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Relating print and speech: The effects of letter names and word position on reading and spelling performance ☆

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Abstract

From an early age, children can go beyond rote memorization to form links between print and speech that are based on letter names in the initial positions of words (Treiman & Rodriguez, 1999; Treiman, Sotak, & Bowman, 2001). For example, children's knowledge of the name of the letter *t* helps them learn that the novel word TM is pronounced as *team*. Four experiments were carried out to determine whether letter names at the ends of words are equally useful. Four- and five-year-olds derived little benefit from such information in reading (Experiments 1 and 3) or spelling (Experiment 2), although adults did (Experiment 4). For young children, word-final information appears to have less influence on reading and spelling performance than does word-initial information. The results help delineate the circumstances under which children can go beyond a logographic approach in learning about print.

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Different cultures have developed distinctive writing systems to represent spoken language. Alphabetic systems use letters or groups of letters to represent the phonemes in spoken words. Understanding the relationship between the grapheme and the phoneme is the foundation on which reading and writing skills develop. Once the alphabetic principle is understood, readers and writers can decipher and construct words with reasonable accuracy. Because the alphabetic principle provides the key to fluent reading and writing, researchers seek to explain how children learn to connect graphemes and phonemes.

Many researchers have examined the developmental process in learning the alphabetic principle (e.g., Byrne, 1992; Ehri, 1995; Frith, 1985; Lomax & McGee, 1987; Share & Gur, 1999). During an initial phase, often called *pre-alphabetic* or *logographic*, children cannot relate graphemes and phonemes. They focus on the salient visual features of printed words, such as the humps on the *m* of *camel*, in order to identify a limited number of words. At this point, the important aspects of print identification involve visual distinctiveness (Byrne, 1992; Ehri & Wilce, 1985) and context (Masonheimer, Drum, & Ehri, 1984; Share & Gur, 1999). The shift into the second phase of development is thought to occur when the features of printed words begin to overlap and visual distinctiveness no longer suffices to identify words. During this *alphabetic* phase, children begin to associate letters with sounds. These associations allow them to decipher and remember words in a systematic way. Ehri (1995) suggested that the alphabetic phase starts with a *partial alphabetic* phase, during which only some of the letters are analyzed, followed by a *full alphabetic* phase, during which most of the letters are linked to sounds. The final step in learning to read involves the use of recurring letter patterns to decipher words. This is referred to as the *consolidated alphabetic* (Ehri, 1995) or *orthographic* phase (Frith, 1985).

Evidence for a logographic phase in the reading of English comes from a study by Ehri and Wilce (1985) in which US children (mean age 5 years, 7 months) were taught to read two sets of novel stimuli that differed in how the printed and spoken forms were related. In the phonetic condition, the letters seen corresponded to the sounds heard, as in JRF for *giraffe*. In the visual condition, the letters varied in size and position but alphabetic correspondences were violated, as in W_CB for *giraffe*. In its use of visually distinctive letters, this condition is similar to some of the commercial logos that children commonly encounter. Children had up to 10 trials to learn to read each set of items. Prereaders (unable to read any of the simple screening words) learned the visual spellings more easily than the phonetic spellings.

Apparently, these children benefited from the visual distinctiveness of the items and were not confused by the violation of spelling-sound correspondences. Novice readers (able to read at least one simple word) learned the phonetic items more easily than the visual ones. The results suggest that children who cannot yet read words out of context rely on visual cues to make the connection between print and pronunciation. de Abreu and Cardoso-Martins (1998) found, similarly, that Brazilian prereaders who knew little about the alphabet were logographic learners.

The view of prereaders as logographic learners focuses on what the children cannot do—form alphabetic connections between print and speech—rather than on what the children can do. Do young children possess any knowledge that might allow them to make principled links between print and speech? A number of studies have shown that US prereaders are reasonably familiar with the names of letters (e.g., Lomax & McGee, 1987; McBride-Chang, 1999; Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998; Worden & Boettcher, 1990). The development of letter-sound knowledge lags behind the development of letter-name knowledge. Young children might be able to use their knowledge of letter names to make certain links between printed and spoken words. For example, children may be able to relate the *t* of *team* to the word's pronunciation because the entire name of the letter *t* is heard in the spoken word.

Preliminary evidence for the idea that young US children can use their knowledge of letter names in learning to read words comes from studies by Treiman and Rodriguez (1999) and Treiman et al. (2001). Treiman and Rodriguez used the word-learning task of Ehri and Wilce (1985) to evaluate the performance of prereaders and novice readers under three conditions. As in the Ehri and Wilce study, the items in the visual condition consisted of arbitrary letters that were not phonologically related to the spoken words but that varied in size and positioning. The phonetic condition of Ehri and Wilce was divided into two conditions, one based on letter names and the other based on letter sounds. In the name condition, each novel word began with a letter whose name was heard at the beginning of the word's pronunciation (e.g., TM for *team*, DL for *deal*). In the sound condition, the entire name of the letter was not heard in the pronunciation of the word but the letter corresponded to its characteristic sound (e.g., TM for *tame*, DL for *dial*). Different sets of items were used to avoid exposure to the same stimuli under different conditions. For each condition, children were shown five simplified spellings, told how to read each one in the "made-up" language, and given up to eight trials to master the pronunciations.

The prereaders tested by Treiman and Rodriguez (1999) (mean age 5 years, 0 months) performed significantly better in the name condition than in either the sound or visual conditions, which were statistically indistinguishable from one another. These children were reasonably knowledgeable about letter names (responding correctly to an average of 15.5 out of 26

letters), but less knowledgeable about letter sounds (averaging 5.5 of 26). Correspondingly, the children benefited from letter-name cues but not letter-sound cues. Thus, it appears that even prereaders can make systematic links between printed and spoken words when those links involve a type of knowledge that they possess, knowledge about letter names.

The novice readers studied by Treiman and Rodriguez (1999) (mean age 5 years, 6 months) knew more letter names and sounds than the prereaders. They performed significantly better in the name condition than the sound condition and significantly better in the sound condition than the visual condition. The superiority for the sound condition over the visual condition suggests that the novice readers had some ability to link graphemes to phonemes. They learned the pairs more easily when the letters corresponded to their characteristic sounds (e.g., TM for *tame*) than when they did not (e.g., T^M for *wide*). The superiority for the name condition over the sound condition shows that the novice readers also benefited from letter names. This result suggests that children do not immediately abandon the letter-name strategy when an alphabetic strategy begins to emerge.

Treiman et al. (2001) extended these findings to lower-functioning prereaders by selecting prereaders (mean age 4 years, 3 months) who could name fewer than six letters of the alphabet. Although the prereaders in this study were younger and less knowledgeable about letters than the prereaders tested by Treiman and Rodriguez (1999), they too performed significantly better in the name condition than in either the sound condition or the visual condition. The lower-functioning prereaders could not produce the names of many letters, but they performed above chance when asked to select the name of a letter from two choices that were provided. The children's ability to recognize letter names may have allowed them to detect and benefit from relationships like that in the pair TM-*team*.

Treiman et al. (2001) extended their findings to spelling by developing a task in which children were presented with spoken words and taught to spell them using either spellings that included initial letter-name cues (e.g., TM for *team*), spellings that included only letter-sound cues (e.g., TM for *tame*), or visually distinctive but nonphonetic spellings (e.g., TM for *wide*, where the two letters were of different colors, sizes, and materials). As in reading, both prereaders and novice readers performed better in the name condition than the sound condition. Even prereaders showed some ability to use letter-sound cues in spelling, performing reliably better in the sound condition than the visual condition.

To determine whether initial letter names continue to have a special status for fluent readers, Treiman et al. (2001) taught nonwords to college students in the name, sound, and visual conditions. During the early trials of the experiment, the adults performed significantly better in the name condition than the sound condition and significantly better in the sound condition than the visual condition. This is the same pattern of performance that

Treiman and Rodriguez (1999) observed for novice readers. These results suggest that fluent readers continue to use a letter-name strategy, consistent with the idea that the phonological processes that operate during the early phases of reading development continue to play a role for adults (e.g., Ehri, 1992).

Collectively, the results of Treiman and Rodriguez (1999) and Treiman et al. (2001) suggest that the use of letter-name cues at the beginning of words emerges even before children learn to read and continues among more advanced readers. The findings with US children, together with findings from children in other cultures (de Abreu & Cardoso-Martins, 1998; Levin, Patel, Margalit, & Barad, 2002; McBride-Chang & Treiman, in press), suggest that letter names can help children bridge the gap between print and speech. The results shed new doubts on the traditional view of young children as limited to rote memorization in learning to read words (see also Laing & Hulme, 1999; Rack, Hulme, Snowling, & Wightman, 1994; Stuart, 1990; Stuart & Coltheart, 1988; Wimmer & Hummer, 1990). In the present study, we examined the position of the letter-name cue within the word in an attempt to delineate when and how young children use their letter-name knowledge to go beyond a logographic approach. Is the use of letter names to connect print and speech a robust, across-the-board phenomenon, one that is found regardless of the position of the letter-name cue, or is it more fragile, perhaps restricted to initial letters?

Two hypotheses about the effects of word position may be distinguished. According to the *boundary hypothesis*, letter-name links are more likely to be made for the first and last letters of a word than for the medial letters, which are often ignored. This hypothesis stems from the work of Ehri (1987), who claimed that children focus on the boundary letters before they evaluate the entire word. Ehri did not distinguish between the processing of initial and final letters and suggested that letters at both extremes of the word are especially salient. A second hypothesis, the *initial-letter hypothesis*, may be considered a further refinement of the boundary hypothesis. It suggests that systematic mappings between print and speech occur first for initial letters. Consistent with this hypothesis, Byrne (1992) found that even preliterate children have had enough exposure to the left-to-right organization of English writing to selectively focus on the left-most letters of words. Rack et al. (1994) and Treiman, Tincoff, and Richmond-Welty (1996) also found a priority for initial letters.

To begin to ask whether the advantage for letter names that is found in the initial positions of words generalizes to other positions, we manipulated cues in the final positions of the stimuli. In the name condition, the second letter of each novel 2-letter word had a name that could be heard at the end of the word's pronunciation. For example, BR corresponded to *bar*. In the sound condition, the conventional sound of the second letter was heard at the end of the word's pronunciation but the letter's entire name was not

present. An example is the pair BR-*bear*. In the visual condition, there was no phonological relationship between the spellings and the sounds. For example, $_{B}$R was pronounced as *coin*. In Experiment 1, we used such stimuli in a reading version of the word-learning task with prereaders and novice readers. Experiment 2 examined the spelling performance of prereaders and novice readers with basically the same stimuli. In Experiment 3, we used a within-subject design to take a closer look at the reading performance of prereaders in four conditions that manipulated type of cue (letter name vs. no letter name control) and location of cue (initial vs. final). Finally, Experiment 4 evaluated adults' ability to use letter-name cues at the ends of words. Together, the results of the experiments should shed light on the robustness and generality of letter-name effects.

Experiment 1

Method

Participants

Thirty-six children from preschools and daycare centers ranging in age from 53 to 64 months (M ¼ 58.4, SD ¼ 2.9) and 36 kindergartners ranging in age from 62 to 75 months (M ¼ 69.4, SD ¼ 3.3) participated. Two other preschoolers began the experiment but chose not to complete it. Two additional kindergartners were dropped because they were accidentally omitted from one of the conditions. The educational institutions were located in middle-class, suburban areas. All of the participants in this and subsequent experiments were native speakers of English.

Stimuli

There were three sets of stimuli (A, B, and C), each containing five items. Table 1 shows the printed stimuli and the pronunciations that were assigned to them in each condition. In the name condition, the name of the second letter of each 2-letter stimulus could be heard in its pronunciation. In the sound condition, the pronunciation contained the conventional sound of the second letter but not its entire name. In the visual condition, neither letter in the printed stimulus was related to the pronunciation. The letters used in the name and sound conditions were uniform in size and positioning. These stimuli were printed in Geneva font in uppercase letters 2.6 cm high. The letters used for the visual condition were altered in size and positioning to increase their distinctiveness. The letters' heights ranged from 2.0 to 3.1 cm, and the letters were offset from as much as 0.8 cm below the line of print to 1.5 cm above it. These parameters match those used by Treiman and Rodriguez (1999) and Treiman et al. (2001). No letters were repeated within a set of stimuli.

Table 1
Pairs used for reading and spelling versions of word-learning task in Experiments 1 and 2

Set	Printed stimulus	Name condition pronunciation	Sound condition pronunciation	Visual condition pronunciation
A	BR	bar	bear	coin
	PN	pen	pine	feet
	JF/JK[a]	Jeff	Jack	room
	MS	mess	mouse	hid
	TL	tell	tall	size
B	TN	ten	town	Ruth
	HM	hem	home	sad
	BS	Bess	bus	whale
	FL	fell	fail	gum
	KR/KD[b]	car	code	job
C	BL	bell	Bill	move
	KN	Ken	cane/cone[c]	Dale
	GS	guess	gas	rich
	JM	gem	jam	heat
	FR	far	fear	pan

[a] JF was used in the name and visual conditions and JK was used in the sound condition.
[b] KR was used in the name and visual conditions and KD was used in the sound condition.
[c] KN, pronounced as *cane* in the reading task, was changed to *cone* for the spelling task.

The words that were assigned to the printed stimuli were similar across conditions according to two child frequency counts (combined frequency across grade levels from Carroll, Davies, & Richman, 1971; *U* values, or frequency per million words adjusted for variations in distribution of words across content areas at kindergarten and first-grade levels, from Zeno, Ivenz, Millard, & Duvvuri, 1995). In order to equate the stimuli for frequency, we found it necessary to substitute different final consonants for two of the printed stimuli in the sound condition. For example, JF, which was pronounced as *Jeff* in the name condition and *room* in the visual condition, was changed to JK and pronounced as *Jack* in the sound condition. The words in the three conditions were similar in imageability, which appears to affect children's performance in this type of word-learning task (Laing & Hulme, 1999). To assess this, 23 preschool teachers rated each word in terms of how imageable they felt it would be for a 4- or 5-year-old child. Ratings were made on a 7-point scale, with 1 representing low imageability and 7 representing high imageability. The average ratings were 4.61 for the name condition, 4.60 for the sound condition, and 4.74 for the visual condition, $F\eth 2, 44\text{Þ} \frac{1}{4} 2.08$, $p \frac{1}{4} .14$.

To assess the children's reading ability, we used the 22 simple words from Treiman and Rodriguez (1999) and Treiman et al. (2001). Eleven cards were prepared, each containing two words and one easily identifiable color

picture. For the tests of letter-name and letter-sound knowledge, 26 cards were used. An upper-case letter was printed on each card.

Procedure

Each child participated in all three conditions of the word-learning task. A different condition was presented in each of the first three experimental sessions, with a different set of stimuli (A, B, or C) used for each condition. The order of the conditions and the sets were counterbalanced across children. The reading task was given at the end of the third session and the tests of letter-name and letter-sound knowledge in a fourth session. The sessions lasted about 20 min each and were an average of 2–3 days apart.

Each of the first three sessions began with the experimenter telling the child that he or she would learn to read some "made-up words." It was stressed that the "silly words" were not real English spellings. Each condition of the word-learning task consisted of a demonstration phase followed by up to eight test trials. During the demonstration phase, the five word cards were presented to the child, one at a time, in a predetermined random order. As the first word card was shown, the experimenter said the word, pointed to the printed stimulus, and ran a finger under the letters. The word was then used in a sentence and stated once more. Participants were asked to repeat the word, and any necessary corrections were made. The experimenter pointed to the printed stimulus one final time and said the word again before repeating the procedure for the next stimulus.

For each test trial, the five printed stimuli were presented in a random order and the child was asked to "read" each word. If the child did not respond within five seconds or if the response was wrong, the experimenter provided the correct answer. Correct answers given by the child were praised before moving to the next word. In this and the subsequent experiments, if a participant responded correctly to all stimuli for two consecutive trials, the participant received credit for correct responses for all remaining trials and no further test trials were given in that condition. Otherwise, eight test trials were given.

For the reading task, the child was shown the 11 cards, one at a time, in a random order. The child was asked to identify any words and pictures that were familiar. If the child did not identify all three items on a card, the experimenter pointed to each one and asked the child to identify it. Liberal praise was given for any correct answers, including the naming of the picture.

To assess the child's knowledge of letter names, the 26 letter cards were presented one at a time in a random order. The child was asked to name the letter on each card. If the child did not respond correctly in this free-choice situation, two alternatives were given. For *h*, for example, the experimenter asked, "Is this *h* or *i*?" The procedure for the letter-sound task was similar except that children were asked for the sounds of the letters. The

order of the letter-name and letter-sound tasks was balanced across children. The letter-name and letter-sound tasks were scored in two ways. By the strict system, children were counted as correct only if they responded correctly in the free-choice situation. By the lenient system, children were scored as correct if they responded correctly in either the free-choice or the two-choice task.

Results

For purposes of analysis, the children were divided into groups based on reading ability. The 21 prereaders were unable to read any of the 22 simple words. The 51 novice readers were able to read at least one of the words. This division was motivated by prior findings that prereaders and readers perform differently in the word-learning task (Ehri & Wilce, 1985; Treiman & Rodriguez, 1999; Treiman et al., 2001). Table 2 provides information about the children in the two groups. Fig. 1 shows the mean number of correct responses on the word-learning task as a function of condition, trial, and reading group. The data for this and the following experiments were analyzed using a multivariate approach (O'Brien & Kaiser, 1985), as preliminary tests showed a lack of sphericity in some cases, especially those involving the trial variable. An analysis of variance (ANOVA) using the factors of condition, trial, and reading group indicated main effects of condition, $F\eth 2, 69\text{Þ} ¼ 10.15$, $p < .001$, trial, $F\eth 7, 64\text{Þ} ¼ 38.88$, $p < .001$, and reading group, $F\eth 1, 70\text{Þ} ¼ 19.31$, $p < .001$. Critically, there was an interaction between condition and reading group, $F\eth 2, 69\text{Þ} ¼ 3.90$, $p ¼ .03$.

Given the interaction between condition and reading group, separate analyses were carried out for each reading group. For the prereaders, the only significant effect was the main effect of trial, $F\eth 7, 14\text{Þ} ¼ 11.50$, $p < .001$. All three sets of stimuli yielded similar performance across the three conditions. For novice readers, there were main effects of both condition, $F\eth 2, 49\text{Þ} ¼ 19.72$, $p < .001$, and trial, $F\eth 7, 44\text{Þ} ¼ 47.58$, $p < .001$. Within-subject contrasts indicated that the novice readers performed significantly better in the name ($M ¼ 25.78$, $S\eth ¼ 10.22$) and sound ($M ¼ 27.06$, $S\eth ¼ 10.67$) conditions than in the visual condition ($M ¼ 19.71$, $S\eth ¼ 9.41$). Performance in the name condition was statistically equivalent to performance in the sound condition. All three sets of stimuli showed the pattern of similar performance in the name and sound conditions and poorer performance in the visual condition.

We also examined the proportion of children who reached the criterion of perfect performance on two successive trials. Because a test such as chi-square was not appropriate for the present design, an ANOVA was run with the expectation that power would be decreased. There was a main effect of condition, $F\eth 2, 69\text{Þ} ¼ 4.08$, $p ¼ .02$, a main effect of reading group, $F\eth 1, 70\text{Þ} ¼ 16.57$, $p < .001$, and an interaction, $F\eth 2, 69\text{Þ} ¼ 3.21$, $p ¼ .05$.

Table 2
Information about children in Experiments 1–3 (standard deviations in parentheses)

Measure	Experiment 1		Experiment 2		Experiment 3
	Prereaders	Novice readers	Prereaders	Novice readers	Prereaders
Number of children attending preschools or daycare centers	19 (12F, 7M)	17 (14F, 3M)	35 (18F, 17M)	16 (9F, 7M)	32 (12F, 20M)
Number of children attending kindergarten	2 (0F, 2M)	34 (22F, 12M)	1 (0F, 1M)	20 (9F, 11M)	0 (0F, 0M)
Mean age in months	59.4 (5.3)	65.8 (5.9)	57.9 (5.7)	65.6 (6.3)	54.9 (4.3)
Mean number of words read (of 22)	0.0 (0.0)	5.4 (5.5)	0.0 (0.0)	3.3 (4.7)	0.0 (0.0)
Mean number correct on letter-name test, strict criterion (of 26)	17.9 (8.1)	24.3 (3.3)	16.3 (9.3)	24.3 (3.0)	18.1 (9.0)
Mean number correct on letter-name test, lenient criterion (of 26)	23.4 (3.9)	25.8 (0.7)	22.6 (4.7)	25.8 (0.6)	23.8 (3.8)
Mean number correct on letter-sound test, strict criterion (of 26)	7.1 (5.5)	17.5 (7.1)	6.2 (6.0)	16.5 (7.3)	10.6 (8.7)
Mean number correct on letter-sound test, lenient criterion (of 26)	18.6 (4.7)	23.8 (3.3)	17.2 (4.7)	23.9 (2.9)	20.4 (4.6)

Note. F denotes female; M denotes male.

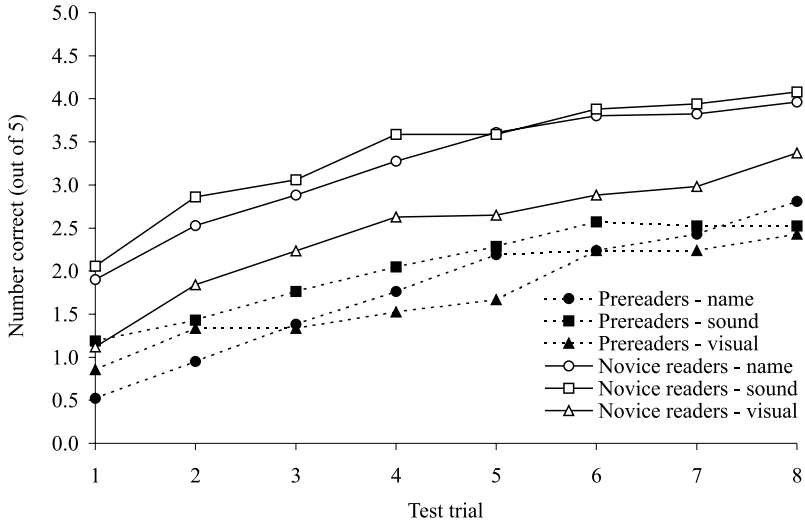

Fig. 1. Mean number of correct responses (of 5 possible) as a function of trial and reading group for children in reading task of Experiment 1.

Of the prereaders, 5% reached criterion in the name condition, 14% in the sound condition, and 10% in the visual condition. The effect of condition was not reliable for this group. The main effect of condition was significant for the novice readers, $F(2, 49) = 10.95$, $p < .001$. The percentage of novice readers who reached criterion was statistically indistinguishable in the name condition (49%) and the sound condition (61%), but significantly lower in the visual condition (27%).

Table 3 shows the types of errors that the children made. A no-response error occurred when a child failed to produce an answer. In a list error, a child responded with another word from the same set. These errors appear to reflect use of rote memorization; the child learned the response words but had difficulty remembering which printed stimuli they were paired with. A response that contained one correct phoneme in the correct position (and that was not an item from the list learned in the previous session) was recorded as a phonological error. Such errors appear to reflect a systematic approach to linking spellings and pronunciations. Any response that could not be assigned to one of the preceding error types was placed in the *other* category. Each type of error was subjected to an ANOVA using the within factor of condition and the between factor of reading group. Reading group was not a significant factor in any of the analyses. No-response errors occurred at a similar and moderately high rate in the three conditions. There was a main effect of condition for list, $F(2, 69) = 4.59$, $p = .01$, phonological, $F(2, 69) = 3.10$, $p = .05$, and *other* errors, $F(2, 69) = 4.29$, $p = .02$. List errors, reflecting rote memorization, were significantly less common in the

Table 3
Mean proportions of errors of various types for children in reading task of Experiment 1

Error type	Reading ability	Condition			
		Name	Sound	Visual	Total
No response	Prereader	.44	.39	.38	.40
	Novice reader	.55	.49	.44	.49
	Total	.52	.46	.42	.47
List	Prereader	.43	.53	.47	.48
	Novice reader	.32	.37	.47	.39
	Total	.35	.42	.47	.42
Phonological	Prereader	.02	.02	.01	.02
	Novice reader	.06	.08	.02	.05
	Total	.05	.06	.02	.04
Other	Prereader	.11	.05	.12	.09
	Novice reader	.07	.04	.07	.06
	Total	.06	.04	.09	.07

name condition than in the sound or visual conditions. The latter two conditions were statistically indistinguishable. Phonological errors, although uncommon, occurred more often in the name and sound conditions than in the visual condition. *Other* errors appeared to be most common in the visual condition.

Additional analyses were carried out to examine individual differences in performance on the word-learning task. The visual condition required children to link a specific visual stimulus to a particular pronunciation. Children could accomplish this through rote memorization. Although some children might continue to rely on rote memorization in the name and sound conditions, others were expected go beyond simple memorization to detect the principled relationships between the printed and spoken stimuli. We thus expected to find a closer relationship between performance in the name and sound conditions than between performance in either of these conditions and the visual condition. The top portion of Table 4 shows the relevant correlations, with results based on total scores above the diagonal and results based on criterion attainment below the diagonal. In both cases, the correlation between the name and the sound conditions was larger than the other two correlations. However, the differences between the correlation coefficients were not significant.

If the name and sound conditions of the word-learning task tap the ability to detect and use principled relationships between print and speech, then performance in these conditions should be associated with children's knowledge of letter names and sounds and their word-reading ability. Therefore, letter-name knowledge, letter-sound knowledge, and reading skill should correlate more highly with number correct in the name and sound conditions

Table 4
Correlation between children's performance in different conditions of word-learning tasks

Condition	Name	Sound	Visual	
Reading task of Experiment 1 ðN ¼ 72Þ				
Name	—	.72***	.69***	
Sound	.56***	—	.62***	
Visual	.50***	.36**	—	
Spelling task of Experiment 2 ðN ¼ 72Þ				
Name	—	.87***	.38***	
Sound	.81***	—	.30**	
Visual	.21*	.23*	—	
Condition	Name initial	Name final	Control initial	Control final
Reading task of Experiment 3 ðN ¼ 32Þ				
Name initial		−.70**	.59**	.53**
Name final	NA[a]	—	.64**	.39*
Control initial	NA	NA	—	.66**
Control final	NA	NA	NA	—

Note. Results based on total scores are shown above the diagonal and results based on criterion performance are shown below the diagonal.

[a] NA indicates that criterion score was not relevant in Experiment 3 because each session involved learning words from two different conditions.

* $p < .05$, one tailed.
** $p < .01$, one tailed.
*** $p < .001$, one tailed.

than with number correct in the visual condition. As Table 5 shows, trends in this direction were found for all three variables. The pattern was significant for letter names and letter sounds ($p < .001$), but not for reading skill.

Discussion

The children in this study were similar to the children tested by Treiman and Rodriguez (1999) in age, knowledge of the alphabet, and reading ability. Although the procedure for the word-learning task was identical to that of Treiman and Rodriguez, the position of the letter-name cue was different. Correspondingly, the pattern of performance across the three conditions was different for the children in this study than for the children tested previously. The present children did not perform better with final letter-name cues such as BR for *bar* than with final letter-sound cues such as BR for *bear*. That is, the children did not benefit from letter names, above and beyond letter sounds, in the final positions of 2-letter words. The children tested by Treiman and Rodriguez, who encountered letter-name cues at the beginnings of 2-letter words, did perform significantly better in the name condition than the sound condition. Thus, it appears that young children's ability to benefit from letter names in connecting print and speech is fragile

Table 5
Correlation between number of correct responses in different conditions of the word-learning tasks and alphabetic and reading knowledge

Condition	Name	Sound	Visual	
Reading task of Experiment 1 ðN ¼ 72Þ				
Letter names	$.52_{a}$***	$.51_{a}$***	$.33_{b}$**	
Letter sounds	$.73_{a}$***	$.65_{a}$***	$.47_{b}$***	
Number of words read	$.67_{a}$***	$.58_{a}$***	$.56_{a}$***	
Spelling task of Experiment 2 ðN ¼ 72Þ				
Letter names	$.48_{a}$***	$.43_{a}$***	$.33_{a}$***	
Letter sounds	$.72_{a}$***	$.68_{a}$***	$.30_{b}$**	
Number of words read	$.53_{a}$***	$.52_{a}$***	$.34_{a}$***	
Condition	Name initial	Name final	Control initial	Control final
Reading task of Experiment 3 ðN ¼ 32Þ				
Letter names	$.31_{}$*	.11	.13	.01
Letter sounds	.12	.12	.01	−.07

Note. Correlation coefficients in the same row that have different subscripts differ at $p < .05$, one tailed.
* $p < .05$, one tailed.
** $p < .01$, one tailed.
*** $p < .001$, one tailed.

and does not extend to the ends of words. The results support the initial-letter hypothesis, which gives a special status to initial position information. We further investigate this issue in Experiment 3 by testing the same children on initial and final letter names and by using the same letters in the two positions.

Although neither the prereaders nor the novice readers of the present study benefited from letter-name cues at the ends of words, the two groups showed different patterns of performance in other respects. The prereaders performed at similar levels in all three conditions. Unlike the prereaders studied by Ehri and Wilce (1985), who did relatively well with visually distinctive stimuli, the present prereaders did not perform best in the visual condition. This difference may arise because our 2-letter stimuli did not have the same degree of visual distinctiveness as the longer stimuli that Ehri and Wilce used.

The novice readers of the present study performed significantly better in the name and sound conditions than in the visual condition. We interpret the novice readers' equivalent name and sound performance to mean that they used the letter-sound cues located in the initial positions of the nonwords to link the printed stimuli and the spoken responses. Both the name condition and the sound condition offered initial letter-sound cues, whereas

the visual condition did not. This interpretation is consistent with the results of Treiman and Rodriguez (1999), who found that novice readers, but not prereaders, use letter-sound cues at the beginnings of words. An examination of the novice readers' phonological errors bolsters the conclusion that they benefited from initial letter-sound information. Of the phonological errors, 46% contained the correct initial phoneme (i.e., the sound indicated by the first letter of the printed stimulus) together with an incorrect final phoneme. Only 19% of the phonological errors paired an incorrect initial phoneme with a correct final one. (The remaining 35% of the phonological errors had both consonant phonemes correct but included some other error, such as an error on the vowel.) Thus, it appears that the novice readers' analysis of the printed stimuli was primarily based on the information available in the initial position, consistent with the initial-letter hypothesis.

Experiment 2

The task of Experiment 1 was designed to simulate the processes that are involved in learning to read new words. In Experiment 2, we examined children's learning of spellings. Our primary question was whether an advantage for a name condition over a sound condition would appear in word-final position in a spelling task. Research has shown that young children sometimes use their knowledge of letter names when inventing spellings for words (e.g., Gentry, 1982; Levin et al., 2002; Treiman, 1993). For example, children may spell *arm* as RM or *bell* as BL, using a single letter to represent a group of sounds in the spoken word. In Experiment 2, we asked whether children use final letter names when remembering spellings for words.

An additional motivation for Experiment 2 was the view that reading and spelling do not develop at the same pace. Frith (1985) suggested that the development of these two skills is sometimes out of step, with the transition from the logographic phase to the alphabetic phase occurring in spelling before it occurs in reading. Goswami and Bryant (1990) expressed a similar view. If children use alphabetic skills for spelling before they do for reading, the discrepancy between performance in the name and sound conditions and performance in the visual condition should be larger for spelling than for reading. Preliminary evidence for this view, at least for word-initial cues, comes from the spelling results of Treiman et al. (2001). Not only did the prereaders learn the name condition spellings better than the sound condition spellings, they also performed better in the sound condition than the visual condition. Also, the novice readers did substantially more poorly in the visual condition of the spelling task than in the conditions that offered alphabetic cues. The spelling task of Experiment 2 used virtually the same

pairs of printed and spoken stimuli as the reading task of Experiment 1, allowing us to compare spelling and reading with word-final cues.

Method

Participants

Thirty-six prereaders and 36 novice readers, defined as in Experiment 1, were recruited from preschools, daycare centers, and kindergartens in the Detroit area. Information about the children is given in Table 2.

Stimuli

Children's reading ability and knowledge of letter names and sounds were assessed with the same materials used in Experiment 1. For the spelling learning task, *cone* was substituted for *cane* in Set C of the sound condition. This substitution eliminated the potentially biasing effect of a letter-name cue in the initial position. The substitution changed the average imageability rating of the sound condition from 4.60 to 4.62, still statistically indistinguishable from the average name rating of 4.61 and the average visual rating of 4.74, $F\delta 2, 44\text{Þ} ¼ 1.78$, $p ¼ .18$.

Experiment 2 used plastic and foam rubber letters in place of the printed stimuli of Experiment 1. The name and sound conditions used yellow, foam rubber, uppercase block letters, 5.1 cm high. For the visual condition, each item was spelled with two uppercase letters that differed in size, color, and material. The larger member of the pair was a 5.1 cm high, foam rubber letter in block style that was either yellow or blue. The smaller one was a 3 cm high, block style plastic letter in either green, blue, red, yellow, orange, or pink. Each word in a set contained a small letter of a different color. The large letter occurred in the first position in some items and in the last position in other items.

For each condition, the letters required to spell the words were displayed on a green and blue 38 cm wide by 32 cm high felt board. The board was placed horizontally in front of the child so that the green side was above the blue side. Letters were laid out randomly on the upper, green portion of the felt board. A specially constructed 16.8 cm wide by 13 cm high spelling board was centered on the bottom blue portion of the felt board. The spelling board was made of plastic canvas covered in green felt. A 3.5 cm wide frame of either red or blue felt surrounded the spelling board, leaving a 9.8 cm wide by 6 cm high opening of green felt in the center of the board. A yellow vertical line placed down the center of the opening divided the inner area into two side-by-side 4.9 cm wide by 6 cm high areas into which letters were placed to spell the words. A small yellow arrow, located in the upper left corner of the spelling board, was used to remind the child where to place the first letter. Puppets were used to demonstrate the spelling of the words.

Procedure

Each child completed the letter-name, letter-sound, and word-reading tasks during the first session. These tasks used the same procedures and scoring methods as in Experiment 1. Sessions 2, 3, and 4 were each devoted to a separate word learning condition, with a different set of stimuli used for each condition. The order of the conditions, sets, and puppets were counterbalanced across the children in each reading group. The sessions lasted between 20 and 30 min each and took place an average of 2–3 days apart.

Each word-learning session began with the experimenter introducing a puppet and telling the child that he or she was going to learn to spell some words as the puppet did. It was stressed that the puppet did not spell the words the same way that people do. The child was told that the puppet always used one of the special spelling boards. The child chose whether to use the red spelling board or the blue one. Next, the experimenter pointed out that the puppet always used two letters to spell each word. The puppet demonstrated the placement of the letters by selecting the first letter and putting it in the left opening on the spelling board. The child's attention was then drawn to the yellow arrow and it was explained that the arrow was a reminder of where to place the first letter. Finally, the puppet directed the child's attention to the remaining opening as the space where the second letter was to be placed.

During the demonstration trial, the puppet presented the words one at a time in a random order. For each word, the puppet picked up the first letter and put it into the left opening on the spelling board, pointing out that it was in the correct place because the yellow arrow pointed toward it. Next, the puppet picked up the second letter and placed it in the second space. The puppet then pointed to the letters, told the child the word that the letters spelled, used the word in a sentence, and repeated the word again. The puppet asked the child to say the word and corrected the child if necessary. The child's attention was directed to the word one final time while the puppet pronounced it. The letters were then removed from the spelling board.

For each test trial, the five words were presented in random order. The experimenter said the word and then asked the child to spell it the same way the puppet did. If necessary, the child was guided as to where to place the chosen letters. If the child was reluctant to choose the proper number of letters, he or she was encouraged to "just try" to spell the word like the puppet did. Once the child had selected and placed two letters, he or she was praised for a correct response or shown the correct spelling. Even when wrong, the child was told that he or she did a good job choosing letters, but that the child's attempt "wasn't quite the way" that the puppet spelled the word. The puppet removed the incorrect letters and replaced them with the correct ones. Once the correct spelling had been shown, the letters were removed and the next word read.

conditions, but significantly worse in the visual condition (M ¼ 8.5, S ¼ 6.23). This pattern held for all three sets of stimuli.

An additional ANOVA was carried out to examine the proportion of children who reached the criterion of two consecutive correct trials. There was a main effect of condition, F¼

$F(2, 58) = 4.94$, $p = .01$, and second letter correct errors, $F(2, 58) = 6.42$, $p = .003$. List errors occurred reliably more often in the visual condition, $F(1, 59) = 6.94$, $p = .01$, than in either the name or sound conditions, which were statistically equivalent. Second letter correct errors occurred significantly more often in the name condition than in the sound or visual conditions, $F(1, 59) = 12.99$, $p = .001$, which were statistically indistinguishable. For first letter correct errors, there was a main effect of condition, $F(2, 58) = 18.47$, $p < .001$, a main effect of reading group, $F(1, 59) = 18.13$, $p < .001$, and an interaction, $F(2, 58) = 10.71$, $p < .001$. The prereaders made equivalently low proportions of these errors across conditions. Novice readers, however, showed an effect of condition, $F(2, 23) = 13.12$, $p < .001$. For this group, first letter correct errors occurred reliably more often in the sound condition than in the name condition, $F(1, 24) = 6.07$, $p = .02$, and reliably more often in the name condition than in the visual condition, $F(1, 24) = 7.11$, $p = .01$.

We further analyzed the two types of phonological errors by comparing the proportion of first letter correct errors to the proportion of second letter correct errors in each condition for each reading group. For the prereaders, there were no significant differences between these two error categories in any condition. The same was true for novice readers in the visual condition. For the novice readers, however, first letter correct errors significantly outnumbered second letter correct errors in the sound condition, $t(35) = 4.33$, $p < .001$, and the name condition, $t(27) = 2.87$, $p = .009$. The priority for first letter correct errors was stronger in the sound condition than the name condition, as shown by a significant interaction between condition and error type in an ANOVA using the factors of condition (name vs. sound) and error type (first letter correct vs. second letter correct), $F(1, 24) = 11.82$, $p = .002$.

An analysis of *other* errors showed main effects of condition, $F(2, 58) = 8.39$, $p = .001$, and reading group, $F(1, 59) = 16.77$, $p = .001$, as well as an interaction, $F(2, 58) = 3.52$, $p = .04$. Prereaders produced an equivalently high proportion of *other* errors across conditions. Novice readers showed a main effect of condition, $F(2, 23) = 6.79$, $p = .005$, producing significantly more *other* errors in the visual condition than in the name or sound conditions, $F(1, 24) = 8.31$, $p = .008$. The name and sound conditions were statistically equivalent.

Additional analyses were done to examine individual differences in children's performance on the spelling task. As with the reading task, we expected to find a closer relationship between performance in the name and sound conditions than between performance in either of these conditions and the visual condition. The center section of Table 4 shows the relevant correlations, with results based on total scores above the diagonal and results based on criterion performance below the diagonal. In both sets of analyses, the correlation between the name and sound conditions was

significantly higher than either the correlation between the name and visual conditions ($p < .001$) or the correlation between the sound and visual conditions ($p < .001$). As Table 5 shows, letter-sound knowledge was more

Trial also interacted with task, $F(7, 134) = 7.37$, $p < .001$, and reading group, $F(7, 134) = 2.75$, $p < .001$. Critically, there was a three-way interaction involving condition, task, and reading group, $F(2, 139) = 6.74$, $p = .002$. Fig. 3 shows the mean number of correct responses by prereaders and novice readers in the three conditions for each task. For prereaders, the only significant effect in an ANOVA using the factors of condition and task was that of task, $F(1, 55) = 25.69$, $p < .001$. The prereaders in the reading task performed better than those in the spelling task. The novice readers showed a main effect of condition, $F(2, 84) = 63.90$, $p < .001$, a main effect of task, $F(1, 85) = 5.58$, $p = .02$, and an interaction between condition and task, $F(2, 84) = 13.14$, $p < .001$. Regardless of task, these children performed similarly in the name and sound conditions and significantly worse in the visual condition, $F(1, 85) = 126.35$, $p < .001$. However, the novice readers who participated in the spelling task found the visual condition especially difficult compared to those who participated in the reading task, $F(1, 85) = 68.11$, $p < .001$.

Discussion

One question that motivated Experiment 2 was whether children focus on the initial elements of words when linking sound to print—spelling—as when linking print to sound—reading. The results suggest that the beginnings of words play a special role in the learning of both spellings and pronunciations. Consider the results for the novice readers. In the name and sound conditions of the spelling task, the novice readers' knowledge of letter sounds allowed them to make a phonetic connection between the first phoneme of the spoken word and the first letter of the spelling. Because both the name and the sound conditions offered this opportunity, the children performed better in these conditions than in the visual condition, which did not offer a word-initial phonetic connection. Further evidence that novice readers focus on the initial positions of words comes from the finding that, in both the name and the sound conditions, the children were more likely to correctly produce just the first letter of the taught spelling than just the second letter. Taken together with the novice readers' similar levels of performance in the name and sound conditions, this result suggests that these children relied primarily on letter-sound cues in the initial positions of stimuli. The novice readers paid most attention to the initial position when they were mapping sounds to spellings in a systematic manner. In the visual condition, where the pronunciations and the spellings did not mesh, the novice readers made no more first letter correct errors than second letter correct errors.

The prereaders, it appears, relied on rote memory to learn the spellings in all three conditions. Any attempts to map the pronunciations to the spellings based on initial letter-name cues were stymied by the fact that the pres-

ent stimuli did not allow for such mappings. Lacking the skills needed to use mappings based on letter-sound cues, these children performed as poorly in the name and the sound conditions as in the visual condition. Our analyses of the prereaders' errors bolster these conclusions. In no condition did these children produce the first letter of the correct spelling significantly more often than the second letter.

When we examined the children's correct responses in the spelling task, we found little or no evidence for use of final letter-name cues over and above final letter-sound cues. The novice readers showed a small superiority for the name condition over the sound condition in the number of correct responses, but it was not statistically significant. However, an examination of the children's errors suggests that they did not completely ignore the word-final letter names. Incorrect spellings that included the correct final letter were significantly more frequent in the name condition than in the sound or visual conditions. For example, if children chose the wrong initial letter for PN, they were more likely to select an *n* to finish the spelling of *pen* than they were to finish the spelling of *pine* or *feet*. This result suggests that the children used the final letter-name information to some degree. A further hint that final letter-name cues were attended to more than letter-sound cues involves the rate at which novice readers produced first letter correct errors. The novice readers made significantly more such errors in the sound condition than the name condition. If they chose the right initial letter, they were more likely to pair it with the right final letter in the name condition than in the sound condition. This led to a correct response in the name condition but an increased number of first letter correct errors in the sound condition. Thus, the children's errors suggest that they derived a small benefit from final letter-name information. However, the final letter-name information was used less than initial letter-name information in previous studies (Treiman & Rodriguez, 1999; Treiman et al., 2001).

Another question that motivated Experiment 2 was whether the alphabetic principle plays a larger role in spelling than in reading. Our comparisons of the spelling and reading results showed that novice readers had more difficulty with the visual condition relative to the other conditions in spelling than in reading. This result highlights the importance of phonetic information in memory for spellings. Lacking principled relationships between print and sound, the novice readers did extremely poorly in the visual condition of the spelling task. This was true even though the letters in the visual condition of the spelling task varied in the salient feature of color, whereas the letters in the visual condition of the reading task did not. Treiman et al. (2001) found similar differences between spelling and reading for the novice group in the case of initial letter-name cues. These findings suggest that beginners rely on the alphabetic principle to a greater degree when learning spellings than when learning pronunciations, in the sense that a lack of alphabetic relationships hurts their spelling more than it hurts their reading.

In the spelling task of Treiman et al. (2001), there was some evidence that even prereaders could use letter-sound based relationships. The prereaders in that study performed significantly better in the sound condition than the visual condition, although they did not show such a difference in the reading task. In the present study, prereaders did not show a difference between the sound condition and the visual condition for spelling or for reading. Possible reasons for this discrepancy will be addressed in the General discussion.

Experiment 3

In Experiments 1 and 2, prereaders did not appear to take advantage of letter names in the second positions of novel 2-letter words. These results differ from those of Treiman and Rodriguez (1999) and Treiman et al. (2001), who found that young children used letter-name cues in initial position. Comparing across studies, it appears that word-initial cues have a special status for young children. However, the different results could have arisen because different sets of letters were used in the word-initial and word-final studies or because different groups of children participated.

The target letters of the initial studies, such as *b*, *d*, and *t*, have consonant-vowel (CV) names. The names of the letters in the final position studies, such as *f*, *l*, and *n*, have vowel-consonant (VC) pronunciations. Previous results indicate that the names of the two sets of letters are equally well known by children of these ages. When we compared the specific letters used in the initial and final position studies, we found no significant differences in letter-name knowledge in data from kindergartners tested by Treiman et al. (1998), 5- and 6-year-olds tested by Worden and Boettcher (1990), or preschoolers tested by Byrne (1992). In three of these four data sets, however, children performed significantly better with the former letters than the latter letters in tests of letter-sound knowledge. Because such differences could complicate cross-experiment comparisons, we used the same letters in initial and final positions in Experiment 3.

Each child in Experiment 3 learned four types of novel items in a reading task. In the name-initial condition, a letter name was heard at the beginning of the pronunciation (e.g., LF for *elf*, RT for *art*). The same target letters appeared in the name-final condition, with a letter name heard at the end of the pronunciation (e.g., FL for *fell*, TR for *tar*). In the control condition, the letter pairs were scrambled so that there was no phonological connection between the phonemes and graphemes. The target letters occurred in the initial position in the control-initial condition (e.g., RS for *elf*, LD for *art*) and the final position in the control-final condition (e.g., MR for *fell*, KL for *tar*). The visual distinctiveness factor was eliminated in this experiment, with the stimuli of the control condition using the same letters and print style as

the stimuli of the name condition. This provided a better baseline against which to gauge the effects of systematic spelling-sound relationships.

The word-learning task of Experiment 3 followed the same procedure as that of Experiment 1. However, a pretrial given before the demonstration trial assessed any prior knowledge that children may have had about the taught pronunciations. Also, any child who did not score at least 75% correct on a recognition test of the target letters' names was dropped from the study on the grounds that such a child did not have the knowledge that would be required to use a letter-name strategy. Only prereaders were included in Experiment 3.

Method

Participants

Thirty-two children from middle-class, suburban preschools contributed data. Table 2 provides information about these children. Five additional children were dropped after the screening session—four who read at least one word and one who scored less than 75% correct on the letter-name recognition test. Two eligible children declined to continue after two word-learning sessions, and another was dropped due to failure to respond in any of the conditions. The remaining children averaged 11.6 correct of 12 possible on the letter-name recognition test.

Stimuli

Table 7 shows the printed stimuli and their pronunciations, as well as how the stimuli were assigned to sessions. As in the earlier experiments, the words were matched across conditions for frequency according to two different child frequency counts (Carroll et al., 1971; Zeno et al., 1995). Each item was printed in Arial font using 2.6 cm. high, uppercase letters. To ensure that the children never saw the same spellings for two different pronunciations, nor heard the same pronunciations for two different spellings, there were two sets of stimuli for each condition. The sets for each condition consisted of five 2-letter items and included the target letters *r*, *l*, and *n* in the relevant position. VC letters were used because their names, unlike those of CV letters, can occur in both the initial and final positions of monosyllabic English words. Within each learning session, children learned either name condition words or control condition words. To avoid duplication of target letters within the same position, each session contained either two initial and three final words or the reverse. A different puppet was used to present the word cards in each session. Each child learned all of the words in the study, half in the name conditions and the other half in the control conditions.

Reading ability, letter-name knowledge, and letter-sound knowledge were assessed as in the previous experiments. The target letter-name

Table 7
Initial and final stimuli used in each session of the word-learning tasks of Experiment 3

Session	Condition	Set 1		Set 2	
		Prounciation	Spelling	Pronunciation	Spelling
A	Name initial (3)	elk	LK	elf	LF
		arm	RM	art	RT
		end	ND	end	ND
	Name final (2)	fell	FL	sell	SL
		tar	TR	bar	BR
B	Name initial (2)	else	LS	elm	LM
		ark	RK	arf	RF
	Name final (3)	den	DN	den	DN
		bell	BL	tell	TL
		far	FR	car	KR
C	Control initial (3)	elf	RS	elk	RS
		art	LD	arm	LD
		wife	NB	wife	NB
	Control final (2)	sell	MR	fell	MR
		bar	KL	tar	KL
D	Control initial (2)	elm	RD	else	RD
		arf	LT	ark	LT
	Control final (3)	mess	KN	mess	KN
		tell	SR	bell	SR
		car	ML	far	ML

Note. The target letters are underlined for illustrative purposes only. The actual word cards did not include the underline.

recognition task used twelve 10.2 cm. high by 15.2 cm. wide cards, each containing two 2.5 cm. high letters in Arial font. A vertical line separated the letters. Each card paired a target letter with one of the filler letters used in the non-target position of the words. Each target letter occurred four times in the set of cards, equally often on the left and right.

Procedure

Each child participated in five sessions spaced an average of two to three days apart and lasting about 15–20 min each. Children completed the screening and assessment tasks during the first session, followed by four sessions of the word-learning task. The orders of the conditions, sets of words, and puppets were counterbalanced across children. The first session began with an assessment of word reading ability, followed by the letter-name and letter-sound tasks, their order balanced across children. The final task of the first session assessed children's recognition knowledge of the names of the target letters. For this task, children were shown the 12 cards and were asked to point to the target letter. Each word-learning session began with a pretrial followed by a demonstration trial and up to eight learning trials.

The procedure was like that of Experiment 1 except for the addition of the pretrial, in which the puppet asked the child to guess the words on the cards.

Results

Fig. 4 shows the mean number of correct responses on the word-learning task as a function of condition (name vs. control), position (initial vs. final), and trial. There were main effects of condition, $F(1, 31) = 16.20$, $p < .001$, and trial, $F(7, 25) = 53.42$, $p < .001$, with children performing better in the name conditions ($M = 15.67$, $SD = 8.87$) than the control conditions ($M = 10.51$, $SD = 6.93$) and improving over trials. There were interactions between condition and position, $F(1, 31) = 4.55$, $p < .04$, and position and trial, $F(7, 25) = 2.69$, $p = .03$, but no three-way interaction, $F(7, 25) = .99$, $p = .49$. Given the interaction between condition and position, separate ANOVAs were carried out for each condition. For initial-position stimuli, there were main effects of condition, $F(1, 31) = 34.40$, $p < .001$, and trial, $F(7, 25) = 14.25$, $p < .001$. Children performed significantly better in the name-initial condition ($M = 17.25$, $SD = 7.44$) than the control-initial condition ($M = 9.75$, $SD = 7.94$). For the final-position stimuli, there was only an effect of trial, $F(7, 25) = 7.21$, $p < .001$. Children did not perform significantly better for name than control stimuli ($p = .17$). Both sets of items showed the same pattern of results.

As Table 8 shows, no-response and list errors were the most common types of errors. Each type of error was analyzed using the factors of condi-

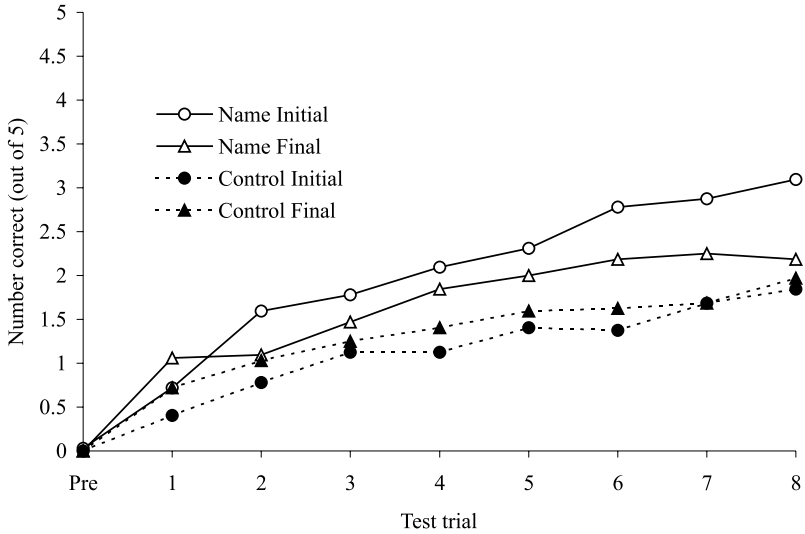

Fig. 4. Mean number of correct responses (of 5 possible) in the word initial and word final reading task for prereaders in Experiment 3.

Table 8
Mean proportions of errors of various types for prereaders of Experiment 3

Error type	Condition				Total
	Name initial	Name final	Control initial	Control final	
No response	.37	.34	.39	.39	.37
List	.41	.40	.45	.43	.42
Phonological	.03	.04	.00	.00	.02
Other	.19	.22	.17	.17	.18

tion and position. Position was not a significant factor in any analysis. Only phonological errors showed a main effect of condition, $F(1, 31) = 6.82$, $p = .01$. Although phonological errors were not very common, they occurred more often in the name conditions ($M = .03$, $SD = .07$) than the control conditions ($M = .00$, $SD = .00$).

There were significant correlations among the four conditions of the word-learning task, as Table 4 shows. None of the differences between the correlation coefficients was significant. Children's knowledge of letter names was significantly correlated only with performance in the name-initial condition (see Table 5). Successful performance in the name-final condition and the two control conditions was not significantly related to children's alphabetic skills. However, the differences among the correlation coefficients were not significant.

Discussion

In this experiment, we compared prereaders' ability to use letter-name information in the first and second positions of 2-letter words, using the same letters in the two positions. Corroborating the conclusions that were tentatively drawn from cross-experiment comparisons, we found that prereaders who were knowledgeable about letter names could use this information to link print and speech when the letter-name cues were at the beginnings of the items. They were not able to do this to a significant degree when the same letters appeared at the ends. These results support the initial-letter hypothesis, according to which the first elements of words have a special status. The results further suggest that young children's ability to go beyond a logographic approach in learning to read depends on the situation. The same child may use letter-name cues in some situations—when these cues are at the beginnings of words—but not in other situations.

Experiment 4

The goal of Experiment 4 was to determine whether fluent readers benefit from final letter names over and above final letter sounds. Although

Treiman et al. (2001) found that both beginning readers and fluent readers use initial letter names to connect print to speech, we have yet to find strong evidence of such a strategy for final letter names. Perhaps information located at the ends of words never achieves the level of salience as information located at the beginnings. If so, even adult readers may fail to attend to

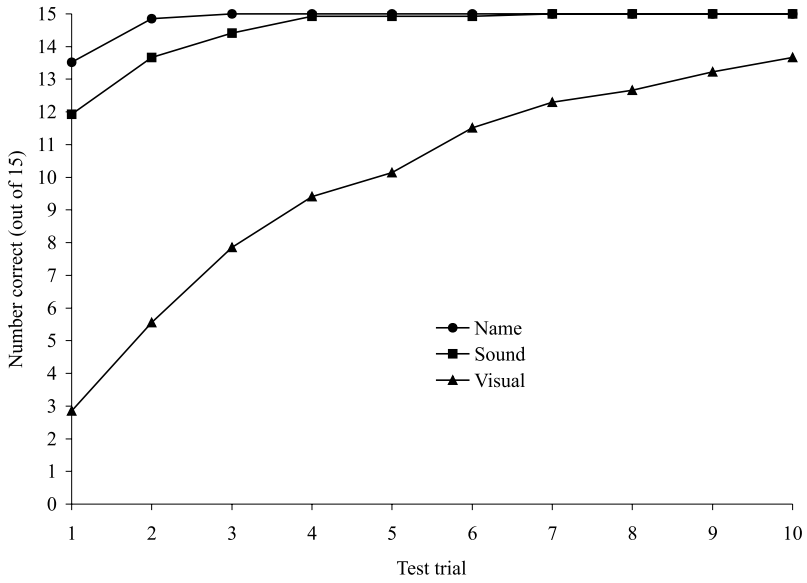

Fig. 5. Mean number of correct responses (of 15 possible) as a function of trial for adults in reading task of Experiment 4.

looked more similar to their conventional spellings than did the corresponding sound items. To assess this possibility, we carried out an analysis in which we eliminated the eight pairs for which the conventional spelling of the name item was visually more similar to the made-up spelling than the conventional spelling of the sound item, where visual similarity was assessed in terms of the proportion of shared letters. For the seven items that remained, performance in the name condition was significantly better than performance in the sound condition both by subjects, $t\eth 26\text{Þ} ¼ 2.48$, $p ¼ .01$, and items, $t\eth 6\text{Þ} ¼ 2.18$, $p ¼ .04$, both tests one tailed. Thus, an advantage for letter names over and above letter sounds still emerged after controlling for visual similarity.

Table 9 shows the mean proportions of errors of various types in each of the three conditions. The means and statistical analyses are based on those

Table 9
Mean proportion of errors of various types for adults in reading task of Experiment 4

	Condition			Total
	Name	Sound	Visual	
No response	.41	.45	.64	.50
List	.00	.00	.25	.08
Phonological	.43	.46	.03	.31
Other	.16	.09	.07	.11

13 participants who made at least one error in each condition. Although no-response errors tended to be more frequent in the visual condition than the other conditions, the difference among the conditions was not significant (p ¼ .07). List errors were reliably more common in the visual condition than the other conditions (p ¼ .001). Phonological errors were more frequent in the name and sound conditions, which did not differ significantly from one another, than in the visual condition, $p < .001$.

Discussion

The adults made some use of word-final letter names in linking print to speech. For example, they found it more natural to pronounce TL as *tell* rather than *tall* during the early trials of the experiment. These adults demonstrated the same pattern of performance as the adults tested by Treiman et al. (2001), who benefited from letter names at the beginnings of novel words and who performed poorly with spellings that deviated from known letter-sound relationships. The present results suggest that generalization of the letter-name strategy to final letter names has occurred by adulthood. Although letter names are less helpful than letter sounds as a guide to pronunciation in English, adults continue to use their entrenched knowledge about letter names in reading-related tasks. Early strategies are not necessarily abandoned as more efficient strategies emerge (e.g., Ehri, 1992; Treiman et al., 2001).

Although the adults took advantage of the information in the final positions of the words, their phonological errors suggest that they focused more on the initial letters than the final letters. Of the phonological errors in the name and sound conditions, 90% were consistent with both of the letters in the 2-letter stimuli, such as responding with *file* for FL instead of *fell* or *fail*. The remaining 10% of the phonological errors contained just the correct initial phoneme. Incorrect answers that contained only the correct final phoneme were never produced. Thus, even though the adults usually considered both letters when responding to the stimuli, they paid more attention to the initial letter.

General discussion

Early theories viewed the acquisition of literacy as involving several discrete stages (e.g., Byrne, 1992; Frith, 1985). In this view, young children are logographic learners, unable to form systematic links between print and speech. Children focus instead on the salient graphic features of printed words, treating each new word as a distinctive pattern. More recently, several investigators have questioned the importance of a logographic approach in learning to read and spell based on the idea that alphabetic

skills may develop early in children with good phonological skills (Stuart, 1990; Stuart & Coltheart, 1988) or children who are learning a highly regular writing system (Wimmer & Hummer, 1990). A more fundamental challenge to the logographic view comes from findings suggesting that young children can relate print and speech using methods *other* than letter-sound links. Specifically, young children who know the names of letters can use this knowledge to form systematic connections between certain kinds of printed words and spoken words (de Abreu & Cardoso-Martins, 1998; Levin et al., 2002; Treiman & Rodriguez, 1999; Treiman et al., 2001). Children in the US and other literate societies typically learn the names of letters from an early age, and so many children may be able to go beyond logographic reading in this way. In the present study, we asked whether children's ability to benefit from letter names in learning to read and spell words extends beyond the word-initial letter names that have been the focus of earlier research.

Our results showed that children made little or no use of letter-name cues in the final position of 2-letter words (Experiments 1–3), although—as in previous studies—they used such cues in the initial position (Experiment 3). Adults benefited from final position letter-name cues above and beyond letter-sound cues (Experiment 4), but children did not show significant differences. The results suggest that the initial position of a word has a special status, consistent with the initial-letter hypothesis. A young child who learns *jail*, for example, may relate the *j* of the printed word to the "jay" in the spoken word. The child may not link the *i* or the *l* to any element of speech. The connections formed by the child are, in Ehri's (1995) terms, only partial.

In addition to asking whether the use of letter-name cues generalizes from the initial position of the word to the final position, we asked whether children show the same patterns of performance in spelling as in reading. For novice readers, the lack of an alphabetic connection was a major stumbling block in learning the spellings of words (Experiment 2), more so than in learning their pronunciations (Experiment 1). Children can apparently achieve some success with a logographic strategy in the visual condition of the reading task. However, rote memorization of associations involving five unfamiliar 2-letter spellings is even more difficult than rote memorization of associations involving five familiar spoken words. The greater demands of the spelling task may thus force children to use any alphabetic knowledge and analytic skills that they possess. Treiman et al. (2001) found a similar difference between spelling and reading in novice readers. Although spelling and reading have yet to be compared within a single study, the cross-experiment comparisons support the view of Frith (1985) and of Goswami and Bryant (1990) that alphabetic strategies are more crucial for spelling than for reading.

In the study of Treiman et al. (2001), the prereaders performed significantly better in the sound condition than the visual condition in the spell-

ing task, although they did not show such a difference in reading. These results suggest that even prereaders can use letter-sound information when learning new spellings. In the present study, however, prereaders did not show a significant superiority for the sound condition over the visual condition in spelling. The different results of the two spelling studies, we suspect, reflect differences in the initial letters that were used. The stimuli of Treiman et al. began with letters such as *t* and *b*. The names of these letters are CVs, and the sound made by the letter is the first phoneme of the letter's name. In Experiment 2 of the present study, only some of the initial letters had this property. Other letters had VC names such as *f*, for which the sound made by the letter is at the end of the letter's name, or *h*, where the sound of the letter is not in the name at all. Previous research (McBride-Chang, 1999; Treiman et al., 1998) has shown that children learn letter sounds most easily for letters with CV names for which the sound of the letter is at the beginning of the name. Thus, even though the prereaders tested by Treiman et al. were not highly knowledgeable about letter sounds, their knowledge about the names of the initial letters that were used in the study may have allowed them some success in the sound condition of the spelling task. The prereaders in the present Experiment 2 may not have benefited from initial letter-sound cues because they were less knowledgeable about the sounds of the particular letters that were used. That is, even prereaders may be able to use word-initial letter sounds in spelling if the letter sounds are closely related to the letters' names. This hypothesis remains to be tested.

Our results suggest that several factors allow young children to go beyond a logographic approach in learning about print. One factor is links between print and speech that make sense based on the knowledge that children possess, which for many young children in the US and other countries includes knowledge of letter names. A second factor is accessible print-speech links in salient positions of words, especially their beginnings. A third is a situation in which rote memorization is unlikely to succeed. One such situation is the present spelling task, in which five 2-letter responses are easily forgotten without some analytic approach. It would be difficult to capture the influences of all three factors in a stage theory. If a letter-name stage were postulated, as in some theories of spelling development (Henderson, 1985), one would expect children at this stage to use letter-name information whenever it is available. As the results of Experiment 3 show, however, the same child may successfully use letter-name information in some situations—when it is at the beginning of a word—but not in other situations—when it is at the end of a word. Stage theories are not flexible enough to capture this variability.

A better theoretical framework in which to view our results may be the overlapping waves theory (Siegler, 1996), which has been applied to spelling by Rittle-Johnson and Siegler (1999). In this view, children have more than

one strategy available at a given time. Development may involve the acquisition of new strategies, but it may also involve the wider or more adaptive application of existing strategies. Our finding that readers continue to use letter names even after they have begun to benefit from letter sounds is consistent with the overlapping waves approach. Also consistent with this approach is the finding that children are more likely to use their knowledge of letter names to connect print and speech in some situations, as when the letter-name information is in a salient position of the word, than in other situations.

Most of the word-learning studies that have been carried out so far have used novel stimuli like TM pronounced as *team* and BR pronounced as *bar*. Artificial stimuli permit good control over print-speech relationships, but how common are relationships between print and speech that are based on letter names in the real words of English? To find out, we examined the 6,232 word forms in Zeno et al. (1995) that appear with a frequency of 1 or more per million words at the kindergarten and first-grade levels and that have a pronunciation in the CMU Pronouncing Dictionary (1998). Of these 6,232 items, 210 (3.4%) have the property that the entire name of the first letter is heard at the beginning of the spoken word, as in *team*. Another 192 (3.1%) offer final letter-name cues, as in *bar*. Many additional words offer letter-name cues in other positions, as in *pile* and *belt*. Indeed, 2,688 of the words, or 43.1%, offer the possibility of linking at least one letter in the printed form of the word to the corresponding letter name in some position of the spoken word. Children are thus likely to encounter words that offer the possibility of letter-name connections between print and speech. The inclusion of such words in early instruction, particularly words that offer letter-name cues at the beginnings, may help children understand that the printed forms of words are related to their spoken forms.

References

Abreu, M. D. de, & Cardoso-Martins, C. (1998). Alphabetic access route in beginning reading acquisition in Portuguese: The role of letter-name knowledge. *Reading and Writing, 10*, 85–104.

Byrne, B. (1992). Studies in the acquisition procedure for reading: Rationale, hypotheses, and data. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 1–34). Hillsdale, NJ: Erlbaum.

CMU Pronouncing Dictionary (version. 0.6) [Data file]. 1998. Carnegie Mellon University, Speech at CMU Web site Available: ftp://ftp.cs.cmu.edu/project/speech/dict/cmudict.0.6.

Carroll, J. B., Davies, P., & Richman, B. (1971). *Word frequency book*. Boston: Houghton Mifflin.

Ehri, L. C. (1987). Learning to read and spell words. *Journal of Reading Behavior, 19*, 5–31.

Ehri, L. C. (1992). Reconceptualizing the development of sight-word reading and its relationship to decoding. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 107–148). Hillsdale, NJ: Erlbaum.

Ehri, L. C. (1995). Phases of development in learning to read words by sight. *Journal of Research in Reading, 18*, 116–125.

Ehri, L. C., & Wilce, L. S. (1985). Movement into reading: Is the first stage of printed word learning visual or phonetic? *Reading Research Quarterly, 20*, 163–179.

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

Gentry, J. R. (1982). An analysis of developmental spelling in GNYS AT WRK. *Reading Teacher, 36*, 192–200.

Goswami, U., & Bryant, P. E. (1990). *Phonological skills and learning to read*. Hove, England: Erlbaum.

Henderson, E. (1985). *Teaching spelling*. Boston: Houghton Mifflin.

Laing, E., & Hulme, C. (1999). Phonological and semantic processes influence beginning readers' ability to learn to read words. *Journal of Experimental Child Psychology, 73*, 183–207.

Levin, I., Patel, S., Margalit, T., & Barad, N. (2002). Letter names: Effect on letter saying, spelling, and word recognition in Hebrew. *Applied Psycholinguistics, 23*, 269–300.

Lomax, R., & McGee, L. (1987). Young children's concepts about print and reading: Toward a model of word reading acquisition. *Reading Research Quarterly, 22*, 237–256.

Masonheimer, P. E., Drum, P. A., & Ehri, L. C. (1984). Does environmental print identification lead children into word reading? *Journal of Reading Behavior, 16*, 257–272.

McBride-Chang, C. (1999). The ABC's of the ABC's: The development of letter-name and letter-sound knowledge. *Merrill-Palmer Quarterly, 45*, 285–308.

McBride-Chang, C., & Treiman, R. (in press). Use of letter names and letter sounds in learning to read English among young Hong Kong Chinese children. *Psychological Science*.

O'Brien, R. G., & Kaiser, M. K. (1985). MANOVA method for analyzing repeated measures designs: An extensive primer. *Psychological Bulletin, 97*, 316–333.

Rack, J., Hulme, C., Snowling, M., & Wightman, J. (1994). The role of phonology in young children learning to read words: The direct-mapping hypothesis. *Journal of Experimental Child Psychology, 57*, 42–71.

Rittle-Johnson, B., & Siegler, R. S. (1999). Learning to spell: Variability, choice, and change in children's strategy use. *Child Development, 70*, 332–348.

Share, D. L., & Gur, T. (1999). How reading begins: A study of preschoolers' print identification strategies. *Cognition and Instruction, 17*, 177–213.

Siegler, R. S. (1996). *Emerging minds: The process of change in children's thinking*. New York: Oxford.

Stuart, M. (1990). Factors influencing word recognition in pre-reading children. *British Journal of Psychology, 81*, 135–146.

Stuart, M., & Coltheart, M. (1988). Does reading develop in a sequence of stages? *Cognition, 30*, 139–181.

Treiman, R. (1993). *Beginning to spell: A study of first-grade children*. New York: Oxford University Press.

Treiman, R., & Rodriguez, K. (1999). Young children use letter names in learning to read words. *Psychological Science, 10*, 334–338.

Treiman, R., Sotak, L., & Bowman, M. (2001). The role of letter names and letter sounds in connecting print and speech. *Memory & Cognition, 29*, 860–873.

Treiman, R., Tincoff, R., & Richmond-Welty, E. D. (1996). Letter names help children connect print to speech. *Developmental Psychology, 32*, 505–514.

Treiman, R., Tincoff, R., Rodriguez, K., Mouzaki, A., & Francis, D. (1998). The foundations of literacy: Learning the sounds of letters. *Child Development, 69*, 1524–1540.

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

Worden, P. E., & Boettcher, W. (1990). Young children's acquisition of alphabet knowledge. *Journal of Reading Behavior, 22*, 277–295.

Zeno, S. M., Ivenz, S. H., Millard, R. T., & Duvvuri, R. (1995). *Educator's word frequency guide*. Brewster, NY: Touchstone Applied Science Associates.