The foundations of literacy: Learning the sounds of letters

Rebecca Treiman

Wayne State University

Ruth Tincoff

Johns Hopkins University

Kira Rodriguez

Wayne State University

Angeliki Mouzaki

University of Houston

David J. Francis

University of Houston

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Abstract

Learning the sounds of letters is an important part of learning to read and spell. To explore the factors that make some letter-sound correspondences easier for children to learn than others, we first analyzed knowledge of letters' sounds (and names) by 660 children between 3 ½ and 7 ½ years old. A second study examined preschoolers' (mean age 4 years, 11 months) ability to learn various sound-letter mappings. Together, the results show that an important determinant of letter-sound knowledge is whether the sound occurs in the name of the letter and, if so, whether it is at the beginning or the end. The properties of the sound itself (consonant vs. vowel, sonorant vs. obstruent, stop vs. continuant) appear to have little or no influence on children's learning of basic letter-sound correspondences. The findings show that children use their knowledge of letters' names when learning the letters' sounds rather than memorizing letter-sound correspondences as arbitrary pairings.

The foundations of literacy: Learning the sounds of letters

An important foundation of literacy is learning the sounds that letters symbolize in words. Children need to know that the grapheme *b* generally corresponds to the phoneme /b/, that *h* generally corresponds to /h/, and so on. Knowledge of letter sounds helps children to decode printed words and to construct the spellings of words in their spoken vocabularies. Of course, knowledge of basic letter-sound mappings is not the *only* prerequisite to literacy. Children also need to know the contexts in which various mappings occur. For example, they must learn that *a* is pronounced differently in *cat* than in *table*. The ability to analyze spoken words into phonemes is another key ingredient of literacy. To understand why the printed words *boy* and *bread* begin with the same letter, children must realize that the corresponding spoken words begin with the same phoneme. Although there is a large body of research on phonological awareness, relatively few studies have investigated children's learning of letter sounds. The goal of the present research is to add to our knowledge of this important topic.

Middle-class children in North America begin to learn the names of the letters at a young age, starting well before they enter kindergarten (Mason, 1980; Worden & Boettcher, 1990). Knowledge of letters' sounds typically lags behind knowledge of the letters' names (Mason, 1980; McBride-Chang, submitted; Worden & Boettcher, 1990), although letter-sound knowledge appears to be more closely related to reading and spelling skill (McBride-Chang, submitted).

It has been suggested that children use their knowledge of letters' names when learning the letters' sounds. Thus, letter-sound correspondences for which the sound of the letter is in the letter's name should be easier to master than letter-sound correspondences for which this is not the case. For example, the name of the letter b, /bi/, contains the phoneme that this letter typically represents and so the b-/b/ mapping should be relatively easy for children to learn[1]. The name of the letter y (/wai/) does not contain the consonant /j/ and so the y-/j/ correspondence should be more difficult. Treiman, Weatherston, and Berch (1994, Study 3) found evidence for these ideas when they tested a group of United States kindergartners both before and after they had been formally taught the names and sounds of y and w (mean age 6 years, 0 months at time of first test and 6 years, 3 months at time of second test). On both occasions, the children generally named y and w correctly (85 - 95% correct responses). However, the children made a number of errors when asked to give the letters' sounds, even on the second test. Children often (58 - 60% of the time) said that the sound of y was /wə/. Apparently, the children used y's name, /wai/, to infer that this letter stood for /w/. The children also sometimes said that w made the sound /də/ (error rates of 25 - 28%). This error probably occurs because /d/ is at the beginning of w's name. The results suggest that many children use the names of letters to learn or remember the letters' sounds (see Thompson, Fletcher-Flinn, & Cottrell, submitted for evidence from New Zealand children).

Further support for the idea that letter names play a role in the learning of sound-letter relations comes from a study in which regression analyses were used to explore the factors that are associated with first graders' ability to use phoneme-grapheme correspondences in spelling (Treiman, 1993). Children did better on correspondences for which the phoneme was all or part of the letter's name (e.g., the correspondence between /b/ and b) than on correspondences for which this was not the case (e.g., the correspondence between /j/ and y). This was true even after other factors, such as the existence of alternative spellings of the phoneme, were statistically taken into account.

Some findings suggest that, when the sound of a letter is in the name, children perform better if the sound is at the beginning of the name (as with b) than if the sound is at the end of the name (as with l). Treiman et al. (1994, Study 2) asked preschoolers (mean age 5 years, 2 months) and kindergartners (mean age 5 years, 11 months) to orally provide the first letters of syllables such as /bɑ/ and /lɑ/ and the last letters of syllables such as /ɑb/ and /ɑl/. In both the initial and final conditions, children did better on beginning letter name phonemes such as /b/ than on end letter name phonemes such as /l/. However, only a limited number of beginning and end letter name phonemes were examined. McBride-Chang (submitted) also reported that kindergartners and first graders were better at providing the sounds of letters such as b than letters such as l. However, Treiman (1993) did not find a significant difference between beginning letter name phonemes and end letter name phonemes in her study of spelling. Thus, reliable differences as a function of the position of a phoneme within a letter name have not been firmly established.

Another factor that may influence children's learning of letter-sound relations is the number of different sounds that a letter may represent. For example, c has two common sounds, /s/ and /k/. This may make c more difficult than a letter such as b, which has one primary pronunciation. Treiman's (1993) first-grade spellers did better when a phoneme was consistently spelled with a particular grapheme than when it had several possible spellings. To our knowledge, the influence of multiple pronunciations on children's ability to produce the sound of a printed letter has not been investigated.

Properties of phonemes themselves may also affect children's ability to relate phonemes to letters. Two specific hypotheses may be identified about how this could occur. The first hypothesis (Stuart & Coltheart, 1988) may be called the syllable position hypothesis. In this view, the earliest grapheme-phoneme correspondences to be learned involve phonemes that commonly occur at the beginnings and ends of syllables. These tend to be obstruent consonants such as the fricative /s/ and the stops /p/ and /b/. Stuart and Coltheart proposed that correspondences involving sonorant consonants such as /w/, /r/, and /m/ are harder to learn. Sonorant consonants often occupy the interior positions of consonant clusters and so are closer to the center of the syllable. For instance, the spoken form of swamp contains obstruent consonants at the beginning and the end and sonorant consonants nearer to the middle. Stuart and Coltheart further suggested that vowels, which typically occur in the middles of syllables and which are highest in sonority, are most difficult for children to connect to letters. Stuart and Coltheart assessed their hypothesis by testing British schoolchildren's knowledge of letter sounds four times, beginning at the age of about 5 years, 4 months and continuing until the age of about 6 years, 8 months. On the sound task, children generally performed most poorly on vowels, at an intermediate level on sonorant consonants, and best on obstruent consonants. No significant differences were found among the three categories in knowledge of letter names. Although these findings are consistent with syllable position hypothesis, it is also possible that obstruents are superior to sonorants because they are more likely to be spelled by a letter whose name begins with the consonant itself.

A second hypothesis about the effects of phoneme class on children's ability to connect phonemes and letters may be called the pronounceability hypothesis. This hypothesis derives from the claim that stop consonants, which cannot be pronounced without a vowel and whose acoustic realizations often differ depending on the adjacent phonemes, are particularly difficult for children to identify as separate units (Byrne & Fielding-Barnsley, 1990). Hence, children may have trouble learning the connections between stop consonants and letters. Some studies have found that children perform more poorly on phonemic awareness tasks with stop consonants than with fricatives and other phonemes that can be pronounced in isolation, but the results are mixed (see Byrne & Fielding-Barnsley, 1990; Content, Kolinsky, Morais, & Bertelson, 1986; Marsh & Mineo, 198l; Skjelfjord, 1976; Treiman & Baron, 1981; Treiman, Broderick, Tincoff, & Rodriguez, 1998; Zhurova, 1963-64). Whether stop consonants cause difficulty for letter-sound learning has not been investigated.

To summarize, the existing research points to several factors that may influence children's ability to connect letters and phonemes. These factors include the characteristics of the letter's name, the existence of alternative mappings, and the properties of the phoneme itself. Most previous studies have examined one factor at a time, which could yield misleading results due to the natural confounding of the factors. In the present research, we examined the roles of all of the factors in combination.

In Study One, we analyzed children's ability to provide the sounds (and names) of each letter of the alphabet. The data were taken from three large-scale studies carried out in the United States – one in California, one in Detroit, and one in Houston. For each data set, we pooled the results for each letter of the alphabet across children. Our primary interest was in children's knowledge of the letters' sounds. Were there systematic differences among letters, and could these differences be explained by the characteristics of the letters' names, the existence of alternative pronunciations, and the properties of the phonemes?

Study One

Method

California study

Participants. The participants in this study (Worden & Boettcher, 1990) were 35 four year olds (range 3,6 - 4,6; 15 girls and 20 boys), 38 five year olds (range 4,6 - 5,6; 20 girls and 18 boys), 40 six year olds (range 5,6 - 6,6; 20 girls and 20 boys), and 37 seven year olds (range 6,6 - 7,6; 19 girls and 18 boys). The children attended preschools and elementary schools in southern California in the late 1980s. Most were from middle-class backgrounds. The elementary school children were in the appropriate grade for their age and all children spoke English as their native language. Worden and Boettcher also tested three year olds, but these children produced fewer than 1% correct responses on the sound task and so their data are not included in the present analyses.

Materials and procedure. The name and sound tasks were part of a larger battery of tests. For the upper-case name task, the child was shown a page of scrambled letters that contained five rows of five or six letters each. The letters were arranged so that no two vowels were adjacent and no adjacent letters formed words. The examiner pointed to each letter in turn and asked the child to name it. The procedure for the lower-case name task was the same, except that a sheet of scrambled lower-case letters was used. The order of the upper- and lower-case name tasks was counterbalanced across children. For the sound task, the child was asked to provide an appropriate sound for each letter on a different page of scrambled letters. If the child had scored higher on the name task for upper-case than lower-case letters, upper-case letters were used for the sound task; if the child had scored higher on lower-case letters, these were used in the sound task. For both the name and the sound tasks, testing stopped if a child did not give adequate answers for the first row of letters. The procedure was sometimes modified if a child did not respond well to the standard procedure. For example, some children were allowed to respond to the letters in whatever order they could rather than going from left to right across the page.

Scoring. For each letter, the percentage of correct responses by children at each age level was calculated separately for the upper-case name task, the lower-case name task, and the sound task. For letters that represented more than one sound, any appropriate response was counted as correct. For example, both /e/ and /æ/ were scored as correct for a in the sound task. In the analyses reported here, the score for the name task was the better of the upper- and lower-case name scores for each letter. We also calculated the probability of a child responding correctly in the sound task given that the child had correctly named the letter when it was shown in the same case in the name task.

Detroit study

Participants. There were 62 kindergartners from parochial schools located in predominantly White middle-class suburbs of Detroit and 57 preschoolers from daycare centers and nursery schools in the same areas. The mean age for the kindergartners was 5 years, 8 months (range: 5,0 - 6,5), and there were 33 boys and 29 girls. The mean age for the preschoolers was 4 years, 10 months (range 4,0 - 5,7), and there were 27 boys and 30 girls. All the children were native speakers of English. Testing occurred in the mid 1990s. The kindergartners had received between one and five months of instruction at the time that they were tested.

Materials and procedure. The letter name and sound tests were conducted in a single session. This session usually followed one or more sessions devoted to other spelling or reading tasks. Of the kindergartners, 46 took the name test before the sound test and the others had the reverse order. For preschoolers, 29 had the name test first and 28 had the sound task first.

For the name task, the child was shown a series of cards, each with an upper-case letter printed on it. The order of the cards was randomly chosen for each child. For each card, the child was first asked to give the name of the letter. If the child did not respond correctly in this free-choice situation, a follow-up question provided the child with two choices. For h, for example, the examiner asked, “Is that h or i?” Half the time the correct name was presented first; the other half the correct name was presented second.

For the sound test, the same cards were used. The child was first asked to provide the sound of the letter. If the child said the name of a consonant letter, the experimenter gave the child another chance to respond. If the child again said the name, this was counted as the child’s answer. Both the “long” and the “short” sounds of vowels were counted as correct in the free-choice sound task. Both /k/ and /s/ were counted as correct for c, both /g/ and /ʤ/ were counted as correct for g, and both /ks/ and /z/ were counted as correct for x. If the child did not respond correctly in the free-choice sound task, two alternatives were provided. These were the sounds of the letters from the two-choice name task (using the “short” sounds for vowels, the “hard” sounds for c and g, and /ks/ for x). For example, the examiner asked whether h made the sound /hə/ or /ɪ/.

Scoring. The percentage of correct responses to each letter in the name task and the sound task was calculated, as was the probability of a correct response in the sound task given that the child knew the letter's name. In the analyses to be reported, children were counted as correct only if they responded correctly in the free-choice task[2].

Houston study

Participants. The participants attended kindergarten in Houston, Texas in the early 1990s. A total of 392 children were tested (mean age: 5, 7; range: 5,1 - 6,2; 196 girls and 196 boys). One child responded to only the first four letters, and so the reported data are based on the remaining 391 children. Testing took place when the children had been in kindergarten for less than two months. All of the children were proficient in English based on an assessment given by the school. The ethnic background of the children was 55% Caucasian, 17% African American, 15% Hispanic, 12% Asian, and 1% other. Socio-economic status of the participating families ranged from upper middle class to government supported.

Materials and procedure. The child was shown a series of cards, each with the upper-case and lower-case versions of a letter printed on it. For each card, the child was first asked to say the name of the letter. The child was then asked to say the sound of the letter. If the child said the letter's name when asked for the sound, the examiner said, "Yes, that's the letter's name. Can you think of any additional sound it makes?" The letters were presented in alphabetical order. The letter name and sound tests were administered near the end of a battery of cognitive tests.

Scoring. For each letter, we calculated the percentage of correct responses in the name task and the sound task. Only the "short" sound of each vowel was counted as correct when the study was run. Thus, /æ/ was considered the correct sound of a and /e/ was scored as incorrect. Both /k/ and /s/ were counted as correct for c, both /g/ and /ʤ/

were counted as correct for g, and both /ks/ and /z/ (as in xylophone) were counted as correct for x. We also calculated the probability of a correct response to a letter in the sound task given a correct response to that letter in the name task.

Results

Appendix A shows the percentage of correct responses for each letter in the name and sound tasks for each sample of children. Appendix B shows the proportion of correct responses in the sound task given that the child knew the letter's name.

Our first analyses focused on the role of letter names in children's learning of letters' sounds. Letters may be categorized according to whether the phoneme which the letter commonly represents occurs in the name of the letter and, if so, its position. For the present analyses, this categorization was carried out only for consonants. Vowels were excluded because the sounds that were counted as correct for vowels differed across the three samples, with the California and Detroit studies counting the name of the vowel as right and the Houston study counting it as wrong. For b, c, d, g, j, k, p, t, v, and z, the sound of the letter (or one of the sounds in the case of c and g) occurs at the beginning of the letter's name. For f, l, m, n, r, s, and x, the sound of the letter (or one of the sounds in the case of x) is at the end of the letter's name. The consonant sounds corresponding to h, q, w, and y do not occur in the name of the letter in American English[3]. Table 1 shows children's performance on the sound and name tasks for the three types of consonants.

On the sound task, children generally performed best on consonants for which the sound of the letter occurs at the beginning of the letter's name, intermediate on letters for which the sound occurs at the end of the letter's name, and most poorly on letters for which the sound is not in the letter's name. This pattern was not seen in the name task, where performance was similar on beginning, end, and not-in-name letters. Statistical support for these findings came from analyses of variance (ANOVAs) using letters as the unit of analysis.

For the California data, the between-item factor was consonant type (beginning vs. end vs. not in name) and the within-items factors were task (sound vs. name) and age (4 vs. 5 vs. 6 vs. 7). There was a main effect of task ($F(1,18) = 286.44$, $p < .001$), a main effect of age ($F(3,54) = 664.06$, $p < .001$), and a task by age interaction ($F(3,54) = 123.14$, $p < .001$). The name task was easier than the sound task, and performance on both tasks improved with age. The task by age interaction arose because the largest improvement on names took place between age 4 and age 5, with the largest improvement on sounds occurring a year later. The ANOVA also showed a main effect of consonant type ($F(2,18) = 7.57$, $p = .004$), and, critically, an interaction of consonant type and task ($F(2,18) = 9.37$, $p = .002$). To understand the consonant type by task interaction, separate follow-up tests were carried out for the sound and name tasks, pooling across age levels because of the lack of a three-way interaction. For the sound task, planned comparisons showed that children did significantly better when the sound was at the beginning of the letter name than when it was at the end ($p = .05$) and significantly better when it was at the end than when it was not in the name at all ($p = .024$). For the name task, there were no significant differences among the three types of consonants.

For the Detroit data, the factors were consonant type, task, and age (preschool vs. kindergarten). There were main effects of consonant type ($F(2,18) = 14.97$, $p < .001$), task ($F(1,18) = 243.99$, $p < .001$), and age ($F(1,18) = 37.04$, $p < .001$), which were qualified by consonant type by task ($F(2,18) = 32.61$, $p < .001$) and age by task ($F(1,18) = 38.55$, $p <$

.001) interactions, as well as a three-way interaction ($F(2,18) = 3.75$, $p = .044$). In view of the interactions, separate ANOVAs were carried out for the name and sound tasks. For both tasks, there were significant effects of age (names: $F(1,18) = 11.89$, $p < .003$; sounds: $F(1,18) = 44.31$, $p < .001$). For the sound task only, there was also a main effect of consonant type ($F(2,18) = 29.76$, $p < .001$) and an interaction between age and consonant type that just missed the .05 level ($F(2,18) = 3.53$, $p = .051$). Kindergartners showed the same pattern of performance on the sound task as in the California data -- better performance on letters for which the sound is at the beginning of the name than on letters for which the sound is at the end ($p = .004$) and better performance on letters for which the sound is at the end than on letters for which the sound is not in the name ($p = .024$). The pattern was similar for preschoolers, but the difference between the end and not-in-name categories was not significant for this group.

The Houston data were analyzed in a similar fashion, except that the factor of age was not included. There was a main effect of task ($F(1,18) = 351.28$, $p < .001$), a main effect of consonant type ($F(2,18) = 10.90$, $p = .001$), and an interaction between task and consonant type ($F(2,18) = 7.53$, $p = .004$). Planned comparisons showed that, in the sound task, children performed better on letters for which the sound is at the beginning of the name than those for which the sound is at the end ($p = .001$). Also, children performed significantly better on end letters than on letters for which the sound is not in the name ($p = .031$). In the name task, there were no reliable differences among the three types of consonants.

The results just presented suggest that letter names play a role in children's learning of letter sounds. To confirm this idea, and to examine other factors that may be associated with children's knowledge of letter sounds, multiple regression analyses were performed. Data from all 26 letters of the alphabet were used, and the coding took account of the fact that the sounds that were counted as correct for vowels differed across the studies. The dependent variable in the multiple regression analyses was the probability of knowing the sound of a letter given correct performance on the name. We chose this dependent variable because it adjusts for differences among letters in children's knowledge of their names, differences that may reflect letter frequency as well as other factors. Hierarchical multiple regressions were performed to test specific hypotheses about the factors that affect children's knowledge of letter sounds.

For the California data, four predictors were included in the first block of variables. One predictor was whether the sound of the letter was in the letter's name or not. A second predictor was whether the sound was at the beginning of the name or not. Because responses such as /e/ for the sound of a were scored as correct in the California study, vowels were categorized as having the sound at the beginning of the name. The third predictor was whether the letter has more than one common pronunciation. The letters that were considered to have more than one common pronunciation were a, e, i, o, u, c, g, x, and y (which has the pronunciations /j/ and /i/). The fourth predictor in Step 1 was age group (4, 5, 6, or 7). In Step 2a, two additional predictors were included -- whether the phoneme(s) represented by a letter was a consonant or a vowel, and whether the phoneme was an obstruent or not[4]. Together, these predictors allow us to test the syllable position hypothesis, according to which consonants as a group are superior to vowels and obstruent consonants are superior to other consonants. In a further analysis, one predictor was added to the variables in the first block – whether the phoneme represented by a letter was a stop consonant or not. Step 2b allows us to test the pronounceability hypothesis, according to which stop consonants are more difficult than other classes of phonemes.

Table 2 shows the results of the regression analyses of the California data. After Step 1, 79.3% of the variance in knowledge of letter sounds was accounted for. Each of the four predictors made significant contributions to the regression. Children did better on letters for which the sound was in the name than for letters for which the sound was not in the name, with performance good when the sound was at the beginning of the name. Children did more poorly than otherwise expected on letters that had more than a single sound. In addition, knowledge of letter sounds was better among older children than younger children. The additional variables included in Steps 2a and 2b did not reliably improve R^2. Thus, there was no evidence in the California data for either the syllable position hypothesis or the pronounceability hypothesis.

The Detroit data were analyzed in the same way as the California data, except that there were only two levels of age (preschool, kindergarten). As Table 3 shows, all of the variables in Step 1 made significant contributions to the regression. As in the California data, performance was better on letters for which the sound was in the name than for letters for which the sound was not in the name. This was especially true if the sound was at the beginning of the name. Performance was poorer than otherwise expected on letters that had more than one common pronunciation, and the older children outperformed the younger children. The total percentage of variance accounted for after Step 1 was 68.0%. Together, the two additional variables in Step 2a increased the percentage of variance explained to 76.1% ($\underline{F}_{inc}(2,45) = 7.63$, $\underline{p} < .005$). There was a tendency for better performance on consonants than on vowels and for better performance on obstruents than on non-obstruents, as the syllable position hypothesis predicts. However, neither of these effects reached significance when considered individually (see Table 3). In Step 2b, performance on letters with stop consonant pronunciations was found to be significantly better than performance on other types of letters. This result is the opposite of that predicted by the pronounceability hypothesis.

Table 4 shows the results of the regression analyses for the Houston data. Because only kindergartners were studied, age group was not included as a factor. Also, vowels were considered not to have the sound in the name because only responses such as /æ/ for a were counted as correct. The percentage of variance accounted for after Step 1 was 72.0%. Performance was better on letters for which the sound was at the beginning of the name than on letters for which this was not the case. However, there was no reliable difference between letters for which the sound was at the end of the name and letters for which the sound was not in the name, as in the California and Detroit data. Performance was poorer than otherwise expected on letters that had more than one common pronunciation. In Step 2a, there was a tendency for consonant letters to yield poorer performance than vowel letters. This results is the opposite of that predicted by the syllable position hypothesis. There was no significant difference between obstruents and non-obstruents. However, the increase from Step 1 to Step 2a in the percentage of variance explained by the regression did not reach significance ($F_{inc}(2,20) = 2.44$). Inclusion of the stop consonant variable in Step 2b did not improve the results.

Discussion

The goal of this study was to determine whether children perform better on some letter-sound correspondences than others. If so, why do the differences occur and what do they imply about the processes involved in the learning of letter sounds? We analyzed data from three separate studies involving a total of 660 children between the ages of 3 ½ and

7 ½ in an attempt to address these questions.

The results support the idea that children bring their knowledge of letter names to the task of learning the letters' sounds. Hence, properties of a letter's name affect children's ability to learn its sound. Most English letter names contain a clue as to the sound the letter makes. Children pick up these clues, implicitly noticing that the relation between a letter's name and the sound that it symbolizes is not arbitrary. In all of our analyses, performance was best for letters such as b which have the sound at the beginning of the name. In addition, most of the analyses showed a reliable superiority for letters such as f (where the letter name contains a clue to the sound in the end position) to letters such as w (where the name does not contain a clue to the sound). The results of our regression analyses go beyond previous findings (McBride-Chang, submitted; Treiman et al., 1994) by showing that properties of a letter's name are associated with children's knowledge of its sound even after other factors are statistically taken into account.

There are two possible reasons why children's letter-sound knowledge is better for letters such as b, where the sound is in the initial position of the name, than for letters such as f, where the sound is in the final position. First, children may find it easier to access the phoneme /b/ in the letter name /bi/ than to access /f/ in the letter name /ɛf/. This is because /b/ is the onset of a consonant + vowel syllable in /bi/ whereas /f/ is part of the syllable's vowel + consonant rime in /ɛf/. Segmentation of syllables at the onset-rime boundary is easier for children than segmentation of syllables at other points (e.g., Treiman, 1992;

Treiman & Zukowski, 1996). A second possible explanation for children's better performance on letters such as b than letters such as f is that, for those English letters that contain the sound that the letter typically represents, the sound is more often at the beginning of the name than the end. Children may pick up this pattern and so look to the beginning of a letter's name for a clue to the letter's sound.

The results of the regression analyses further show that children have difficulty with letters that do not always symbolize the same sound . Children experience some confusion when learning about a letter such as c, which makes the /s/ sound in words such as city but the /k/ sound in words such as cat. Similarly, Treiman (1993) found that multiple spellings cause problems when children are learning to map from phonemes to graphemes.

We tested two hypotheses about how the properties of phonemes themselves influence children's ability to connect them to letters. According to the syllable position hypothesis (Stuart & Coltheart, 1988), children learn letter-sound correspondences more readily for letters that usually appear at syllable boundaries (i.e., letters that correspond to less sonorous phonemes) than for letters that usually appear in the middles of syllables (i.e., letters that correspond to more sonorous phonemes). Our tests of this hypothesis yielded inconsistent results across the three data sets. In the Detroit data, there was a tendency for better performance on consonants than vowels and better performance on less sonorous consonants than more sonorous consonants. However, no significant effects were observed in the California data. And the Houston children tended to perform more poorly on consonants than vowels, contrary to the prediction of the syllable position hypothesis. Across the three data sets, then, there was no consistent evidence in favor of the syllable position hypothesis.

A second hypothesis about how the ease of connecting phonemes with letters varies across classes of phonemes is the pronounceability hypothesis. This hypothesis states that stop consonants, which cannot be pronounced on their own, are harder to bring to awareness and harder to connect to letters than other types of phonemes. However, the regression analyses did not reveal any special difficulty with stop consonants. There were no significant differences between stop consonants and other phonemes in the California and Houston data, and stop consonants were actually easier than other types of phonemes in the Detroit data.

To summarize, the results suggest that children's ability to map from letters to phonemes is affected by whether the name of the letter contains the phoneme and, if so, whether it occurs at the beginning or the end. It is also affected by whether the letter has a common alternative pronunciation. The properties of the phoneme itself – whether it is a consonant or a vowel, an obstruent consonant or a sonorant consonant, a stop consonant or a phoneme that can be pronounced on its own – do not appear to have a consistent influence on children's ability to relate the phoneme to its spelling.

One might argue that the observed differences among letters in children's knowledge of their sounds are solely a result of instruction. In this view, correspondences such as that between <u>v</u> and /v/ are taught earlier or more intensively than correspondences such as that between <u>w</u> and /w/ and so children do better on the former than the latter. However, alphabet instruction is <u>not</u> standardized in the United States. Pre-kindergartners learn letter sounds (if at all) informally at home or in preschool. The informal instruction follows different sequences for different children. When formal teaching of letter sounds begins, typically in kindergarten, the sequence of instruction varies from one school to another and even from one classroom in a school to another. Moreover, kindergartens in the United States typically teach the names and the printed forms of letters at the same time that they teach the letters' sounds. Based on instruction alone, it would be difficult to explain why the discrepancy between knowledge of names and knowledge of sounds is larger for some letters than for others. We believe, therefore, that our results reflect factors intrinsic to the child rather than purely extrinsic factors.

Study Two

The goal of Study Two was to test the view that factors intrinsic to the child – letter-name knowledge and phonological skills – make some correspondences between letters and sounds easier to learn than others. To do this, we selected preschoolers who knew the names of certain consonant letters but who did not yet know most of these letters' sounds. Over the course of several sessions, the children were taught the letters that are used to symbolize these sounds. We asked whether children learned the sound-letter relations more quickly for some letters than others. For example, if a given amount of instruction is more effective for v than for w, this would suggest that children use their knowledge of v's name to help learn its sound in a way that they cannot do for w.

Table 5 shows the sound-letter mappings that were taught in Study Two. The mappings varied along two dimensions. The first dimension was whether the sound occurs at the beginning of the letter's name, the end of the letter's name, or is not in the letter's name at all. Based on the results of Study One, we predicted that gains from pretest to posttest in sound-letter knowledge would be largest for letters of the first type, intermediate for letters of the second type, and lowest for letters of the third type. The sound-letter mappings varied also varied in whether the phoneme was an obstruent consonant or a sonorant consonant. Given that the results of Study One did not provide consistent support for the idea that mappings are easier to learn for obstruent consonants than sonorant consonants, we did not expect the sonority of the phoneme to be influential. Because the children in Study Two knew few sound-letter relations at the outset, and because only one letter was taught for each phoneme, the dimension of alternative spellings was not relevant here.

We selected for the training study preschoolers who were familiar with the names of all ten critical letters. The children's pretest knowledge of the letters' sounds had to be relatively poor (less than 3 out of 10 correct). These criteria were adopted because our goal was to examine the learning of letter sounds by children who knew the letters' names but who had little familiarity with their sounds. As discussed earlier, North American children do generally know the letters' names at the time that they learn their sounds.

Method

Participants

We screened preschool children to find those who performed perfectly (10/10) or close to perfectly (9/10) on the first administration of a pretest assessing knowledge of the names of the ten critical letters. To participate in the experiment, a child also had to score less than 3 correct on the 10-item pretest of letter sound knowledge. A total of 98 preschoolers were screened. These children had a mean age of 4 years, 9 months (range: 3,9 - 5,7; information about age was not available for three children); 57 were girls and 41 were boys. The children attended one of seven different daycare centers and nursery schools that were located in Detroit or its suburbs. Most served primarily White middle-class populations. Eighteen children fit the criteria for inclusion in the study. Six of these children participated in a pilot study and 12 began the study itself. One of these 12 children did not wish to complete the experiment. Another 2 were dropped because they failed to perform perfectly on the posttest of letter name knowledge, suggesting that their knowledge of the letters' names was not in fact secure. The 9 children who contributed data to the final analyses had a mean age of 4 years, 11 months (range 3,9 - 5,7). Six were girls and 3 were boys.

Of the 80 children who did not fit the criteria for participation in the study, some performed at or close to ceiling on both the name and sound pretests, others performed at or close to floor on both, and still others did better on the name task than the sound task but did not show a large enough difference to qualify. Only 7 children performed better on the sound task than the name task. Overall, the children who did not qualify had a mean score on the letter-name pretest of 5.61 and a mean score on the letter-sound pretest of 2.54, a significant difference ($t(79) = 10.35$, $p < .001$).

Materials and procedure

For the pretest of letter-name knowledge, 10 plastic upper-case letters (d, f, g, h, l, m, s, v, w, y) were placed before the child in a haphazard arrangement. The experimenter asked, "Can you find the letter that has the name ___?," asking about each of the letters in an order that was randomly chosen for each child. The child responded by pointing. The experimenter did not comment on the correctness of the child's responses. The pretest of letter-sound knowledge was given next, using a similar procedure. The experimenter began by saying, "Now we're going to talk about the sounds of letters." She asked, "Can you find the letter that makes the sound ___?," asking about each of the letters in a randomly chosen order.

For the one child who scored 9 correct on the first administration of the letter name task and 3 or fewer correct on the letter sound task, the experimenter picked out the letter whose name the child got wrong on the name task and the letter with which he confused it. The experimenter told the child the names of these two letters. She asked the child to say the names of each of the letters two times, and the child did so correctly. The letter name task was then readministered, and the child did perfectly. This child was considered to have met the criteria for participation in the study.

For those children who did not meet the criteria, testing stopped at this point. For those children who met the criteria, the experimenter then said, "Now we're going to learn the sounds that some letters make." She showed the child one of the letters and said, "This is the letter ___. It makes the sound ___. Can you say that?" The child repeated the letter's sound after the experimenter, who corrected any errors. The experimenter then said, "So, ___ (letter name) makes the sound ___ (sound)." The experimenter demonstrated the sounds of all 10 letters in this manner, presenting the letters in a randomly chosen order for each child. Following this demonstration trial was a training trial. The experimenter placed all 10 letters on the table in a haphazard arrangement. She said, "Which letter makes the sound ___?," and the child responded by pointing. If the child responded incorrectly, the experimenter told the child the correct answer, saying "The letter that makes the sound ___ is ___" and pointing to the correct letter.

The second session, which took place an average of 3 days after the first, began with a demonstration trial like that of the first session. Two more training trials were then given, using the same procedure as the first session. One child's data for the last training trial are incomplete, as the child responded to the first letter of this trial but did not wish to continue. The third session of the training study took place the day after the second session. In this final session, posttests of letter-name and letter-sound knowledge were given following the same procedure as in the pretests.

Results

Table 6 shows the mean proportion of correct responses to each type of letter on the letter-sound pretest, the three training trials, and the letter-sound posttest. For statistical analyses, the results for the three training trials were pooled and an ANOVA was performed using the within-subject factors of phase (pretest, training, posttest) and letter type (d, v vs. f, s vs. l, m vs. g, h vs. w, y). There were main effects of phase ($F(2,16) = 13.03$, $p < .001$) and type ($F(4,32) = 4.58$, $p = .005$), as well as an interaction between them ($F(8,64) = 3.81$, $p = .001$). Planned comparisons were carried out to examine the results for each type of letter separately. For d and v, performance on the training trials and posttest was statistically indistinguishable and significantly better than performance on the pretest. The same was true for f and s and for l and m ($p > .05$ for the difference between the training trials and posttest for all three of the above pair types; $p < .006$, one tailed, for the difference between the training trials and posttest trials combined and the pretest). For g and h and for w and y, for which the sound of the letter is not in the name, there were no reliable differences among the pretest, training, and posttest trials. Thus, the children benefited from the instruction when the sound of the letter was in the letter's name. There was no appreciable learning when the sound of the letter was not in the letter's name.

Planned comparisons were performed to determine whether the improvement in performance from the pretest to the training and posttest trials combined was larger for some kinds of letters than for others. The first comparison showed that there was significantly more improvement when the sound of the letter is at the beginning of the letter's name than when the sound of the letter is at the end of the name ($p = .04$, one tailed). A second comparison examined the effect of sonority for end letters, contrasting f and s (which correspond to obstruents) with l and m (which correspond to sonorants). This difference was not significant. The third comparison contrasted the not-in-name obstruents g and h with the not-in-name sonorants w and y. Again, there was not a significant difference[5].

The pattern of results is graphically depicted in Figure 1. As shown, most improvement took place for d and v, for which the sound of the letter is at the beginning of the name. An intermediate degree of improvement took place for f, s, l, and m, for which the sound of the letter is at the end of the name. Least improvement occurred for g, h, w and y, for which the sound of the letter is not in the letter's name.

Discussion

In Study Two, we focused on preschoolers who knew the names of certain critical letters but who had little knowledge of these letters' sounds. Over the course of several sessions, these children were taught the sounds of the letters. We asked whether the factors identified in Study One – whether the sound of the letter is in the name and its position in the name – played a role in children's ability to benefit from instruction.

The results showed that whether the phoneme is in the letter name and, if so, its position, affect children's learning of phoneme-letter links. Most learning occurred when letter's sound is at the beginning of its name, as with d and v. The preschoolers went from 17% correct on the pretest to 67% correct on the posttest for these letters, a substantial improvement. Apparently, a relatively small amount of instruction helps children to learn the sounds of letters such as d and v. Intermediate in ease of mastery are letters such as f and l, for which the letter's sound is at the end of its name. Children went from 6% correct in the pretest to 31% correct on the posttest for these letters, a significant improvement but less than that for letters such as d. The children had most trouble learning the sounds of letters such as h and w. They scored 14% correct on the pretest and 19% correct on the posttest for these letters, not a reliable improvement. Thus, an amount of instruction that is sufficient to improve performance when the letter sound is in the name is not effective when the sound is not in the name.

The results of Study Two fail to support the syllable position hypothesis (Stuart & Coltheart, 1988), according to which children learn the mappings between letters and sounds more easily for obstruent phonemes than for sonorant phonemes. No significant differences were found between these two classes of phonemes in the present study. The study was not specifically designed to test the pronounceability hypothesis, according to which stop consonants cause particular difficulty. However, this hypothesis predicts especially slow learning for d, and this was not observed. As in Study One, then, there was no clear evidence that certain classes of phonemes are easier to connect to letters than others.

Some limitations of Study Two must be acknowledged. The number of participants was small due to the stringent criteria for participation. The small number of participants may account for the unexpected drop on d and v in the third training trial. The children in

Study Two differed from other preschool children in that they showed an especially large difference between knowledge of letter names and knowledge of letter sounds. However, the direction of the difference – better performance on names than sounds – was in the typical direction. Thus, although many children were excluded from Study Two, the children who participated did not show an unusual pattern of performance.

Despite its limitations, Study Two succeeded in its main goal of showing that children who know the names of letters benefit more from a given amount of instruction about the letters' sounds for some letters than for others. To understand why children perform better on certain letter-sound correspondences than others, we must consider not only the instruction that children have received but also their ability to learn from and make sense of that instruction.

General Discussion

The purpose of this research was to examine children's knowledge of the relations between letters and sounds in American English. Alphabet knowledge is an important foundation of literacy, and United States kindergartens typically devote a good deal of time to teaching children about the names and the sounds of letters. For example, one week may be spent on the letter b, teaching children the visual form of this letter and the sound that it represents. Another week may be devoted to h, another week to y, and so on. Many children already know the names of most of the letters when they enter kindergarten; it is the sounds that may be new to them and that they most need to learn.

Are all letter sounds equally difficult for children to learn, or are some easier than others? We used two approaches to address the question. In Study One, we examined data on knowledge of letter sounds (and names) by 660 children from 3 ½ to 7 ½ years old. In

Study Two, we trained preschoolers on sound-letter mappings and asked whether a given amount of instruction is more effective for some letters than for others. The results of both studies reveal systematic differences among letters. The findings point to several factors that make some letter sounds easier for children to learn than others.

One factor that influences children's ability to learn the mappings between letters and phonemes is whether the phoneme appears in the name of the letter and, if so, whether it is at the beginning or the end. Children generally did better when the phoneme was in the letter's name (as with b and f) than when it was not (as with w and h). The position of the phoneme in the letter's name was also important. In both studies, children did better when the phoneme was at the beginning of the letter's name (as with b) than when it was at the end (as with f). These results indicate that children use their knowledge of letter names, together with their phonological skills, when attempting to learn the sounds of letters. Children who have a sufficient degree of phonological awareness to access /b/ at the beginning of /bi/ can use their phonological and letter-name skills to learn that b generally symbolizes /b/. Children have more trouble learning the sound of a letter like l, in part because /l/ is more difficult to access in /ɛl/ than is /b/ in /bi/. And children have special difficulty learning the sound of a letter like w because the phoneme symbolized by this letter is not in the letter's name.

The results of Study One point to another factor that influences children's knowledge of letter sounds – the existence of one-to-many mappings. Other things being equal, it is harder for children to master letter-sound relations for letters that have more than one common sound (such as c) than for letters that have a single dominant sound (such as b). Similar results have been reported for sound-to-spelling mapping (Treiman, 1993).

Once the factors just discussed have been taken into account, the properties of the phoneme itself – whether it is an obstruent consonant or a sonorant consonant, whether it is a consonant or vowel, and whether it is a stop consonant or not – do not appear to affect children's learning of basic grapheme-phoneme correspondences. At first glance, these results seem to conflict with the commonly reported finding that children learning to read and spell in English make more errors on vowels than consonants (e.g., Bryson & Werker, 1989; Fowler, Liberman, & Shankweiler, 1977; Stage & Wagner, 1992; Treiman, 1993). The apparent discrepancy may be resolved by noting that vowels differ from consonants orthographically as well as phonologically. For example, vowel letters are more likely to have multiple pronunciations. A child may be able to supply /æ/ as the sound of a but may not know that a is pronounced as /æ/ in some contexts (e.g., cat), as /e/ in others (e.g., table), and as another phoneme in still other contexts (e.g., car). Learning the sounds of letters in isolation is one important foundation for learning to read and write, but it is by no means the only contributor.

Our results show that children bring their knowledge of letter names and their phonological skills to the task of learning letters' sounds. Children -- at least those with normal levels of letter-name knowledge and phonological awareness -- do not memorize letter-sound links as rote paired associates. Rather, they try to make sense of these relations based on what they know about the letters' names and the sounds that the names contain. A link such as that between /bi/ and /b/ makes more sense, given children's existing knowledge, than a link such as that between "doubleyou" and /w/. Hence, children find it easier to learn the sound of b than the sound of w. It remains to be seen whether the same is true for children who later develop serious reading problems.

Our findings imply that letter-sound knowledge and phonological awareness, rather than being two separate foundations of literacy, are intimately related. Children must have some degree of phonological skill to benefit from the clues provided by many English letter names as to the sounds the letters represent. Children who have this phonological awareness should be better at learning the sounds of most letters than children who do not. Conversely, learning the sounds of letters may foster children's phonological skills. For example, a child may first learn the association between b and /b/ by rote but may come to understand that /b/ is in fact the first sound of /bi/ and that the association makes sense on that basis. These suggestions fit with previous proposals that alphabet knowledge and phonological awareness are closely related (e.g., Bowey, 1994).

The present results shed doubt on the practice, common in United States kindergartens, of spending the same amount of time on each letter-sound pair. As we have shown, amount of instruction is not the only factor that affects letter-sound learning. Factors intrinsic to the child are also important, for they make some letter-sound mappings easier for the child to understand than others. Thus, it is probably not wise to spend the same amount of time teaching the sound of b as the sound of w. Given that the former is easier for children to learn than the latter, why not devote less time to it and more time to the harder letters? An understanding of which letter sounds are difficult for children to learn, and why, should be valuable in designing curricula for young children.

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Author addresses and affiliations

Author affiliations:

Rebecca Treiman, Department of Psychology, Wayne State University; Ruth Tincoff, Department of Psychology, Johns Hopkins University; Kira Rodriguez, Department of Psychology, Wayne State University; Angeliki Mouzaki, Department of Educational Psychology, University of Houston; David J. Francis, Department of Psychology, University of Houston.

Corresponding author:

Rebecca Treiman

Department of Psychology

Wayne State University

71 W. Warren Ave.

Detroit MI 48202 USA

phone: 313 577 2852

fax: 313 577 7636

email: treiman@math.wayne.edu

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Footnotes

[1] Key to notation: /i/ as in beat, /ai/ buy, /ə/ sofa, /ɑ/ father, /e/ bait, /æ/ bat, /ɪ/ bit, /ɛ/ bet, /j/ yet, /ʤ/ gym

[2] Analyses were also carried out in which children were scored as correct if they responded correctly in either the free-choice task or the two-choice task. The patterns were similar to those reported, but the kindergartners performed close to ceiling on a number of letters.

[3] The letter q was included in the not-in-name category because only one phoneme of its /kw/ sound occurs in the name.

[4] y was considered to be a consonant in these analyses since it is most commonly associated with its consonantal sound.

[5] The nonsignificant tendency toward lesser improvement on y and w than on g and h probably occurs not because y and w represent sonorant phonemes but because within-experiment confusion based on the initial phoneme of the letter name was most likely for y. Indeed, a common error was pointing to y when asked for the letter that makes the sound /wə/.

Table 1

Proportion Correct in Study One on Consonant Letters for which the Sound is at the Beginning of the Letter Name, the End of the Letter Name, or Not in the Letter Name

Sound task

	California Study				Detroit Study		Houston Study
Type of consonant	Age 4	Age 5	Age 6	Age 7	Preschool	Kindergarten	
Sound at beginning	.25	.40	.84	.96	.52	.67	.40
Sound at end	.21	.29	.71	.93	.17	.43	.27
Sound not in name	.11	.15	.61	.81	.10	.19	.17

Name task

	California Study				Detroit Study		Houston Study
Type of consonant	Age 4	Age 5	Age 6	Age 7	Preschool	Kindergarten	
Sound at beginning	.50	.85	.98	.99	.71	.77	.72
Sound at end	.57	.88	.98	.99	.76	.83	.73
Sound not in name	.54	.84	.95	.99	.74	.75	.67

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Table 2

Results of Regression Analyses for California Data of Study One

Step	Variable	B	β	sr^2
1	Sound in name	.107**	.142	.015
	Sound at beginning of name	.096**	.175	.020
	More than one sound	-.165***	-.288	.075
	Age group	.200***	.819	.670
		intercept = -.601		R^2 = .793 (.784 adjusted)
				R = .890***
2a	Consonant	.035	.050	.001
	Obstruent	.004	.007	.000
				R^2 = .794 (.782 adjusted)
				R = .891***
2b	Stop	.006	.100	.007
				R^2 = .799 (.789 adjusted)
				R = .894***

** $p < .01$, *** $p < .001$

Table 3

Results of Regression Analyses for Detroit Data of Study One

Step	Variable	B	β	sr^2
1	Sound in name	.156*	.208	.032
	Sound at beginning of name	.362***	.660	.300
	More than one sound	-.225***	-.396	.143
	Age group	.149**	.275	.076
		intercept = .162		R^2 = .680 (.653 adjusted)
				R = .825***
2a	Consonant	.155	.225	.014
	Obstruent	.097	.177	.013
				R^2 = .761 (.729 adjusted)
				R = .872***
2b	Stop	.183**	.300	.060
				R^2 = .740 (.712 adjusted)
				R = .860***

* p < .05 , ** p < .01, ***p < .001

Table 4

Results of Regression Analyses for Houston Data of Study One

Step	Variable	B	β	sr^2
1	Sound in name	.005	.163	.014
	Sound at beginning of name	.195***	.602	.242
	More than one sound	-.010*	-.293	.065
		intercept = .326		R^2 = .720 (.682 adjusted)
				R = .849***
2a	Consonant	-.155*	- .388	.052
	Obstruent	.014	.045	.001
				R^2 = .775 (.719 adjusted)
				R = .880***
2b	Stop	-.008	- .023	.000
				R^2 = .720 (.667 adjusted)
				R = .849***

* $p < .05$, ***$p < .001$

Table 5

Sound-Letter Relations Taught in Study Two

Type of phoneme	Sound at beginning of letter name	Sound at end of letter name	Sound not in letter name
Obstruent	/d/-d	/f/-f	/g/-g[a]
	/v/-v	/s/-s	/h/-h
Sonorant	--[b]	/l/-l	/w/-w
		/m/-m	/j/-y

[a] Because g was taught as the spelling of /g/, not /ʤ/, the /g/-g case was one in which the sound is not in the letter's name.

[b] There were no stimuli in this category because English does not include any sound-letter relations of this kind.

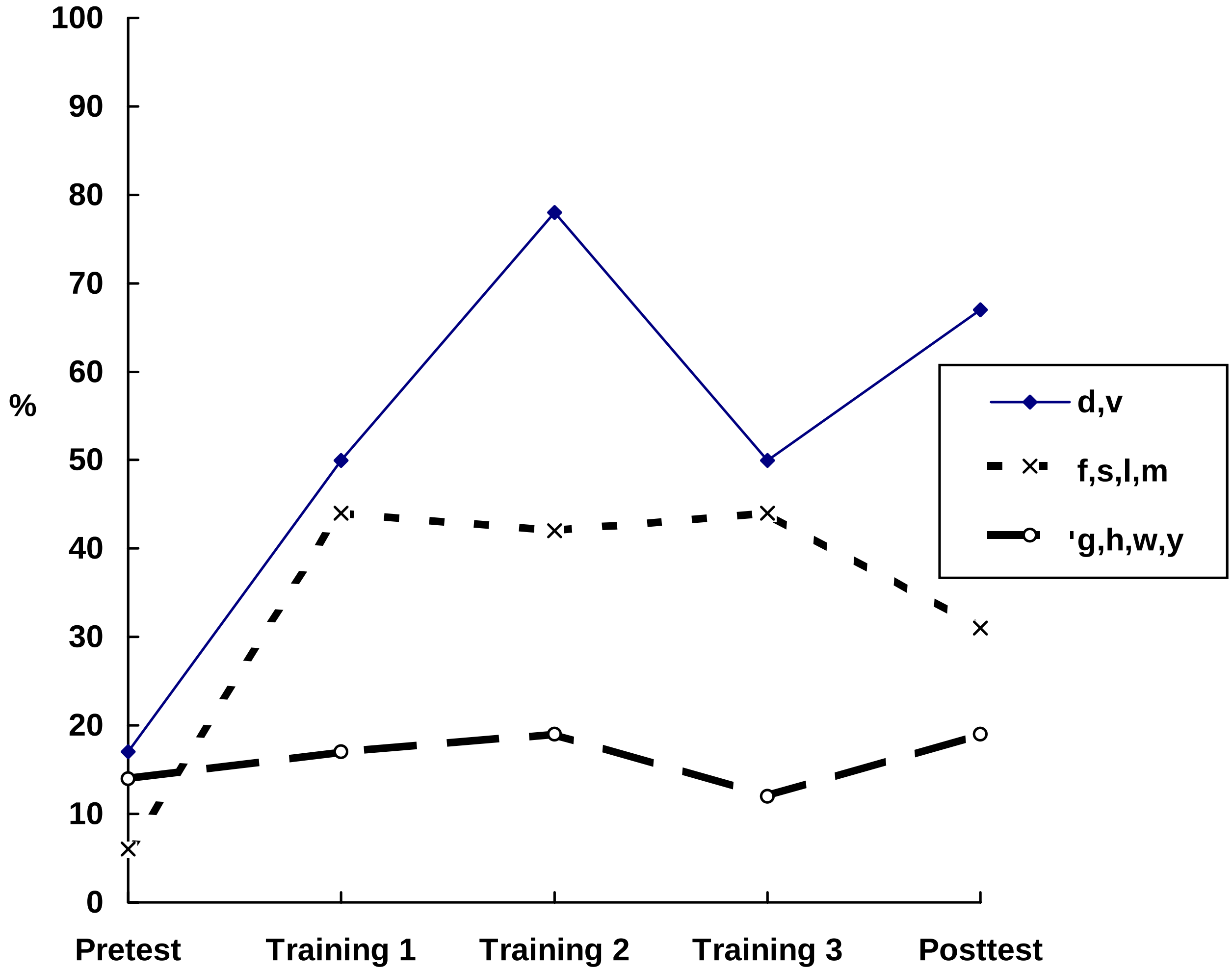
Table 6

Proportion of Correct Responses in Letter-Sound Pretest, Training Trials, and Letter-Sound Posttest for Children in Study Two

Letter type	Pretest	Training trial 1	Training trial 2	Training trial 3	Posttest
Obstruent, sound at beginning of letter's name (d , v)	.17	.50	.78	.50	.67
Obstruent, sound at end of letter's name (f, s)	.06	.50	.39	.56	.28
Sonorant, sound at end of letter's name (l, m)	.06	.39	.44	.31	.33
Obstruent, sound not in letter's name (g, h)	.17	.22	.17	.12	.33
Sonorant, sound not in letter's name (w, y)	.11	.11	.22	.13	.06

Figure Caption

Figure 1. Percentage of correct responses in letter sound pretest, training trials, and letter sound posttest for children in Study Two.


100
90
80
70
60
50
40
30
20
10
0
%
Pretest
Training 1
Training 2
Training 3
Posttest
d,v
f,s,l,m
'g,h,w,y