successful in producing a standard phonic response. The standard phonic response for *o* is the short vowel of *cot*, which in NZE is an open back rounded vowel, /ɒ/. This is near, but not more closed than, the starting point for the (closing diphthongal) NZE pronunciation of the letter name of *o*, an open rounded vowel. In NZE, the pronunciation for the standard phonic response to the letter *a* is more closed than the starting point of the pronunciation of the letter name for *a*. The other nearest short vowel to this starting point in NZE is the vowel of *up*, an open central unrounded vowel in the region of /ɐ/. For the letter name of *i*, the starting point is an open vowel pronunciation. The nearest short vowel is /ɐ/ or, in the broader variety of NZE, /ɒ/. (See Gordon and Deverson, 1985, for descriptions of varieties of NZE. The International Phonetic Alphabetic [IPA] is used here in a transcription system consistent with Wells, 1982.) In NZE the letter name for *r* is a lengthened open unrounded vowel followed by a pronunciation tending toward /r/. In this case, the starting point is in the region of the short vowel /ɐ/. The letter name for *e* in NZE is not clearly diphthongal, unlike the names for *a*, *i*, and *o*. Hence, application of the acrophonic principle to the pronunciation of the letter names of *a*, *i*, *r*, and *e* in NZE would not yield the standard phonic responses. However, some evidence of the use of the principle could be gained from the prediction that responses would include short vowels near, but not more closed than, the pronunciation starting points of the letter names *a*, *i*, and *r*.

Summary of predictions tested. Taking into account this particular accent of English, specific expectations for the children's application of the acrophonic principle to both consonant and vowel letters were examined. In addition, a test was made of the more general prediction that a uniformly high level of standard phonic responses would be given to letters that are compatible with the principle; conversely, the influence of the ISR source of knowledge would be evident in responses to letters that are incompatible with the principle. For these letters, the level of standard phonic responses would vary according to the frequency of the particular letter–phoneme correspondences among words of the children's print experience. These frequencies were ascertained by analyzing the vocabu-

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lary in the children's reading books. Pronunciation responses ("letter sounds") were obtained for isolated letters as were letter name responses for the entire English alphabet for children receiving their first year of school reading instruction. While this instruction, a version of the whole language approach, did not include explicit teaching of individual letter–phoneme correspondences, letter names were used by teachers and children for identifying letters in classroom tasks.

METHOD

Participants

Children were selected from three schools in the Wellington–Hutt area in New Zealand. The children were taught to read using the "book experience" approach (a type of whole language teaching), which emphasizes the semantic–syntactic context of the word and the word's initial letter as cues to word identification. Explicit phonics was not included insofar as the children did not receive explicit instruction in the pronunciations for isolated letters or in the correspondence between component letter sequences of words and their pronunciations. There was no instruction in assembly (blending) of sounds. Letters were referred to by names and not by their corresponding sounds. On the few occasions when the component sound of a word was considered, the children usually listened for the sound corresponding to the initial letter of a selected word in a story text as the word was pronounced by the teacher. Sometimes this guidance would extend to a comparison with another word having the same initial sound and letter. This approach to reading instruction has been used in New Zealand since the 1960s. Researcher observation in the classrooms from which the children were drawn indicated that the teachers' practice was consistent with this approach. While the children read, attempts at sounding out segments of a word were rare and did not extend beyond the word's initial phoneme. Further information on this approach and its effects, compared with instruction that includes phonics, may be found in Thompson (1993), Thompson and Johnston (1993), Johnston and Thompson (1989), and Johnston, Thompson, Fletcher-Flinn, and Holligan (1995). Children in New Zealand commence school on their fifth birthday, and reading instruction commences within the first two months at school. In the initial months, there is concurrent emphasis on self-expression in written language. This provides incidental learning of letter names, as letters are identified for writing. The teachers encourage children to invent spellings for words as they attempt to write their own stories. Afterwards, each child reads to the teacher what he or she has written, and the teacher writes the correct version for the child. Lists of spelling words for memorization are not used nor are spelling or phonics workbooks.

A total of 171 children, aged 5;1 to 6;3, from three schools were initially tested on word reading attainment. To ensure that the sample comprised only those at the very early level of beginning reading (rather than prereaders or more advanced beginners), children who were unable to score on the word test and children with a reading age over 6;9 were not included. The resulting sam-

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ple was 72 children (33 girls, 39 boys) with a mean chronological age of 5;9 (SD = 3.9 mos., range = 61–75 mos.). Word reading attainment levels were assessed using the New Zealand revision of the Burt Word Reading Test (Gilmore, Croft, & Reid, 1981) in which individual words of increasing difficulty are read orally. The mean raw score was 13.2 (SD = 9.3, range = 1–28). This was below a reading age of 6;1 (raw score 20), which is the lowest level presented in the published norms. All participants were speakers of NZE. Their aural vocabulary was assessed using the British Picture Vocabulary Scale, Long Form (Dunn, Dunn, & Whetton, 1982). The mean standard score (IQ) on this test was 100 (SD = 9.9, range = 85–121).

Materials and procedures

The stimuli for the tasks were the 26 letters of the English alphabet, each printed in lowercase Helvetica (sans serif) font on a separate white card. Letters with ascenders were 6 mm in height. The two tasks were administered to the children individually in the same session and in the following order. The first task was to name the letters. The order of presentation of the letters was randomized for each participant. In the second task, the children were instructed to pronounce the sound for each letter; again, the order of presentation was randomized. When necessary, the researcher reminded the children to pronounce "the sound, not the name of the letter."

The children's experience of particular letter–phoneme correspondences in print words was indexed by a word count. This count was made from the books in use for the first year of instruction in two of the three schools. The third school used a similar range of books, but a word count was not made of them as only 10 of the 72 participants were drawn from that school. There was a total of 20,482 word tokens and 1,518 word types (different words) in the texts of 244 books for this level in the first school. For the second, smaller school there was a total of 7,335 word tokens and 913 word types in the texts of 80 books. Most books carried only one brief story. It was expected that the frequency of a grapheme among word types would indicate the number of available lexical contexts for that grapheme within the children's print word experience. ("Grapheme" is understood here as the letter or letter combination that corresponds to a phoneme of a word.) The token frequency (total occurrences) of a grapheme would be a less useful indicator: very high frequencies may occur but may involve only two or three different words, which would be insufficient for the induction of sublexical relations. The frequency values used were the sums of the two word type counts, which in effect weighted the values by the size of the total number of word types from each school.

For each letter of the alphabet, a determination was made of the frequency (f_1) of word types with the letter as an initial-position grapheme that corresponded to a NZE phoneme compatible with the standard phonic response. (The f_1 values are listed in Appendix 1.) This frequency was weighted by the proportion of word types for initial position that had this correspondence, giving $W = \left(\frac{f_1}{f_1 + f_2} \right) f_1$. The variable f_2 was the frequency of word types with the letter as an

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initial-position grapheme that corresponded to a phoneme incompatible with the standard phonic response. (The f_2 values are also listed in Appendix 1.) The weighting proportion $\frac{f_1}{f_1 + f_2}$ is unity when $f_2 = 0$, that is, when there is complete consistency; all word types with the letter as initial-position grapheme have the same compatible corresponding phoneme. For example, this was the case for the letter *b*, $f_1 = 230$, $f_2 = 0$: hence, the consistency weighted frequency, $W = 230$. However, this was not the case for the letter *a*, $f_1 = 32$, $f_2 = 33$: hence, $W = 15.8$. There were a number of words in the counts (e.g., *after, all, away*) in which the letter *a* corresponded to an NZE phoneme incompatible with the standard phonic response. For the purposes of the descriptive group results, the letters were classified into three groups: those with low values of *W* (under 20), medium values (20–119), and high values (120 and over).

A test of phonological awareness was administered (Tunmer, Herriman, & Nesdale, 1988). In this task, the children tapped out the number of sounds they heard in each aurally presented syllable. The task did not involve pronouncing or blending isolated phoneme segments. It was therefore considered an appropriate measure of awareness for children who had no school experience in producing such pronunciations. The children listened to 20 pseudoword items of one syllable, each comprising one to three phonemes. Each item included one of the five short vowels corresponding to *a, e, i, o, u.* Five items were in consonant–vowel–consonant (CVC) form (*baf, dez, tiv, pok, sug*); five were in consonant–vowel (CV) form (*da, pe, ti, vo, fu*); five were in vowel–consonant (VC) form (*ab, ez, ig, os, uk*); and five comprised each short vowel only. There was a balance of plosive and fricative consonants between the sets of CV and VC items. Both the CVC and CV items are onset–rime segments, and the VC items are rime segments, where onset and rime are segments that can be intermediate between phoneme and syllable (Goswami & Bryant, 1990; Treiman, 1992).

RESULTS AND DISCUSSION

Phonemic awareness

The mean total accuracy score on the test of phonological awareness was 12.3 ($SD = 3.5$, range = 5–19), which was one standard deviation above the mean score reported by Tunmer, Herriman, and Nesdale (1988) for a Western Australian sample who were the same age but had not commenced school instruction in reading. The mean percentage accuracy of the one-phoneme items was 82%; for the three-phoneme items, it was 42%. Among the two-phoneme items there was a 49% mean accuracy for awareness of the onset–rime segments, which were the CV items. This was significantly lower than the 72% accuracy for awareness of phoneme segments within rimes, which were the VC items, $F(1, 69) = 34.20$, $MSE = 546.14$, $p < .001$, in the analysis by subjects, and $F(1, 8) = 25.33$, $MSE = 153.80$, $p < .01$, in the analysis by items.

Goswami (1993) and Treiman (1992) regarded awareness of onset and rime segments as the developmental precursor of phoneme awareness and, hence, as particularly important for the initial learning of reading. Contrary to the expecta-

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tion based on these views, awareness of segments within the VC rimes was easier for the children than awareness of segmentation of onset from rime in the CV items. (It should be noted that awareness of phoneme segments within consonant or vowel clusters is another matter and thus is not considered here.) Similar results have been reported elsewhere (Seymour & Evans, 1994; Treiman & Baron, 1981, p. 171; Tunmer & Rohl, 1991). One possible explanation for these results is that the children adopt a particular pronunciation strategy (Tunmer & Rohl, 1991). Whatever the explanation, the present results show that for the two-phoneme stimulus items there was some awareness of phoneme segments. Use of the acrophonic principle involves substituting the vowel phoneme of letter names that compose two phonemes. For the child to use the acrophonic principle, sensitivity to phonemes within two-phoneme items is necessary. Hence, for these children, a failure to use the acrophonic principle cannot be attributed to an absence of appropriate phonemic sensitivity.

Group results for responses to the letters

If a child uses the acrophonic principle, then the letter name must be known. In the letter name task, correct responses were given by a high percentage of the children for all lowercase letters except *q*. The percentages ranged from 69% to 97% for individual letters. However, only 33% of the children correctly named *q;* 51% named it as *p*. Because the letters were presented to the children in a sans serif font, *p* and *q* were exact lateral reversals, which may have contributed to their confusion. In response to this likely visual perceptual confusion, the letter *q* was excluded from the main analyses. In the analyses of the group results, sample statistics were not appropriate, as a universe of 25 items was examined.

In the letter sound task, the standard phonic response accepted for a consonant letter was the phoneme followed by any short central unrounded vowel (the class of which will here be indicated as /../). In the NZE pronunciation of the children, such vowels were close to their pronunciations of *up* or *it.* Hence, the accepted standard phonic response to the letter *b* was /b../. For the letter *c*, the standard phonic response accepted was /k../; for *g*, /g../; for *x*, /ks../; and for *y*, /j../ (/j/ = initial sound of *yes*). For other letters representing consonants, the accepted responses were unambiguous, the consonant component being the one commonly associated with the letter in the initial position of English words. In the letters representing vowels, the accepted standard phonic responses were as follows: *a*, the vowel in the NZE pronunciation of *at; e*, the vowel in *egg; i*, the vowel in *it; o*, the vowel in *cot;* and *u*, the vowel in *up.*

The mean percentages of correct responses to the letter name task and of standard phonic responses to the letter sound task for the six categories of letters are shown in Table 1. Also shown in Table 1 are the percentages of standard phonic responses to the letter sound task, based on only those instances in which the correct letter name was given in the letter name task. The level of standard phonic responses was uniformly very high for letters that provide compatibility between application of the acrophonic principle and the phonic response. Furthermore, as predicted, the level of such responses was relatively high for letters

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Table 1. *Mean percentages of responses to letters in the letter name and the letter sound tasks, Study 1*

Frequency (*W*)	Letter name accuracy		Letter sounds: Standard phonic responses			
			All instances[a]		Letter named correctly	
	Compatible	Incompatible	Compatible	Incompatible	Compatible	Incompatible
High	79	90	77	70	91	75
Medium	79	84	75	56	91	63
Low	89	86	76	21	85	22

Note: Letters compatible with the acrophonic principle: high *W* frequency, *b, p, t*; medium, *d, j, k*; low, *v, z, o*. Letters incompatible with the acrophonic principle: high *W* frequency, *c, f, h, m, s*; medium, *g, l, n, r, w, y, e*; low, *x, a, i, u.*
[a]Values for individual letters are given in Table 2.

that are incompatible with the acrophonic principle but have a high *W* frequency as an initial grapheme among word types, with a corresponding phoneme consistent with the standard phonic response. The responses to these letters could be achieved through application of the children's knowledge of ISRs (i.e., knowledge of letters and corresponding phonemes induced from their accumulated experience of print words). In contrast, as predicted, the letters that are incompatible with the acrophonic principle and have a low *W* frequency had a very low percentage of standard phonic responses.

Word position of ISRs. Very early in learning to read, children acquire knowledge of initial-position letters of words more quickly than of other parts of words, although knowledge of final-position letters is apparently the next to be acquired (Stuart & Coltheart, 1988). ISRs are coded by position within words, and it has been shown that, early in learning to read, children can gain knowledge of ISRs for final- as well as initial-position graphemes of words (Thompson, Cottrell, & Fletcher-Flinn, 1996). The responses in the letter sound task for the 16 letters that are incompatible with the acrophonic principle could be based on final-position ISRs as well as those of initial position. This was examined by determining the frequencies h_1, h_2 (listed, in Appendix 1) for final-position letters that parallel the frequencies f_1, f_2 for initial-position letters. The frequencies h_1, h_2 were used to calculate the weighted frequencies, *Z*, for final position that parallel the *W* frequencies for initial position, using the same numerical values to divide high, medium, and low levels. Also determined were the percentages of standard phonic responses to the letter sound task, based on those instances in which the name of the letter was correctly given in the letter name task.

There was a mean of 77% ($SD = 12\%$) of such standard phonic responses to incompatible letters with both *W* (initial position) and *Z* (final position) frequencies at a high/medium level (*l, m, n, s*), 63% ($SD = 15\%$) for letters with high/medium *W* frequencies but low *Z* frequencies (*c, f, g, h, r, w, y, e*), and 22%

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Table 2. *Letter sounds, Study 1: Percentage of standard phonic responses, with other responses in parentheses*

Frequency (*W*)	Compatible	Incompatible
High	*b*, 69 (/d../, 18) *p*, 78 *t*, 83	*c*, 43 (/s../, 42) *f*, 76 (/e/, 8) *h*, 67 (/ɐ/, 10) *m*, 74 *s*, 89
Medium	*d*, 69 (/b../, 14) *j*, 75 *k*, 82	*g*, 46 (/ʤ../, 35) *l*, 56 (/e/, 10, /ɐ/, 10) *n*, 63 (/e/, 8) *r*, 65 (/ɐ/, 10) *w*, 69 (/d../, 11) *y*, 39 (/w../, 24) *e*, 51 (/iː/, 24)
Low	*v*, 78 *z*, 79 *o*, 71	*x*, 6 (/e/, 18, /eks/, 15) *a*, 31 (/ɐ/, 43) *i*, 28 (/ɐ/, 31, /ɒ/, 11) *u*, 17 (/j../, 39)

Note: Other responses are listed only if given by 6 (8%) or more of the 72 participants. "Don't know" or no response are not included. See text for an explanation of the use of the IPA symbols for the transcription of New Zealand English.

(*SD* = 12%) for letters with low *W* and *Z* frequencies (*x*, *a*, *i*, *u*). There were no incompatible letters with low *W* frequencies and high/medium *Z* frequencies. (It should be noted that *h*, *r*, *w*, *y*, *a*, *e*, *i*, and *u* all had zero *Z* frequencies. In contrast, *x* was the only letter with a zero *W* frequency.) These results suggest that the ISRs used in phoneme responses to isolated letters are formed from the initial-position rather than final-position graphemes of words.

Responses other than standard phonic. For the letters that are incompatible with successful use of the acrophonic principle, the letter sound responses other than standard phonic responses appeared to be attempts to use the acrophonic principle (see Table 2). In response to the letter *c*, many participants gave /s../; the /s/ component is the initial pronunciation element of the letter name for *c*. In response to *g*, many gave /ʤ../; the /ʤ/ (= the initial phoneme of *jam*) component is the initial element of the letter name for *g*. For both *c* and *g*, responses in accordance with the acrophonic principle were relatively frequent among the participants and at a level similar to their standard phonic responses. It is possible that, for these letters, there is competition between two sources of knowledge: the letter names for the acrophone responses and the ISRs, which are more likely to provide the standard phonic responses. This possibility was examined in Study 2.

In response to *w*, some children gave /d../, where /d/ is the initial pronuncia-

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tion element of the letter name for *w*. In response to *u*, some children gave /j../, where /j/ (= initial phoneme of *yes*) is the initial element of the name for *u*. In response to *y*, some children gave /w../, where /w/ is the initial element of the name for *y*. The letters *f*, *n*, and *x*, which are also incompatible with a standard phonic response from the acrophonic principle, received the response /e/, which is the initial pronunciation element of their letter names (/ef/, /en/, and /eks/). The symbol /e/ is the IPA symbol for a half close front unrounded vowel (the NZE pronunciation of the vowel of the word *dress*). (Note that in some transcription systems for American English, such as that of Kenyon and Knott, /e/ is used to represent a very different pronunciation – the vowel diphthong of the word *bait*.)

The letter *m* also received the response /e/ but only from 7% of the children; this was just below the criterion for inclusion in Table 2. The initial pronunciation element of the name of the letter *l* in NZE is often different from /e/, being an open central unrounded vowel, /ɐ/. Hence, the other responses were sometimes /ɐ/ rather than /e/. These responses would be expected if the children were attempting to use the acrophonic principle. If, on the contrary, the children were responding mainly to the elements that distinguish the sounds of the letter names, then /e/ would not have been a response to the letters *f*, *l*, *m*, *n*, or *x*. Probably as a result of its very high frequency as an initial grapheme, the letter *s* had such a high level of standard phonic responses that no other responses to the letter were sufficiently frequent to be classified in Table 2. The other responses given to *b* and *d* indicate visual lateral reversal errors and, as such, are outside the interests of the present study. The result for the letter *q*, although named correctly by only 33% of the children, was also examined. The pronunciation of the name of this letter, /kjuː/, has an initial consonant component which only partially matches the initial /kw/ component of the standard phonic response for *q*. Hence, *q* is only partially compatible with the acrophonic principle. (Also, it has a low *W* frequency.) The level of standard phonic response to this letter given by the children who knew its letter name was only 46% – much lower than that to letters that are fully compatible with the principle (Table 1).

The results for *a*, *e*, *i*, *o*, and *r*, the letter names of which have a vowel pronunciation, are given in Table 2. The letter *h* is also included here. Although the name for this letter includes more than a vowel pronunciation, the initial phoneme of the name is a long vowel, which is itself the letter name for *a*. In this case, application of the acrophonic principle would initially yield this letter name, which could then be treated in the same way as other vowel letter names. The letter *o* is the only one which has a name that is compatible with the acrophonic principle. Therefore it was expected that the level of standard phonic response to the letter *o* would be high. This was indeed the case. In contrast, letters which have names that are incompatible with the acrophonic principle (*a*, *i*) yielded standard phonic responses at a very low level. The influence of the acrophonic principle was apparent, however, in the other responses. In NZE, the short vowel that is near, but not more closed than, the starting point of the pronunciation of the letter name for *a* is /ɐ/. This was the response of some children. However, the response could have derived from one of their stressed pronunciations of the word *a*. The starting point of the pronunciation of the

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letter name for *i* is an open position that is near either /æ/ or /ɒ/, depending on how broad the variety of NZE is. Both these short vowels occurred in the responses of some children.

The letters *h, r,* and *e* have high or medium frequencies as initial graphemes among word types that are consistent with the standard phonic response. As expected in view of the children's knowledge of ISRs, these letters showed a relatively high level of such responses. The influence of the children's experience of the letters as initial graphemes of print words was apparent. Although even here there was some indication of influence by the acrophonic principle. For *h* and *r,* some children gave /æ/, which in NZE is the acrophone of the letter name for *a* (the initial phoneme of the names for letters *h* and *r*). For the letter *e,* the letter name itself was given as a response by some children. Unlike the letters *h* and *r,* which each have more than one pronunciation element, the letter name for *e* often approximates a monophthong (vowel /iː/).

Alternative explanations. The results in Table 2 cannot be attributed to letter sound instruction received by the children of which the researchers were unaware. If such teaching had taken place, possibly by parents, then the level of standard phonic pronunciations given for, say, *a* and *i* would not have been so low and would have been more comparable to that of the other letters. Moreover, frequently occurring pronunciation responses, such as /j../ to the letter *u* and /w../ to the letter *y,* are not taught in phonics instruction and so cannot be explained as the result of hidden phonics instruction.

It may be argued that letter names which have any component pronunciation element that is the same as the distinguishing phoneme of the standard phonic response will provide the child with the appropriate response; in other words, the initial position of the pronunciation element is not critical, as is claimed in the acrophonic principle. However, this argument only offers partial information or cues about the phonic response. For example, the child would not know whether this type of response to the letter *m* should be /e/ or /m../; the letter name provides both pronunciation elements. This partial information may be useful as a cue if the child has heard the standard phonic response given to the letter. Such was apparently not the case for the children examined here.

An alternative argument could be that the children were able to distinguish the consonant and vowel elements of the letter name pronunciations and used any consonantal element of the letter name, irrespective of temporal position within the pronunciation of the name. If this were the case, however, the /e/ responses to the letters *f, l,* and *n* in Table 2 would remain unexplained. Moreover, by this account it would be expected that the noninitial consonantal elements in the pronunciations of the letter names for *w, h,* and *z* (named /zed/ in NZE) would appear among the children's responses to these letters. These are /b../ or /l../ for *w,* /tʃ/ for *h,* and /d/ for *z.* The results in Table 2 show that this was not the case. Furthermore, this account provides no explanation for the obtained responses to the vowel letters, *a, e, i, o, u.*

Another possible interpretation of the relative difficulty levels of letter–phoneme correspondences has been proposed by Stuart and Coltheart (1988). Whether or not these correspondences are explicitly taught, they claimed that

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the relative difficulty of learning them is dependent on the child's developing awareness of the specific phoneme segments. The easiest phoneme correspondences to learn would be those for phonemes that are most easily segmented by the child from the phonological form of the word. These are claimed to be the obstruent ("strong") consonants: the stops and fricatives (e.g., /b/, /d/, /f/, /v/). The nonobstruent consonants (e.g., /m/, /w/) are expected to be more difficult, and the vowels, the most difficult. Their proposal draws on linguistic theory about the relative strength of segments (Hooper, 1976, pp. 195–207). The results in Table 2 are inconsistent with the proposal of Stuart and Coltheart. The phoneme correspondences for the letters *m*, *w*, and *o* are not more difficult than those for *b*, *d*, *f*, and *v*.

Individual participants' responses to the letters

The preceding group analysis is not sufficient to show whether most of the individual participants were making use of ISRs. A possible interpretation is that there were two subgroups of participants, one which used ISRs and the other (a smaller subgroup) which did not. Almost all of the children with knowledge of letter names apparently used the acrophonic principle, as indicated by the extremely high percentage of standard phonic responses to the letters that are compatible with this principle (Table 1). The possibility that only a subgroup is making use of ISRs was tested by examining the generality of the results across children. To achieve a meaningful analysis, it was necessary that relevant data be available for most of the letters of the alphabet for each child. If the child did not know a letter name, then there would be no opportunity for him or her to use the acrophonic principle for that letter. To ensure that the selection included children who have had such an opportunity, the 15 (of the 72) children who did not know six or more of the 25 letter names were excluded. For each child, only those letters that were named correctly were included in the analysis. To ensure that the results were not confounded by overall floor or ceiling effects in the dependent variable, the analysis did not include the children with 8% (2 out of 25) or fewer standard phonic responses or the six children with 92% or more such responses to correctly named letters.

As well as determining each child's level of standard phonic responses to the compatible and incompatible letters, we also examined the extent to which the occurrence of such responses to incompatible letters varied with the *W* frequency of the letter by conducting a point-biserial correlation for each child. Four children were not included because they had insufficient standard phonics responses (less than 10%) to determine a meaningful point-biserial correlation. The resulting sample of 46 children was very similar to the total group of 72 children on the several descriptive variables. There were 19 girls and 27 boys, with a mean chronological age of 5;10 ($SD = 3.3$ mos., range = 63–75 mos.). Their Burt Word Reading mean raw score was 15.6 ($SD = 8.4$, range = 1–28); their British Picture Vocabulary mean standard score was 103 ($SD = 9.5$, range = 86–121); and the phonemic awareness test mean total score was 13.0 ($SD = 3.0$, range = 6–19).

The mean percentage of standard phonic responses given by each child for

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the letters that are compatible with the acrophonic principle was 92%, with 27 of the 46 children reaching 100%. The mean for the incompatible letters was 62%, with none of the children reaching 100%. This difference was statistically significant, $t\,(45) = 12.43$, $p < .001$, for correlated pairs of values. For the incompatible letters, determinations were made of the relationship between the child's standard phonic response to the letter and the level of *W*, the consistency-weighted frequency of the letter (as an initial-position grapheme among the word types in the children's reading books). These determinations were made by obtaining a point-biserial correlation between the variables for each child. Diminishing effects of *W* would be expected as *W* increases; hence, a logarithmic transformation of the variable, $\log_{10}(W + 1)$, was made to approximate this nonlinear relationship. The mean of these correlations for the 46 children for the incompatible letters was .54 ($SD = .18$), a value significantly different from zero, $t\,(45) = 19.99$, $p < .001$. No such meaningful correlation could be determined for the compatible letters; the variance was too restricted due to the majority of children who gave standard phonic responses to these letters at the 100% level.

It should be noted that the difference in the patterns of responses to the letters that are compatible and those that are incompatible with the acrophonic principle cannot be explained by the differences in the *W* frequency of the letters. The mean $\log_{10}(W + 1)$ frequency of the compatible letters was 1.59 ($SD = 0.66$), and for the incompatible letters it was 1.69 ($SD = 0.61$), $t\,(23) = 0.36$, $p > .10$.

It could be argued that the frequency measure, *W*, merely indexed the extent of the children's visual experience of each letter rather than specifically represented their level of experience of the letter as an initial grapheme that corresponds to a phoneme consistent with the standard phonic response. If this were the case, then the correlations between the standard phonic response to each letter and the total frequency, *V*, of the letter as the initial component of words would be higher than the correlations previously obtained for *W*. Using the data in Appendix 1, $V = f_1 + f_2 + f_3$, where f_3 is the number of word types in which the letter is an initial component but is not itself a grapheme (e.g., *c* as in *children*, *o* in *out*, *t* in *they*). The point-biserial correlations between the standard phonic response and $\log_{10}(V + 1)$ were calculated for each child. The mean was .47 ($SD = .16$), which was not greater but significantly lower than the mean obtained previously, .54 ($SD = .18$), based on the frequency *W*, $t(45) = 5.20$, $p < .001$, for correlated pairs of values.

The results are consistent with the predictions that the children would use both ISRs and the acrophonic principle for their letter sound responses. An analysis was also made to check the alternative hypothesis – that the children would use not just the initial pronunciation element of the letter name but any consonantal element, irrespective of its temporal position in the pronunciation. The letters with names that are compatible with this alternative principle are *b, d, f, j, k, l, m, n, p, s, t, v, x,* and *z*. Those that are incompatible are *a, c, e, g, h, i, o, r, u, w,* and *y*. For the 46 children, the mean percentage of standard phonic responses to the incompatible letters was 56% (with none of the children reaching the 100% level), and the mean for the compatible letters was 86% (with 3 children reaching the 100% level). This mean level for the letters that

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are compatible with this alternative principle was significantly lower than the mean (92%) for the 9 letters (Table 1) that are compatible with the acrophonic principle, $t\,(45) = 4.33$, $p < .001$, for correlated pairs of values. The acrophonic principle offers a better fit for the data than the alternative explanation that the children use any consonantal pronunciation element, irrespective of temporal position in the letter name.

SUMMARY

Study 1 yielded evidence that children, who are not explicitly taught individual letter–phoneme correspondences, very early in learning to read obtain knowledge of these correspondences from two distinct sources: (a) their knowledge of pronunciations of letter names used in the self-generated application of the acrophonic principle, and (b) ISRs, their induction of knowledge of the letters and corresponding phonemes from accumulated experience of them as components of print words, predominantly as initial-position graphemes.

Nevertheless, the evidence on sources of letter–phoneme knowledge in Study 1 is limited to sets of associations. The conditions that determine the children's use of alternative sources were not manipulated. Converging results from an experimental manipulation would strengthen the interpretation given to these results. Study 2 was designed to provide such evidence.

STUDY 2

If induction from print lexical experience is a source of childrens' letter–phoneme knowledge, then that knowledge is encoded from elements in the context of the print word, particularly the initial position. If children do use ISRs acquired from such experience, it would be expected that phoneme responses to letters presented in the initial position context of an unfamiliar print word or pseudoword would reflect that source better than responses obtained from letters presented singly (i.e., in isolation from words). In the former but not the latter case, the conditions of retrieval bear some similarity to the context conditions of encoding during acquisition of the knowledge source (see Tulving, 1983).

In Study 1, where letters were presented in isolation, /s../ was often given as a response to the letter *c* and /d ../ as a response to the letter *g* (Table 2). Such responses are compatible with the children's use of letter names as a knowledge source by self-generated application of the acrophonic principle. However, ISRs originate from children's experience of print words. Retrieval conditions for the use of ISRs would be similar to the encoding conditions of print experience if letters were presented as the initial graphemes of unfamiliar words or pseudowords. Under such conditions, the incidence of responses such as /k../ for *c* and /g../ for *g* would be expected to be much higher and the acrophone responses to be much lower.

In the print lexical experience of the children, the correspondences *c:*/k/ and *g:*/g/ predominated over any other, as indicated by the counts from the reading books in use in the schools. In the count from the larger school, 90 word types contained an initial *c* grapheme (not including *ch*, which was defined as a sepa-

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rate grapheme corresponding to a single phoneme). In 98% of the word types the phoneme /k/ corresponded to the initial *c* grapheme. Only 4 word types had *c* in final position. There were 61 word types with an initial grapheme *g;* of these, 93% corresponded to the phoneme /g/. There were 16 with a grapheme *g* in final position (not including *ng*, which was considered a separate grapheme corresponding to a single phoneme). The count from the books in the smaller school gave similar results. Thus, there was ample opportunity from the children's print word experience for them to acquire the correspondences *c:*/k/ and *g:*/g/ for initial position but relatively little opportunity for them to acquire the correspondences *c:*/s/ and *g:*/ʤ/.

In Study 2, a comparison was made of the children's phoneme responses to *c* and *g* when presented as isolated letters and as initial-letter or final-letter components of pseudowords. It was expected that the two sources of knowledge would be in competition, and that the dominant source in each condition would be the one that involves similarity between the conditions of retrieval and those of encoding during acquisition of the source. Hence, the use of letter name knowledge by self-generated application of the acrophonic principle would be the dominant source of knowledge for phoneme responses to the isolated letters. However, ISRs would be expected to provide the dominant source for the children's phoneme responses to letters in the initial-position context of pseudowords.

METHOD

Participants

Children were selected from two schools in the same population area as Study 1. Neither school had participated in Study 1, but both used the same approach to teaching reading and written language and a similar range of books for the first two years of instruction in reading. The sample comprised 24 children with a mean chronological age of 6;3 (*SD* = 3.9 mos., range = 67 to 81 mos.). They were selected to have a mean word reading attainment level similar to those who participated in Study 1. The mean raw score on the New Zealand Revision of the Burt Word Reading Test was 15.2 (*SD* = 3.5, range = 8–20). All the children had reading ages below 6;2. They all spoke NZE. Their level of aural vocabulary was assessed by the British Picture Vocabulary Scale, Long Form. The mean standard score (IQ) was 100 (*SD* = 9.8, range = 84–116). Their mean percentage accuracy in naming the letter *c* was 100%, and for the letter *g* it was 92%.

Materials

The pseudowords comprised only two letters to reduce the processing load as much as possible for the children at this early reading level. While many studies by convention have used three-letter pseudowords in CVC form, it is worth noting that at this early level a significant proportion of the print words reliably known by children are made up of two letters (e.g., *he, my, is, up, at*).

The isolated letter items were *c, g,* and six filler letters. The letters *p* and *m*

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served as demonstration items. Pseudoword reading items were constructed for the letters *c* and *g* and two consonant letter fillers. The four consonant letters were combined with vowel letters to form three different CV pseudowords for each consonant letter in initial position: *ca, co, cu, ga, gi, gu,* and six filler items. The VC pseudowords for each consonant letter in final position were *ac, ec, oc, ag, ig, ug,* and six fillers. The combinations provided three replications in different pseudoword contexts for each of *c* and *g* in both initial and final position. Combinations of consonants and vowels that form real words or letter names were excluded. Hence, it was not possible to have an exact match of attached vowel letters between initial and final positions for *c.* The vowel context for initial *c* excluded *i* and *e,* which in sufficiently advanced reading vocabularies tend to mark the initial *c* as representing /s/ rather than /k/. Initial *g* followed by *i* or *e* in such a reading vocabulary tends to mark the initial *g* as representing /ʤ/ rather than /g/. As *go* is a real word, it was not possible to exclude both *gi* and *ge* as CV items. The item *gi* was included as one of the three CV pseudowords. However, the relevant reading vocabulary is that of beginning readers. In the counts of word types in the reading books, the only word types with initial *gi* were *girl, girls, give, gives, giant, giant's,* and *giraffe.* In the case of the experimental item *gi,* then, there was no overall bias from the child's print experience toward the *g:*/ʤ/ correspondence. Moreover, the children had not been taught that the vowel letters *i* or *e* may mark variant corresponding sounds for the letters *c* and *g* in the initial position of words.

There was a demonstration CV item (*pa, pi, mo, mu*) for each of the vowels in the CV pseudowords and similarly for the VC pseudowords. Each letter was printed on a small white card in a lowercase san serif font. To form either a CV or VC pseudoword, the cards were placed adjacent to each other.

Procedures

The experimental tasks were administered individually to the children in two sessions. The isolated letters were first presented to the children for naming, followed by three successive blocks of letters in which the children were asked to give the sound for each letter. Three replications were thus provided for each letter–phoneme response. Each block, which was preceded by two demonstration items, included all the letters in an order that was randomized individually for each child. The researcher provided correction for the demonstration items but not for the experimental items.

On a subsequent day the pseudoword reading task was administered. This was introduced as a game with made-up words. For presentation the pseudoword items were grouped by common vowel letter (e.g., *ab, ac, ag*). Each of these blocks of items was preceded by a demonstration item (e.g., *ap* for this block of items) which was read aloud by the researcher for the child, who was required to imitate the pronunciation. If necessary, this was corrected, and a second attempt at imitation was obtained from the child; this was also corrected if necessary. The researcher reiterated, when necessary, that the items were not real words. The demonstration items provided the children with the standard phonic pronunciation for the vowel letter common to the block of items that would

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follow. The vowel letter card remained in place while the researcher changed the consonant letter card for the demonstration items and the experimental items within the block. This was done to minimize the difficulty caused by the vowel letters themselves, as the experimental interest was in the children's accuracy of reading the consonant letters in vowel contexts. There were four blocks of items, one for each of the vowel letters (*a, i, o, u*) of the CV pseudowords and similarly for the VC pseudowords. Three replications were thus provided for each consonant letter in the different CV contexts and in the different VC contexts. All blocks of CV pseudowords either preceded or followed all blocks of VC pseudowords, the order being counterbalanced across randomly assigned children. The order of blocks and the order of experimental items within each block were randomized individually for each child. The child was required to attempt a reading of each experimental item. No correction was given.

The experimental interest was in the responses to the consonant letters *c* and *g* in a vowel context. Hence, for the pseudoword reading, an acceptable response was a pronunciation of the consonant letter and a vowel sound of any kind in the position appropriate to the VC or CV form. If the target consonant was pronounced as a component of a consonant cluster, this was scored as not acceptable, as were real word or letter name responses. Responses to both tasks were recorded by the researcher at the time and were also tape-recorded. There was interrater agreement exceeding 99% between the scoring of the target responses by the researcher and an independent scoring from the tape recording.

RESULTS AND DISCUSSION

There were two classes of acceptable responses: standard phonic responses, such as /k../ for the letter *c* and /g../ for *g*, and letter name acrophone responses, such as /s../ for the letter *c* and /ʤ../ for *g*. The mean percentages of standard phonic responses made under the three conditions (letters in isolation and as initial and final components of pseudowords) are given in Table 3. The level of standard phonic responses to the letters in isolation was lower than that in Study 1, but this was expected. Although the mean reading level of the children in Study 1 was similar, the variance was much greater. A third of the children had a reading age of 6 years, a level barely reached by the children in this study. In an analysis of variance with two within-subjects factors, there was a significant main effect of context conditions in the present study, $F\,(2, 46) = 16.75$, $MSE = 796.67$, $p < .001$. The main effect of letters was not significant, $F\,(1, 23) = 0.50$, $MSE = 2{,}222.22$, nor was the interaction between these factors significant, $F\,(2, 46) = 0.30$, $MSE = 691.11$. The effect of context, therefore, was common to both *c* and *g*. The mean percentage of standard phonic responses was lower when the letters were presented in isolation than when they were presented as initial components of two-letter pseudowords, $F\,(1, 46) = 23.25$, $MSE = 796.67$, $p < .001$. However, the percentage of responses to letters in isolation was not significantly different from those to letters as final components of the pseudowords, $F\,(1, 46) = 0.13$, $MSE = 796.67$.

As predicted, when the children responded to the letters *c* and *g* as initial

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Table 3. *Mean percentages of phoneme responses to letters* c *and* g, *Study 2*

	Isolated letter	Position in two-letter pseudowords	
		Initial	Final
Standard phonic responses			
c → /k../	28	51	24
g → /g../	18	50	18
Acrophone responses			
c → /s../	58	24	3
g → /ʤ../	68	33	7

Note: "Don't know" or no response and other responses are not included.

components of pseudowords, they gave standard phonic responses much more frequently than they did when these letters were presented in isolation. This result cannot be explained solely by the children's knowledge of standard phonic correspondences for the individual isolated letters. If the children had received instruction on letter–sound correspondences which the investigators were unaware of, then it would be expected that their level of standard phonic responses would be at least as high for individual letters as it was for initial components of pseudowords. The obtained effect of pseudoword context ran contrary to this expectation. The effect, however, can be explained if the children were using their accumulated experience of print lexical experience to form ISRs (i.e., letter–phoneme correspondences common to the initial components of several experienced print words) – in this case, experience of print words with *c* and *g* as initial-position graphemes. The retrieval conditions of the pseudoword reading provide the initial-position context, which is similar to the context conditions of encoding during acquisition of this source of letter–phoneme knowledge. The requisite print lexical experience was available to the children, as indicated by the incidence of *c* and *g* as initial-position graphemes corresponding to /k/ and /g/ in the words of the books used to teach reading. In contrast, the incidence of *c* and *g* as final-position graphemes was very low, thus severely limiting similar opportunity for the children to acquire letter–phoneme correspondences common to final components of print words. Hence, the level of standard phonic responses to letters in the final position of the pseudowords was relatively low. It was not zero, however. Some limited transfer may have taken place from initial position at encoding to final position at retrieval.

The mean percentage of responses that were not standard phonic but acrophone are given in Table 3. As the percentages of these responses had a mean and variance approaching zero for the final position of pseudowords, the analysis of variance was only applied to the isolated letter and initial-component conditions. In the isolated letter condition, there was a significantly greater percentage of acrophone responses than there was in the initial-component condi-

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tion, F (1, 23) = 18.21, MSE = 1,588.89, $p < .001$. Neither the main effect of letters nor the interaction between letters and context conditions was significant, $F < 1$ in each case. Acrophone responses were much more common for the letters in isolation than for the same letters in pseudowords. This result suggested that the children, without explicit instruction in letter–phoneme correspondences, used letter name knowledge by application of the acrophonic principle as a major source of knowledge when giving phoneme responses to letters in isolation. The children did not receive instruction on the acrophonic principle; hence, their use of it was self-generated.

Other responses that were neither standard phonic nor acrophone were analyzed. For the items in each of the three conditions there was a low incidence of "Don't know"/no response (1 to 14%) as well as a low incidence of varied consonantal substitution responses for isolated letters and initial-position letters in pseudowords (4 to 13%); but there was a high incidence of such substitution responses for final position in pseudowords (39% for *c* and 46% for *g*). For the pseudowords there were some vowel substitution responses, but these were mainly for final-position letters (0% for *c* and 3% for *g* in initial position; 11% for *c* and 19% for *g* in final position). In addition, there was a small proportion of real word responses to the pseudowords (0 to 17%).

The converging results of Studies 1 and 2 indicated that children in their first year of reading, without explicit instruction in letter–phoneme correspondences, used at least two sources of knowledge from which to derive phoneme responses to letters. One source was ISRs, the induction of orthographic–phonological relations experienced in print words (Thompson et al., 1996; Thompson & Fletcher-Flinn, 1993). The other source was their self-generated application of the acrophonic principle to their knowledge of letter names. In attempting to grapple with an unfamiliar word, young readers were less likely to use letter names as a source of knowledge in responding to the initial grapheme of the word. They were more likely to use their knowledge of orthographic–phonological relations, which had been acquired by induction from their experience of initial graphemes of words. Before adopting this as a conclusion, however, it remains to be seen whether the obtained results on use of the acrophonic principle in Studies 1 and 2 could be accounted for by another knowledge source – the children's spelling experience. This was examined in Study 3.

STUDY 3

There is a view that the child's early spelling experience provides knowledge of phoneme-to-letter correspondences that may be transferred to enable responses in the reverse direction – namely, phoneme responses to letters in reading. Frith (1985) and Seymour and MacGregor (1984) suggested that knowledge of letter–phoneme correspondences for reading can be obtained from early experience of phoneme-to-letter correspondences in spelling. If such transfer does occur, then the child's use of letter name acrophones, which was found in Studies 1 and 2, could have arisen indirectly through spelling experience, as this included "invented spelling" in which the child commonly produces nonstandard sound-to-letter correspondences.

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Children's self-taught invented spellings produced before first grade have been studied intensively (Bissex, 1980; Read, 1975, 1986; Treiman, 1994; Treiman, Tincoff, & Richmond-Welty, 1996). A consistent finding is that letter names are a source of children's choice of a spelling for some phonemes. Of interest here is the finding that, among the words children produced with a nonstandard spelling, /ʤ/ was spelled as *g* more often than as *j* (Read, 1975, p. 159). However, /s/ was nearly always spelled as *s* and rarely as *c* (p. 164). These results were taken from the spelling of words in the children's spontaneous writing. Some of these nonstandard spellings could have been produced from partial word-specific memory of printed words and not all by a process of finding letters to correspond with the phonemes of the word. Of direct relevance here is the child's selection of a letter to spell a phoneme when isolated from a word. This would give an indication of the child's phoneme-to-letter knowledge not confounded with partially recalled spellings of specific words. If the children's phoneme-to-letter knowledge from their spelling experience were the source for their letter sound responses to the isolated letters *c* and *g* in Studies 1 and 2, then the phoneme /s/ would be spelled as the letter *c* at least as frequently as /s/ is given as the pronunciation for the letter *c*, presented in isolation. A similar prediction was made for /ʤ/ and *g*. The purpose of Study 3 was to test these predictions from this alternative interpretation of the results in Studies 1 and 2.

METHOD

Participants

The children were selected from three schools in the same population area as Study 2. None of the schools had participated in that study. The approach to teaching reading and written language was the same, and the range of books used in the first two years of reading instruction was similar. (Details, including the approach to teaching spelling, are given in Study 1.) This approach involved the use of "invented spelling." The sample was 23 children. Their mean chronological age was 5;10 ($SD = 5.1$ mos., range = 63 to 81 mos.). Their reading attainment level was matched to that of the participants in Study 2. The mean raw score on the New Zealand Revision of the Burt Word Reading Test was 14.1 ($SD = 2.7$, range = 8–18). Because a standardized test of spelling attainment for very early reading levels was not available, a spelling task was constructed to determine the overall spelling performance of the children. In this task, 21 words that occur with high frequency in the school reading books of the children were selected and presented on visually blank, extended-size Language Master cards. These cards, when inserted into the Language Master (Model No. 1757 BX, Bell & Howell Co., Chicago, IL), play back the sound from a magnetic recording on the card. From each card the children listened to the word, followed by a simple sentence in which the word was embedded and then again the word in isolation. The children were asked to print the spelling of the word. The items were presented in an order randomized for each child. The percentage of children who spelled each word correctly is given in Appen-

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dix 2. All the children spoke NZE. Their level of aural vocabulary was assessed by the British Picture Vocabulary Scale, Long Form. The mean standard score (IQ) was 99 ($SD = 12.5$, range = 80–121). Their mean percentage accuracy in naming the letter *c* was 96%, and for the letter *g* it was 100%.

Materials and procedures

In the phoneme-to-letter spelling condition, the consonant sounds /s../ and /ʤ../, two demonstration sounds, and a filler (/w../) – each with a weak central vowel – were recorded on a visually blank, standard-size Language Master card. The children listened to the sound from the loudspeaker of the Language Master and imitated the pronunciation. The pronunciations of the experimental items were correctly imitated by the children. In only one instance with one participant was correction of the pronunciation needed. After imitating the sound, the children were asked to select the letter that was the best spelling of the sound. Selection was made from an array of 14 letter cards (*c, s, g, j, b, d, k, m, s, w, a, e, i, u*), the order of which was randomized for each child. The task commenced with two demonstration sounds, /b../ and /m../. The child imitated the sound (corrected if necessary), and the researcher provided the correct letter response by slowly pointing to the letter cards in left-to-right order and showing that, after a letter is selected initially, all the other letter cards need to be examined to ensure that the best spelling of the sound has been chosen. No correction of the spelling responses was provided for the experimental and filler items. These were presented again in a second and a third block, thus providing three replications. The order of the items within each block was randomized for each child.

In the letter sound pronunciation condition, the children were presented with the letters *c* and *g* and the filler letters (each in isolation) and were required to give the sound for each one. The children were assigned to one of two presentation formats which were designed to examine the generality of the results over different contexts of items. In the inclusive format, the letters *s, j,* and *w*, which were the correct letter responses for the items in the spelling condition, were included among the filler items. In the exclusive format, these letters were excluded, and only one filler item remained, *y*. The letters were also presented to the children for letter naming (along with the five vowel letters as additional fillers). The letter sound pronunciation condition followed, beginning with two demonstration letters. The letters *c* and *g* and fillers appropriate to the presentation format were presented three times in successive blocks, as in the spelling condition. The letters presented in both conditions were printed in a lowercase sans serif font.

All the children were administered both the experimental spelling and the letter sound pronunciation conditions. A total of 13 children received the inclusive format, and 10 received the exclusive format of the letter sound condition. Half of the children in each format were randomly assigned to receive the spelling condition first; the other half received the letter sound pronunciation condition first. The median duration between administration of the two conditions was 11 days (range = 3–15 days).

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RESULTS AND DISCUSSION

In 14% of the children's responses to the phoneme /s/ they spelled it *c;* for letter sound pronunciation, in 33% of their responses they gave /s../ as the phoneme response to the letter *c.* In 30% of their responses the children spelled the phoneme /ʤ/ as *g;* for letter pronunciation, in 55% of their responses they gave /ʤ../ as the phoneme response to the letter *g.* An analysis of variance was applied to the percentage scores aggregated over the two items. (An analysis of variance applied to the individual item scores was inadmissible due to the very high proportion of zero values among them.) The spelling/letter pronunciation conditions were a within-subjects factor, and the inclusive/exclusive presentation formats were a between-subjects factor. There was a significant main effect of spelling/letter pronunciation conditions, $F\,(1, 21) = 9.63$, $MSE = 505.56$, $p < .01$, but the direction of the effect was contrary to that predicted if the source of the children's phoneme responses to isolated letters were a simple transfer from spelling experience. The main effect of presentation format was not significant, $F\,(1, 22) < 1$, nor was the interaction of format with the spelling/pronunciation conditions, $F\,(1, 21) = 1.24$. All other spelling responses to /s/ were *s* and to /ʤ/, *j.* Apart from a 3% no response for the letter *c,* all other letter sound pronunciation responses to *c* were /k../ and to *g,* /g../.

The results contradicted the interpretation that the children's pronunciation responses to isolated letters have their source in the phoneme–letter correspondences of their spelling knowledge. The phoneme /s/ was spelled as the letter *c* less frequently than /s/ was given as the pronunciation response for the isolated letter *c;* the findings were similar for /ʤ/ and the letter *g.* Considering the results of Studies 2 and 3, the conclusion can be drawn that beginning readers who have not received explicit instruction in letter–phoneme correspondences are likely to respond to isolated letters with a sound that derives directly from the letter name by application of the acrophonic principle rather than indirectly through experience of invented spelling.

GENERAL DISCUSSION

This series of studies was conducted to determine the sources of learning by which beginning readers acquired knowledge of individual letter–phoneme correspondences when these were not explicitly taught in the whole language reading instruction they received. The results of Study 1 indicated that, after only a few months of school instruction, 5-year-old children were able to use two sources of knowledge to make phoneme responses to isolated letters: (a) ISRs from their experience of print words; and (b) acrophones from their knowledge of letter names.

In Study 2 the orthographic context of the letter was manipulated to examine the effects on the phoneme responses to the letter. It was predicted that when the letter was in the initial-position context of a pseudoword, the influence of ISRs on the responses would be dominant, but that when the letters were presented in isolation, acrophones of letter names would be influential. This was the result obtained. It is a result that would be incompatible with the alternative

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theoretical view that ISRs and acrophones represent one source of knowledge rather than two, as postulated here.

While the results of Study 2 are limited by the fact that they were based on two letters, this is balanced by the fact that the predicted effects were strong enough to be demonstrated with only two letters. The limited sampling of letters in this study arose from the requirements of the experimental design. The interest was in letters for which the children would show a high level of responses, derived from knowledge of ISRs as well as from knowledge of acrophones. Only two letters, *c* and *g*, fulfilled these requirements (Table 2) for examination of the postulated competition between the two knowledge sources.

The objection may be raised that the three studies provided no comparison with children who were taught letter–phoneme correspondences. No direct comparison could be made as no New Zealand school was found that consistently and explicitly taught individual letter–phoneme correspondences in reading instruction. In New Zealand, literacy teaching has for many years been quite uniform across all districts. As the specific predictions of Study 1 required a particular accent of English, a comparison with children in other countries who did not receive explicit letter–phoneme instruction would not be satisfactory as they would not have the same English accent.

The results of Study 3 are inconsistent with the notion of a simple parallelism between the beginning readers' phoneme responses to isolated letters and their knowledge of phoneme-to-letter correspondences obtained from spelling experience. Moreover, the results do not support the supposition that children's knowledge of particular letter–phoneme correspondences is transferred from their knowledge of parallel, but reverse direction, phoneme-to-letter correspondences. In Study 3, the results are for only two phonemes (for reasons already cited). However, for four other phonemes, independent results were obtained that are also inconsistent with such transfer (Thompson et al., 1996, Experiment 1). It is worth noting that all these results are distinct from, and not informative about, the transfer of knowledge of spelling of specific words to knowledge of reading of those words. Nor do the results contradict the possibility that experience of phoneme-to-letter correspondences, acquired during attempts at spelling, assists the learner's awareness of phoneme segments and access to their identities. These would be very early effects and would be general rather than specific to particular correspondences. With respect to the results of Study 3 on specific correspondences, it may be noted that Carol Chomsky (1979, pp. 50–51), a prominent advocate of encouraging invented spelling before formal teaching of reading, recognized in her observations of children that knowledge of phoneme-to-letter correspondences did not transfer to knowledge of letter–phoneme correspondences. This appears to be true – at least for children who do not receive explicit instruction in letter–phoneme correspondences.

The present studies concern the consequences for children who are taught to read but do not receive instruction in individual letter–phoneme correspondences. Whether the children are directly taught these correspondences may be less important than whether they learn the "alphabetic principle" – that letters of words systematically map onto phonemes in words. This is essential to satisfactory progress in learning to read. It involves more than just giving an appro-

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priate sound for an individual letter (Byrne & Fielding-Barnsley, 1989; Shankweiler & Lundquist, 1992; Thompson, 1997, 1999). The alphabetic principle involves not only the identity of the letter, but also the identity of the corresponding phoneme within words; this requires segmentation of the phoneme within the words (Byrne & Fielding-Barnsley, 1989, 1990). Those children who were able to use ISRs were using letter and phoneme identities and their relations to respond to simple pseudowords. The results of Study 2 show that ISRs have a greater influence on phoneme responses to letters when located in a word-like positional context than when presented as isolated items. The children were making elementary use of the alphabetic principle, which involves the identities of letters and phonemes within words. The results in Study 1 indicated that such use was predominantly from those ISRs formed from the initial-position graphemes of words.

This discussion should not be taken to imply that all the children in the studies learned the alphabetic principle without aid from teachers. The children did not receive explicit instruction on phoneme correspondences for the individual letters of the alphabet. Nevertheless, their teachers did on occasion direct them to listen to the initial sound in a word which corresponded to the initial letter. The children did not need a large set of instances of the principle to learn it. If children could learn it as a principle rather than as just a specific set of correspondences, then they would be able to apply it to numerous new correspondences. They would be able to use the principle to self-discover or "self-teach" untaught instances of the principle.

The children's use of acrophones from letter names does not imply an ability to use the alphabetic principle. The children in these studies who had not received direct instruction on individual letter–sound correspondences were able to use this source of knowledge as well as ISRs as another source of knowledge. However, they made greater use of ISRs when attempting to read a word or word-like item than when attempting to provide a sound label for an isolated letter. The alphabetic principle is more relevant to reading responses to words than to providing sound labels for isolated letters. In the absence of instruction to the contrary, these children inferred that the letter name labels they already knew would help them provide sound labels for isolated letters. This inference may be regarded as inappropriate only on the assumption that sound labels for isolated letters ought to coordinate transparently with use of the alphabetic principle. As a result of their inference, the children responded to some letters with sound labels that did not coordinate with their use of the alphabetic principle. It is important to note that the children were making some use of the alphabetic principle very early in learning to read, in spite of this lack of coordination with their letter–sound responses for isolated letters.

The children's acquisition of ISRs – their induction of orthographic–phonological relations – was made possible by their learning lexical orthographic representations, although these may often have been incomplete for particular words. Their use of ISRs to provide sounds for letters is a partial form of phonological recoding, based on the lexical orthographic source and associated sublexical components. It is notable that this type of phonological recoding occurred very early in the children's learning of reading. This would not be expected

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according to several theoretical accounts (Ehri, 1992; Frith, 1985; Marsh et al., 1981) in which the acquisition of a lexical orthographic source depends on the child's prior use of phonological recoding based on another source of knowledge, such as taught letter–sound correspondences. Such a source is expected to be consistent with the alphabetic principle. In the studies reported here, 5-year-old children who were just beginning to read were already using partial phonological recoding based on the lexical source. This occurred even though no other source of recoding consistent with the alphabetic principle was available to them.

APPENDIX 1

Word-initial position

f_1, f_2, and f_3 frequency values for each letter in the counts of word types, Study 1.

a, 32, 33, 13
b, 230, 0, 0
c, 139, 4, 31
d, 112, 0, 0
e, 28, 6, 13
f, 146, 0, 0
g, 86, 7, 4
h, 151, 0, 0
i, 23, 12, 0
j, 43, 0, 0
k, 28, 0, 9
l, 98, 0, 0
m, 138, 0, 0
n, 46, 0, 0
o, 8, 15, 18
p, 165, 0, 1
r, 82, 0, 1
s, 253, 0, 52
t, 146, 0, 50
u, 13, 1, 0
v, 8, 0, 0
w, 117, 0, 30
x, 0, 0, 0
y, 26, 0, 0
z, 7, 0, 0
[*q*, 0, 0, 6]

Word-final position

h_1, h_2, and h_3 frequency values for each letter in the counts of word types, Study 1.

a, 0, 25, 7
b, 3, 0, 4
c, 5, 0, 0
d, 107, 0, 105
e, 0, 12, 365
f, 16, 2, 4
g, 19, 0, 128
h, 0, 0, 76
i, 0, 4, 3
j, 0, 0, 0
k, 48, 1, 34
l, 37, 0, 52
m, 52, 0, 0
n, 120, 0, 4
o, 0, 29, 19
p, 55, 0, 0
r, 0, 2, 173
s, 114, 328, 13
t, 192, 0, 15
u, 0, 0, 3
v, 0, 2, 0
w, 0, 0, 52
x, 7, 0, 0
y, 0, 133, 59
z, 0, 0, 2
[*q*, 0, 0, 0]

APPENDIX 2

Percentage of correct spelling responses to each item of the spelling task, Study 3.

the, 96
and, 91
a, 87
is, 87
mum, 87
to, 87
on, 74
up, 74
am, 65
went, 65
you, 65
not, 61
in, 57
can, 48
get, 35
of, 26
come, 13
said, 4
some, 4
too, 4
mother, 0

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