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Beginners remember orthography when they learn to read words: The case of doubled letters

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ABSTRACT
Sight word learning and memory were studied to clarify how early during development readers process visual letter patterns that are not dictated by phonology, and whether their word learning is influenced by the legality of letter patterns. Forty kindergartners and first graders were taught to read 12 words containing either single consonants (e.g., FAN) or doubled consonants in initial illegal or final legal positions (e.g., RRUG or JETT). Children required fewer trials to learn to read legally spelled words with single or doubled consonants than illegally spelled words containing initial doublets. On a spelling posttest, children recalled single consonants somewhat better than final doublets, and final doublets much better than initial illegal doublets. More advanced beginning readers tended to regularize illegal initial doublets by doubling the final rather than initial consonants when they wrote these words. Poorer learning and memory for initial doublets occurred despite the salience of their position in words. Findings indicate that beginning readers use orthographic patterns to read and remember words earlier than predicted by phase theory, but their memory is constrained by their knowledge of written word structure.

Although alphabetic writing systems are structured according to the phonemic principle that graphemes represent phonemes, alphabetic writing systems differ in the variability of these mapping relations (Venezky, 1999; Ziegler & Goswami, 2005). Seymour, Aro, and Erskine (2003) categorized alphabetic languages along two dimensions: orthographic depth and syllabic complexity. Shallow writing systems exhibit consistent mappings between graphemes and phonemes, whereas deep orthographies contain inconsistencies. Languages with simple syllabic structures have open consonant–vowel (CV) syllables with few consonant clusters, whereas complex languages have numerous closed consonant–vowel–consonant (CVC) syllables and complex consonant clusters. The English writing system stands apart from other writing systems in being both deep and complex. As a result, beginning readers' rate of development in English is much slower. In fact, Seymour et al. (2003) found that learning to read in English took twice as long as learning in more shallow orthographies.

One feature of English complicating the task of working out grapheme–phoneme relations is that regularities extend beyond single-letter–sound correspondences. Ziegler and Goswami (2005) refer to this as the problem of grain size. From the start, beginning readers in English are confronted with inconsistencies in single-letter–sound correspondences as they attempt to construct mappings between orthography and phonology. Some resolution is achieved as they learn to pay attention to larger orthographic units. These orthographic units include two- and three-letter patterns such as the LL in *bell*, the CK in *back*, the SH in *ship*, the NG in *sing*, the TCH in *match*. They include onset and rime spellings that recur in different words, such as the common rimes *-all*, *-ook*, *-ing*, and *–ake*. Knowledge of these regularities is needed to attain word reading skill in English. One purpose of the present study was to examine when beginning readers become aware of and are able to use units larger than single letters, specifically, doubled letter units, to read and remember words.

Ehri has proposed phase theory to portray children's development in learning to read words from memory by sight (Ehri, 1999, 2005; Ehri & Wilce, 1985). People used to believe that sight words were learned by remembering associations between visual features of the words and their meanings without any contribution from letter–sound relations (Barron, 1981). However, more recently researchers have theorized and provided evidence that sight words are secured in memory when readers apply their knowledge of the alphabetic writing system to form connections between graphemes in spellings and phonemes in pronunciations of specific words (Ehri, 1980, 1992; Ehri & Saltmarsh, 1995; Perfetti, 1992; Rack, Hulme, Snowling, & Wightman, 1994; Reitsma, 1983; Savage, Stuart, & Hill, 2001; Seymour & Duncan, 2001; Share, 1999, 2004; Stuart & Coltheart, 1988; Vandervelden & Siegel, 1995). In Ehri's view, sight word learning entails securing spellings of words to their pronunciations and meanings in memory so that when the words are seen, they are read automatically from memory rather than by applying a decoding strategy.

Ehri's (1999) phases are based on the predominant types of connections that secure sight words in memory at various points during development: pre, partial, full, and consolidated alphabetic phases. Prealphabetic phase readers have little knowledge of letter names or sounds so they form connections between salient visual cues and the meanings of words to remember how to read them, for example, the two posts in *bell* and the clanging sound. Partial phase readers have limited phonemic segmentation and some letter–name or –sound knowledge so they can form connections between partial letters and sounds, typically beginning and ending letters, to remember how to read words, for example, B and L to remember *bell*. Full alphabetic phase readers know the major grapheme–phoneme relations, including short vowels. As a result, they can store sight words in memory by forming complete connections between graphemes and phonemes, for example, B-E-L to remember *bell*. Consolidated phase readers have learned about multiletter graphemes and spellings patterns in words (e.g., *sell, fell, tell, well*), so they can use orthographic patterns to secure sight words in memory, for example, B-ELL to remember *bell*. Studies of phase theory have been interpreted by Ehri to show that when partial and full-phase readers acquire knowledge of letter–sound relations, they shift from using nonalphabetic visual features to using grapheme–phoneme connections to secure words in memory (Bowman & Treiman, 2002; deAbreu & Cardoso-Martins, 1998; Ehri & Wilce, 1985; Roberts, 2003; Scott & Ehri, 1990; Treiman & Rodriguez, 1999). It is not until the consolidated phase that beginners use predominantly visual orthographic patterns to learn words.

Cassar and Treiman (1997) have challenged phase theory for its claim that beginners in the partial and full phases read and spell words by processing letter–sound relations and do not attend to visual features or spelling patterns until a later phase of development. They point out that kindergartners and first graders have been observed to include doubled letters occasionally when they spell words and pseudowords. They gave kindergartners and first graders the task of selecting which of two nonwords containing initial or final doublets looked like the best spelling for a word, for example, FFOL versus FOLL. Children selected the legally spelled nonwords with final doublets over the nonwords with initial illegal doublets significantly beyond chance. Even children who were partial alphabetic spellers showed a slight but significant preference for final doublets. Pacton and Fayol (2004) also used this recognition task and found that French first graders were sensitive to doubled letters sitting illegally in the initial positions of words. These findings place the emergence of orthographic knowledge earlier than that expected by phase theory.

However, Cassar and Treiman's (1997) study has some shortcomings that make conclusions premature. Although beginners performed beyond a chance level (50%), their selection of final doublets was only slightly above chance, with means ranging from 55 to 62% and far short of perfect (100%). Clearly children did not respond consistently, and they frequently chose the illegal initial doublet (i.e., $M = 38–45\%$), indicating that knowledge about legal doublet position was not firmly established. Moreover, children were only asked to choose between words containing doublets, not between doublet and single-consonant words. Thus, we do not know how plausible children regarded doubled consonants compared to single consonants. In addition, it is possible that a response bias inflated doublet scores. As children moved through the task and made choices from among pairs of items all having doublets, their initial choices may have strengthened their tendency to respond similarly on subsequent items. Most importantly, the study did not examine children's ability to *use* their orthographic knowledge in reading and writing words. They just sat passively making choices, so only minimal recognition knowledge was assessed. The purpose of the present study was to investigate children's functional knowledge of doublets by examining their performance in a word learning and memory task.

Although beginners may have some general, recognition-based knowledge about doubled letters, there are reasons for questioning whether they actually use this knowledge. Beginners have difficulty remembering the correct spellings of words, especially letters that are not predicted by their sounds in words (Ehri, 1997). Moreover, when beginners write words, they tend to record only one letter for every sound they detect. Use of two letters is less common, although Treiman (1993) observed some instances. Elbro (2005) has proposed the principle of economy in his model of the acquisition of orthographic knowledge. In studies of Danish children, he found that the most common, productive, and reliable grapheme–phoneme associations were learned first in the form of single letters. More complex graphemes including digraphs made words harder to read and emerged later.

The main purpose of the present study was to extend our knowledge about word learning and memory processes in beginning readers by clarifying whether they notice and remember visual letter patterns that are not dictated by phonology, or whether their memory for letters in words is limited to letter–sound connections. Furthermore, if beginners do process visual letter patterns, is their word learning affected by whether the patterns conform to or violate conventions of the writing system? Finally, are any of these processes affected by the beginners' phase of development?

To address these questions, a word-learning task was utilized. Real words with meanings were taught rather than nonwords to study the process of retaining words with semantic as well as orthographic and phonological identities in memory. Children in the partial and full alphabetic phases practiced reading 12 modified spellings of words containing single or double consonants appearing at the beginnings or endings of words, for example, RRAG (*rag*), PADD (*pad*), or WIP (*whip*). To study word learning and memory processes, we measured the number of words of each type read correctly during the learning trials and the number of spellings remembered following learning. We reasoned that if beginners process the visual orthographic features of words, then their spellings should show memory for double as well as single consonants. If beginners are sensitive to orthographic constraints on words, then their word learning and memory should be affected by the legality of doublets' position in words. Illegal initial doublets should impair learning and memory more than final legal doublets.

METHOD

Participants

From 60 children whose parents provided written consent, 40 were selected who had sufficient alphabetic skills to qualify as beginning-level readers. They could name at least 20 alphabet letters and sounds, they read no higher than a first-grade equivalent (1.9 grade equivalent [GE]) level on the Woodcock Reading Mastery Tests—Revised (WRMT-R; Woodcock, 1987), they spelled at a beginning level on a developmental spelling test, and they were able to follow directions on the pretests. The participants included 15 kindergartners (mean age = 6.0 years), and 25 first graders (mean age = 6.4 years, 22 females, 18 males). They were drawn from two low socioeconomic, urban public elementary schools with free-lunch eligibility above 80%. Ninety percent were African American and 10% were Hispanic. Excluded were children who lacked sufficient alphabetic skills ($N = 15$), were too advanced ($N = 7$), or did not complete all the tasks ($N = 3$). The reading instruction followed a literature-based approach in five of the classrooms and a systematic phonics approach in four classrooms.

Materials

Pretests. Several pretests were administered in the following order.

LETTER KNOWLEDGE. Children's accuracy and speed to name 26 randomly ordered capital letters and 26 randomly ordered lower case letters were timed with a stopwatch. In addition, their accuracy to say the sounds of letters was assessed.

WORD READING. Children read a graded list of words (preprimer through second grade) from the WRMT-R (Woodcock, 1987). Words were mixed with pictures that children named to minimize nonreaders' sense of failure. Children reading above the 1.9-GE level were excluded.

DEVELOPMENTAL SPELLING. Three practice words were modeled and then children wrote sound spellings of 10 test words from Morris and Perney (1984). The words included phonemes known to distinguish more from less advanced spellers (e.g., *sink, dress, picking, picked, stick*). Morris and Perney's scoring system was applied to assess whether sounds were spelled phonetically, conventionally, or correctly (0–5 points per word). Students whose average scores per word indicated they were too immature (scores ≤ 1) or too advanced (scores ≥ 4) were excluded from the study.

NONWORD READING. Children were told to read some silly, meaningless words. One practice item (*zown*) was followed by five test items (*vip, wub, sog, fen,* and *zak*).

DOUBLE LETTER RECOGNITION. Children's awareness of legal and illegal doubled letters in nonwords was assessed with items drawn from Cassar and Treiman (1997). Four practice items were followed by 30 test items, 10 consisting of an illegal initial doublet paired with a final legal doublet (e.g., LLUS vs. LUSS), 10 consisting of illegal and legal final doublets (e.g., JUKK vs. JULL), and 10 consisting of illegal and legal vowel doublets (e.g., JAAT vs. JEET). Children were told to choose the nonword that looked most like a word.

PHONEMIC SEGMENTATION. Children were shown how to say five practice words slowly and raise a finger for each sound. Then they segmented 15 test words (5 CVCs, 5 CCVCs, and 5 CVCCs).

Word Learning Task. Each child learned to read modified spellings of 12 meaningful words over several practice trials. Two parallel sets shown in Table 1 were created to increase the generalizability of findings beyond a single word list. The words were selected from Harris and Jacobson's (1982) *Basic Reading Vocabularies* reporting frequency and GE analyses of words occurring across eight basal reading series. Words thought to be unfamiliar to children reading below the second-grade level were targeted. All but two words had GE levels between second and fourth grade. One word (*pat*) was primer level, and one word (*fizz*) did not appear on the list. These two words were assigned GE ratings of 1 and 5, respectively, on the GE measure reported below.

Table 1. *Two sets of words taught in the Word Learning Task*

Consonant Type	Set A Spelling Learned[a]	Set A Conventional Spelling	Set B Spelling Learned[a]	Set B Conventional Spelling
Illegal initial doublets	RRAG	(rag)	LLAM	(lamb)
	LLIM	(limb)	RRUG	(rug)
	LLES	(less)	RRIP	(rip)
	LLUK	(luck)	RREK	(wreck)
Legal final doublets	PADD	(pad)	PATT	(pat)
	FITT	(fit)	DEDD	(dead)
	NUTT	(nut)	KIDD	(kid)
	JETT	(jet)	MUDD	(mud)
Legal single consonants	DEF	(deaf)	WEB	(web)
	WIP	(whip)	FIZ	(fizz)
	FAN	(fan)	TUF	(tough)
	TUB	(tub)	VAN	(van)

[a]In Set A, doublets LL and TT each occurred in three words whereas doublets RR and DD each occurred in one word. In Set B, the number of words for each doublet was reversed.

Each word set included four modified spellings with doubled initial consonants, four with doubled final consonants, and four single-consonant spellings. Each doublet set included a single instance of one doubled consonant and three instances of another doubled consonant. This was to see whether children remembered multiple instances of doublets better than single instances. Single-consonant words were included to ensure that memory for doublets was selective and did not extend to these words. Words were presented in capital letters because these are more familiar and less easily confused by beginners (Worden & Boettcher, 1990), and also because this eliminated any distinctive shape cues arising from ascending or descending letters (i.e., *rrag* vs. *llam* vs. *padd*) and any confusion between lowercase l (el) and the numeral 1.

Modified spellings have been used in many previous laboratory studies to explore word learning processes in beginners (Bowman & Treiman, 2002; deAbreu & Cardoso-Martins, 1998; Ehri & Saltmarsh, 1995; Ehri & Wilce, 1985, 1987; Rack et al., 1994; Reitsma, 1983; Treiman & Rodriguez, 1999). Although deviating slightly from the correct spellings of words, the modified spellings resemble invented spellings written by children of this age before they have learned conventional spellings (Treiman, 1993). Studies indicate that incorrect invented spellings are forgotten when children learn the conventional spelling system and the correct spellings of individual words (Clarke, 1988; Ehri, 1989; Ehri, Gibbs, & Underwood, 1988). At the end of the present experiment, children were debriefed and taught the correct spellings of the words.

Students were randomly assigned to learn one or the other list of words to a criterion of two perfect successive trials. The anticipation method of paired associate learning was used to teach the words. The experimenter informed students, "Now I am going to teach you to read some words." During the first study trial, the experimenter spoke each word while sliding a finger under its letters, then embedded the word in a meaningful sentence, then had the student read the word. During all subsequent trials, children were shown the words and asked to read them. If wrong, the word and sentence were spoken and they repeated the word. The order of presentation of the words varied across trials.

Posttests. One spelling posttest was given at the end of word learning, and two were given 2 to 3 days later.

SPELLING RECALL. Children's memory for letters in the spellings of the 12 training words was assessed. The experimenter spoke each word and then embedded it in a sentence, children repeated the word, and then were told to write the spelling that they had just learned including all the letters they remembered seeing in the word. Scored were the numbers of single and double consonants recalled.

DOUBLET SPELLING RECOGNITION. Children's recognition memory for the eight training words containing doubled letters was assessed. They were shown each word spelled three different ways and pointed to the one they had previously learned. The position of the correct choice was varied across items. Foils were spelled with single or doubled consonants in incorrect positions (e.g., FITT, FIT, FFIT).

DOUBLET SPELLING TRANSFER. Children's productive use of the doublets they saw in training words was assessed. They heard, repeated, and wrote eight new words that shared rimes or initial and final sounds with the training words containing doublets, for example, "fed" related to the training word DEDD, "rock" related to RREK. All but two of the words were above the first GE level (Harris & Jacobson, 1982). Children were told that the words they just learned might help them spell the new words. Each transfer word was pronounced alone and in a sentence, children repeated the word, and then wrote its spelling.

Design and procedure

Children were trained and tested individually in five sessions each lasting up to 30 min on a different day. Three sessions were taken to administer pretests, one session for word learning followed by the spelling production posttest, and a final session occurring 2 or 3 days later for assessing spelling recognition and transfer. At the end, participants were debriefed about the correct spellings of the words whose modified spellings they had learned to read. Each word's conventional spelling was shown and pronounced, and students repeated the word as they slid their finger beneath its letters.

Scores on the nonword decoding and developmental spelling pretests were used to distinguish groups of partial and full alphabetic phase readers. Independent variables included reader group (partial vs. full-phase readers), word set learned (A vs. B), type of spelling (doublet vs. single consonant), and position of the consonant in words (initial vs. final). Responses on the doublet recognition pretest, the word

Table 2. *Characteristics, mean performance, and standard deviations on pretests for partial and full alphabetic phase readers*

Characteristics and Tests	Reader Group: Partial ($N = 20$)	Full ($N = 20$)	Mean	Test Statistic t (38)
Gender (female, male)	9F, 11M	12F, 8M		
Grade (K, first)	8K, 12F	7K, 13F		
Age (years)	6.16 (0.35)	6.39 (0.60)	6.3	1.47 *ns*
Letter knowledge				
Naming capitals per second	1.13 (0.36)	1.35 (0.35)	1.2	1.97 *ns*
Naming lowercase per second	0.90 (0.24)	1.13 (0.29)	1.0	2.80**
Sounds of letters (26 max)	21.30 (1.5)	23.55 (1.9)	22.4	4.12**
Phonemic segmentation (15 max)	4.75 (3.6)	7.35 (2.8)	6.1	2.56*
Developmental spelling (5 max)	1.91 (0.65)	3.20 (0.22)	2.6	8.40**
Reading words (35 max)	9.65 (7.6)	20.30 (10.9)	15.0	3.59**
Grade-equivalent score	1.2 GE	1.5 GE		
Reading nonwords (5 max)	0.40 (0.60)	3.30 (0.73)	1.9	13.71**
Choosing legal doubled letters[a]				
Position (initial vs. finals, 10 max)	6.30 (2.9)	7.15[b] (2.4)	6.7	1.00 *ns*
Final consonant (10 max)	4.60 (2.0)	6.40[b] (1.5)	5.5	3.29**
Vowel (10 max)	6.05[b] (2.1)	7.30[b] (1.5)	6.7	2.20*

[a]Examples of items with illegal and legal choices, respectively: position (LLUS vs. LUSS), final consonant (JUKK vs. JULL), vowels (JAAT vs. JEET). Chance-level performance = 5 correct.
[b]Mean performance was beyond chance at $p < .05$. The t statistics for the partial phase group were $t = 1.98$, (position), $t = 0.91$ *ns* (final consonant), $t = 2.28$, $p < .01$, (vowel). The t statistics for the full phase group were $t = 3.99$, $p < .01$ (position), $t = 4.27$, $p < .01$ (final consonant), $t = 6.90$, $p < .01$ (vowel).
$*p < .05$. $**p < .01$.

learning trials, and the immediate and delayed posttests provided the dependent measures for several analyses of variance (ANOVAs).

RESULTS

Pretests

Students were grouped into more and less advanced beginning readers. Partial alphabetic-phase readers ($N = 20$) read few if any nonwords (i.e., 0–2, 65% reading no nonwords, 30% reading only 1), and they spelled most words with beginning or beginning and ending consonants but left out vowels. Full alphabetic-phase readers ($N = 20$) decoded three or more nonwords and spelled most sounds including correct or phonetically close vowels when they wrote words. Characteristics and mean performance of the two groups on pretests are reported in Table 2. The groups included students from both grades. The t tests revealed that they did not differ significantly in mean age. From Table 2 it is apparent that full-phase readers outperformed partial phase readers not only in nonword decoding and spelling but also in letter knowledge, phonemic segmentation, sight word vocabulary, and awareness of legal and illegal doubled letters. These findings indicate that the two groups clearly differed in their level of development as beginning readers.

The 30-item, two-choice, doubled-letter recognition test (Cassar & Treiman, 1997) consisted of 10 items testing each of three types of illegal doubled letters. By chance, students could score 5 correct on each type. To determine whether mean performance exceeded chance, the difference between each child's score and 5 was averaged, and tested statistically. Results of the t tests revealed that full-phase readers recognized all three types of illegal doublets, whereas partial phase readers recognized only illegal vowel doublets but not illegal initial or final doublets (see Table 2). Although mean scores significantly exceeded chance, they were not far above the chance score of 5, with mean values ranging from 6.1 to 7.3 (10 maximum; see Table 2). These findings replicate those of Cassar and Treiman (1997), indicating that quite early during development, beginning readers acquire some awareness about orthographic features of words that are not dictated by phonemes in the words. They also show that full-phase readers know more about orthographic patterns than partial phase readers.

Word-learning trials

Children practiced reading a set of 12 words (either Set A or B) over several trials until they read the words perfectly on two successive trials. Scored was the number of trials completed prior to the two perfect trials. Results are presented in Table 3. Although everyone reached criterion, full-phase readers required significantly fewer trials before performing perfectly than partial readers, $F(1, 38) = 9.51$, $p < .01$.

To analyze effects of the independent variables, the number of words read correctly on the first three trials was subjected to a four-way ANOVA. Scoring was limited to three trials because learning ended for several readers after this point. The independent variables were: reader phase (partial vs. full), word set (A vs. B), word type (initial doublet vs. final doublet vs. single consonant), and trial (1–3). The latter two variables were repeated measures.

Results revealed significant main effects of reader phase, $F(1, 36) = 8.34$, $p < .01$, word type, $F(2, 72) = 4.48$, $p < .05$, and trials, $F(2, 72) = 12.99$, $p < .01$. Word set was not significant ($F < 1$), indicating that findings generalized across both sets of words. None of the interactions was significant (all ps $> .05$). Full-phase readers read significantly more words than partial phase readers (see Table 3). Performance increased across trials. One type of word was harder to learn than the other types. Mean scores are shown in Table 3. Post hoc Tukey's pairwise comparison tests revealed that learning to read words with initial doublets was significantly harder than learning to read words with final doublets or with single consonants (all ps $< .05$). Learning final doublet words did not differ from learning single-consonant words. These findings show that illegal letter patterns involving doubled consonants in initial position of words increased the difficulty of sight word learning for partial as well as full-phase readers. However, legal doubled letters in final position did not make word learning any harder compared to single consonants.

Table 3. *Mean performance, standard deviations, and test statistics during word learning trials and on posttests for partial and full alphabetic phase readers*

Characteristics and Measures	Reader Group: Partial ($N = 20$)	Full ($N = 20$)	Mean
Word learning			
Trials prior to reaching criterion	5.2 (3.5)	2.2 (2.7)	3.7 (3.1)
Mean words read correctly per trial[a]			
Words with initial doublets (4 max)	2.5 (1.2)	3.3 (0.9)	2.9 (1.1)
Words with final doublets (4 max)	2.9 (1.1)	3.6 (0.8)	3.2 (0.9)
Words with single consonants (4 max)	2.9 (1.3)	3.5 (0.8)	3.2 (1.1)
Posttests			
Spelling recall			
Single initial letters (4 max)	3.5 (1.1)	3.8 (0.5)	3.6 (0.8)
Single final letters (4 max)	3.2 (1.4)	3.8 (0.4)	3.5 (1.0)
Doubled initial letters (4 max)	0.8 (1.0)	1.3 (1.5)	1.0 (1.3)
Doubled final letters (4 max)	2.8 (1.6)	3.1 (1.1)	3.0 (1.4)
Spelling recognition (8 max)[b]	4.9 (1.9)	4.4 (1.8)	4.7 (1.9)
Spelling transfer			
Doublets written (8 max)	0.4 (0.8)	0.4 (0.8)	0.4 (0.8)
No doublets written (% of students)	70	80	75

[a]The performance on the first three trials was scored.
[b]Chance-level performance = 2.7 items correct.

A regression analysis was conducted with the number of trials prior to reaching criterion as the dependent variable and four pretests as the predictor variables. Correlations between word learning and the predictors were: WRMT-R word reading ($r = -.69$), developmental spelling ($r = -.64$), nonword reading ($r = -.54$), and double letter recognition ($r = -.10$). All but the final r were statistically greater than zero at $p < .01$. Variables were entered freely into the regression. The resulting model included two significant predictors, word reading that explained 48% of the variance and developmental spelling that raised the variance explained to 55%, $F\,(2, 37) = 25.05$, $p < .01$. These findings indicate that ease of learning to read the 12 training words was predicted by students' existing sight word vocabulary plus their knowledge of the alphabetic system as assessed by the phonetic quality of their spellings. In contrast, double-letter recognition on the pretest was not related to word-learning performance, even though the words learned contained doubled letters. These findings support the validity of the experimental word-learning task as an indicator of sight word learning processes in beginning readers.

Spelling recall posttest

At the end of the final word learning trial, students wrote the words they had learned to read. Scored were the numbers of single and double initial and final

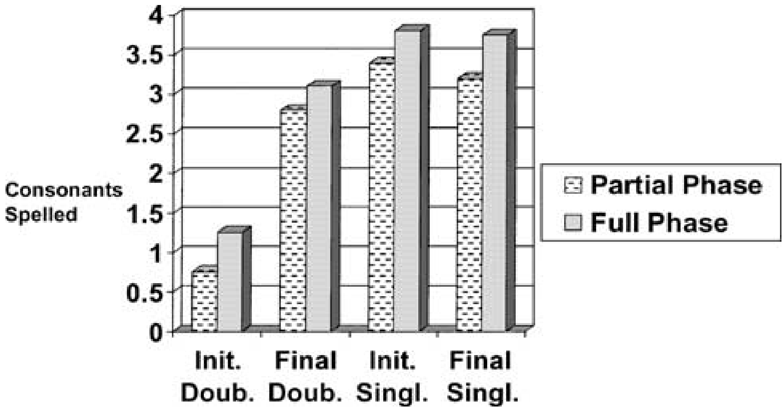

Figure 1. Mean number of single- and double-consonant letters recalled in the spelling test as a function of their initial or final position in words by children in the partial and full alphabetic phases of development.

consonants spelled correctly. The Cronbach α value revealed high reliability at .88 for Set A and .96 for Set B. A four-way ANOVA was conducted. The independent variables were reader phase (partial vs. full), word set (A vs. B), type of consonant recalled (single vs. double), and position of the consonant in the word (initial vs. final). The latter two variables were repeated measures. A main effect of reader phase was detected, $F\ (1, 36) = 5.06$, $p < .05$. Main effects were also found for consonant type, $F\ (1, 36) = 56.68$, $p < .01$, and position, $F\ (1, 36) = 25.19$, $p < .01$, as well as an interaction between type and position, $F\ (1, 36) = 41.42$, $p < .01$. No other main effects or interactions were significant (all ps $> .05$).

As evident in Table 3 and Figure 1, full-phase readers recalled significantly more letters than partial-phase readers across all consonant types and positions. The locus of the significant interaction between consonant type and word position is apparent. Single consonants were recalled equally well regardless of their position in the words. However, double consonants were recalled differently depending on position. Final doublets were recalled much better than initial doublets. In other words, recall difficulty centered on the illegal initial letter pattern. Interestingly, this letter type made words harder to recall even though it sat in the most salient position of words, and even though the words were all learned to criterion. These findings do not support the predictions of phase theory. Visual orthographic features of words were retained in memory by both partial and full phase beginning readers. Mean accuracy for final doublets was in fact substantial, 75%.

In each list of words that were learned (see Table 1), the same final doubled letter appeared in three words (i.e., DEDD, KIDD, MUDD), whereas a different final doubled letter appeared in one word (i.e., PATT). A two-way ANOVA was conducted with reader group (full vs. partial phase) and letter recurrence (once vs. thrice) as the independent variables and number of final doubled letters spelled correctly as the dependent variable. (Recall of the doublet occurring once was

Table 4. *Misspellings of initial doublet words by doubling the final consonant*

Spellings Learned	Conventional Spelling	Misspellings Produced
Set A		
LLES	(less)	LASS (5), LESS
LLIM	(limb)	LAMM (4), LEMM (2), LUMM
LLUK	(luck)	LAKK (3), LUKK (2), KAKK
RRAG	(rag)	RAGG (2)
Set B		
RREK	(wreck)	REKK (2), RIKK
RRIP	(rip)	RIPP (2), REPP, RPP
RRUG	(rug)	RUGG (2), RGG, ROGG
LLAM	(lamb)	LAMM, LEMM
Total		34

multiplied by 3.) Results revealed no main effects or interactions involving reader group ($F < 1$) or letter recurrence, $F(1, 38) = 1.04$, $p > .05$. Mean performance was 2.03 (adjusted) for the nonrecurring doublet and 2.28 for the recurring doublet (maximum = 3). Thus, seeing the same letter doubled in three words did not make it easier to recall than seeing a doublet in only one word. This suggests that memory for doubled letters was word specific, that students did not generalize the recurring spelling pattern across words.

Because recall of initial doublets was poor, students' spelling errors on these words were examined. Many students misrecalled initial doublets as single consonants (e.g., 16 out of 20 students misrecalled RREK as REK), hence transforming an illegal letter pattern to a legal pattern. Interestingly, a number of these students committed an additional error by doubling the final consonant (e.g., RREK misrecalled as REKK). These errors are given in Table 4. Because none of these misspellings included a doubled initial consonant, this suggests that students remembered that there was a doubled letter in the word but assigned the feature to a legal position. Of those who wrote a correct final consonant in spelling these words, 28% doubled it. More of these doublings were produced by full alphabetic readers (79%) than by partial alphabetic readers (21%). It was not the case that students doubled final letters generally in all words. This error was much less apparent for CVC words containing single consonants. Of the students who wrote correct final consonants in CVC words, only 6% doubled them. These findings reveal the influence of beginning readers' knowledge about legal and illegal doubled letters on their word memory.

As evident in Table 1, most of the words that students were taught had modified rather than conventional spellings (i.e., 20 out of 24 words across lists). For example, *mud* was taught as MUDD. When asked to recall the spellings they learned, very few students wrote conventional spellings, only 5%, indicating that knowledge of correct spellings did not interfere with most students' memory for the words they were taught. Students were not expected to know conventional spellings because most of the words were rated above their reading grade level, at second grade or above (Harris & Jacobson, 1982).

Doublet spelling recognition posttest

A delayed spelling recognition test was given 2–3 days after word learning to see whether students recognized correct spellings of the doublet words they had learned from among very similar foils (i.e., FITT, FIT, FFIT). The alpha reliability for List A was .87 and for List B was .88. A three-way ANOVA was conducted with reader group, word set, and doublet position within words as the independent variables. Results revealed one significant effect, an interaction between word set and position, $F\ (1, 36) = 5.55$, $p < .05$. All main effects and the remaining interactions were nonsignificant (all ps > .05). Mean performance overall was 4.7 spellings recognized correctly (eight maximum), which was significantly greater than chance (2.7 correct; $p < .01$). Full and partial phase readers did not differ (see Table 3). These findings indicate that beginning readers retained some visual orthographic features of words in memory even after a 3-day delay.

Inspection of mean performance on initial and final doublet spellings on the two lists revealed the source of the interaction. Words with final doublets were recognized better than words with initial doublets on word set A ($M = 2.9$ for final vs. 1.8 for initial correct, maximum = 4) but not on word set B where performance on the two types was similar. Why the expected difference was evident on only one set of words is not clear. One problem with multiple choice spelling tests is that similarly spelled foils are seductive and undermine the speller's ability to remember which choice is correct, as Brown (1988) has shown. In fact, more advanced readers performed slightly but not significantly worse than less advanced readers (see Table 3).

Doublet spelling transfer posttest

On the spelling production transfer task with new words resembling the learned words, few students doubled any consonants when they wrote transfer words (see Table 3). In fact, 75% doubled no consonants. Thus, little if any generalization of orthographic patterns to new words occurred despite the fact that 67% of the words they had learned contained doubled consonants. Although Treiman (1993) observed some doubling of consonants when children spelled words, our findings indicate that children are not disposed to write doubled letters in words unless they have learned that those specific words contain doubled letters and unless the doubled letters occur in legal positions.

Evaluation of alternative explanations

Because the three sets of words differed (see Table 1), other possible explanations for the poorer learning and recall of initial doublet words requires consideration. One explanation is that children were less familiar with these words than with the other words. Because children's prior familiarity with the words was not pretested, we utilized two types of familiarity indices to assess whether this factor might explain findings. Word frequency and GE norms for each of the 24 words were drawn from Harris and Jacobson's (1982) *Basic Reading Vocabularies,* and correlations with performance on the words were examined. The metric of word learning was the number of children who made one or more errors reading each word during the first three learning trials ($M = 8.0, SD = 3.1$). The metric of spelling recall was the number of children who spelled the target consonants correctly in each word ($M = 11.7, SD = 5.2$). Results revealed that neither word frequency nor GE level correlated significantly with word learning ($r = .01$ and .14, respectively, both $ps > .05$) nor with spelling recall ($r = .03$ and $-.27$, respectively, both $ps > .05$). These findings indicate that poorer performance with initial doublet words was not explained by children being less familiar with these words.

The 24 words also varied in image ability. To assess whether this factor made initial doublet words harder to learn, "blind" adults were asked to judge the ease of forming mental images of the words presented in isolation. Seven of the 24 words were distinguished as more difficult. These seven words were not more common to the initial doublet set but were distributed among the three sets: two initial doublet words (*less, luck*), four final doublet words (*pat, dead, pad, fit*), and two single consonant words (*tough, deaf*). However, in the experiment, the words were not taught in isolation but rather in meaningful sentences spoken by the experimenter (i.e., "Two is *less* than five." "Do your shoes *fit* or are they too big?"). Adults judged that these sentences increased the ease of imaging these seven words. These findings indicate that image ability does not explain why words with initial doublets were harder to learn and recall.

Because different letters were doubled in initial position (LL, RR) and final position (TT, DD), we considered whether less familiarity with the doublets LL and RR might explain why memory was poorer. Familiarity was assessed by examining the numbers of words containing these doublets in preprimer, primer, and first grade level words (i.e., 515 words total) listed in Harris and Jacobson (1982). This analysis revealed 18 words ending in LL, 2 words containing medial RR, 5 words with medial TT, and no words containing DD. The fact that LL and RR were not less common than TT and DD argues against familiarity as an explanation for performance differences. Because LL was found to be especially common in words, much more so than RR, we wondered whether this influenced students' memory for the spellings of these doublets. Although only a few students spelled initial doublets correctly, more did so in writing LL words than RR words: $M = 6.25$ LL (range = 5–9) versus $M = 3.75$ RR (range = 2–5), based on 40 students maximum.

A final alternative explanation to consider is whether words beginning with L and R made them harder to learn than the other word sets. Two points make this unlikely. First, L and R are ranked as the fourth and sixth most common consonants in words and the 11th and 12th most common initial letters (Gibson & Levin, 1975). Second, in the spelling recall task, 95% of the children wrote L and R correctly, either as single or doubled letters. This was even slightly higher than students' mean recall of other initial letters in words (92%). This shows that L and R were not less well known than the other letters.

DISCUSSION

To summarize our findings, beginning readers learned to read words with final doubled consonants as easily as single consonants, but it took them longer to learn to read words containing doubled consonants positioned illegally at the beginnings of words. On a spelling recall test given after the words had been learned to criterion, children remembered final doubled consonants almost as well as final single consonants. However, their memory for initial doublets was very poor compared to the other types. These findings were observed for readers in the partial as well as the full phases of development. Even partial phase readers remembered orthographic information involving doublets. On the spelling recall test, they wrote 70% of the final doubled consonants correctly and 20% of the initial doubled letters. On the delayed spelling recognition task, they recognized spellings they had learned with doublets correctly beyond the level of chance. These findings show that beginners do process and remember visual orthographic features of words that are not dictated by phonemes in the words, and that this process is active as early as the partial alphabetic phase during the course of development. These results extend Cassar and Trieman's (1997) findings to word-learning and memory tasks, and they support their suggestion that phase theories of development such as Ehri's (1999) need to take account of the involvement of visually based orthographic patterns when children first begin reading and writing words.

How might Ehri's (1999) phase theory incorporate present findings? According to the theory, children in the partial and full phases use their graphophonemic knowledge to secure sight words in memory and do not process and remember orthographic patterns until later after they have learned to read words containing those patterns. One way to reconcile findings with the theory is to recognize that doubled letters were not only visual but also at least partially graphophonemic. Although memory for doubled letters in words required attention to a visual feature that was not dictated by phonology or by beginners' knowledge of 1:1 correspondences, this feature did not *violate* graphophonemic constraints. That is, doubled letters did not sit in words as extra silent or nonphonemic letters, but rather both letters could be connected to the same phoneme in a word. As such, the letters performed a graphophonemic function much like SH, TH, and CH digraphs. In the present study, beginners remembered double-letter graphemes almost as well as single-letter graphemes (i.e., $M = 74\%$ final doublets vs. 87% singles spelled correctly). These digraphs may have been especially easy to learn because each letter was already known as a symbol for that phoneme.

In terms of revising phase theory, this suggests that when beginners move into the partial phase of development and learn to read words, they notice not only phonemic properties but also visual properties of beginning and ending letters in the words. When the visual features can be connected to phonemes in the words and are consistent with their knowledge of how letters map sounds, the visual features become secured to phonemes as part of the word's representation in memory. This enables beginners as early as the partial alphabetic phase to remember double letter patterns in words.

Present findings bear on grain size theory proposed by Ziegler and Goswami (2005). Findings indicate that very early, beginning readers in English begin to process grain sizes larger than single letters. Perhaps the earliest to be processed are doubled letters symbolizing single phonemes. This may initiate beginners' awareness of the grain size problem in English, that regularity between orthography and phonology must be sought in multiletter patterns. It may pave the way to enabling beginners to work out more complex two-letter units symbolizing phonemes that differ from those represented by their constituent letters (e.g., SH vs. S and H separately). Further research is needed on beginning readers' acquisition and use of multiletter units.

Children's poor memory for initial doubled letters was surprising in light of their good memory for final doubled letters. We know that beginners pay special attention to initial letters in words when they learn to read them, so initial doubled letters should have been among the easiest to remember (Bowman & Treiman, 2002; Ehri & Saltmarsh, 1995; Rayner, 1976; Savage et al., 2001). Moreover, if graphophonemic connections are activated to link spellings to pronunciations in memory when words are learned, then why should a repeated initial letter that maps the initial phoneme be processed any differently from the same letter appearing as a singleton? One explanation is that knowledge about the illegality of doubled initial consonants created interference, making it harder for children to learn and remember these words. This could explain word learning among full-phase readers who displayed some awareness that initial doublets are illegal on the doublet pretest and who regularized illegal doublets when they spelled them in words. However, it fails to explain learning among partial phase readers who did not show awareness of this regularity on the doublet pretest, unless the pretest, being a metalinguistic task, was insensitive and did not detect these beginners' implicit knowledge about the illegality of initial doublets.

Another possible explanation involves how words are stored and accessed in memory. If beginning letters serve as the locator initiating retrieval of specific words in memory, their integrity as a phonemic symbol may be especially influential. The presence of two duplicate letters may have disrupted this process. This could have occurred if beginning readers expected each letter to represent a separate sound, as Elbro (2005) has suggested. Or it could have occurred if students regarded these initial doublets as possibly novel units whose sounds they had not yet learned. Although not adaptive in English, entertaining this possibility would uncover an important distinction in Finnish where doubled letters differ from their single counterparts in representing different phonemes (i.e., long vs. short). Because two-letter graphemes appear in many of the earliest words that children learn to read in English, being sensitive to grain sizes involving two-letter units would be expected (Ziegler & Goswami, 2005).

In analyzing initial doublet spelling errors, we were surprised to find that sometimes children shifted the doublet to the final letter while spelling the initial letter as a singleton, for example, RRAG was recalled as RAGG. This did not occur because there were more words with final than initial doublets on the list. Also this type of error was limited to these words and did not extend to single-consonant words. One possible explanation is that readers remembered that something was doubled in these words. This caused them to double a consonant, but to do it in a legal rather than an illegal position. This error was more common among full-phase readers who showed some awareness on the pretest that doubled initial letters are illegal. These findings provide evidence that children's general knowledge about the structure of spellings can distort their memory for the spellings of specific words.

The present study was designed to examine the generalizability and transfer of doubled letters to shed light on the acquisition of general knowledge of the alphabetic system. However, findings yielded little evidence. On the spelling recall test, children did not spell doublets appearing in three words any better than doublets in one word. On the spelling transfer task, children included few if any doublets in new words closely resembling the words they had learned. It may be that more practice with a larger number of words having the same orthographic patterns is needed to learn them. Alternatively, beginners may need explicit instruction to learn general patterns (Detterman & Sternberg, 1993).

One possible limitation of the present research is that it was conducted as a laboratory rather than a naturalistic study. However, it followed up previous naturalistic work revealing the presence of doubled letters in beginners' spontaneous spellings (Treiman, 1993). The advantage of laboratory studies is that targeted variables can be isolated and manipulated while competing variables are controlled, making it possible to uncover outcomes and pinpoint causes that would not otherwise be possible to detect. The fact that performance on the word learning task was strongly correlated with the WRMT-R word identification subtest as well as the developmental spelling task indicates that it reflected naturally occurring reading and spelling processes.

In conclusion, results of this study advance our understanding of word learning and memory processes in beginning readers. English is not a shallow writing system. Learning to read requires learning regularities that involve letter–sound relations that are more complex than one-letter symbolizing one sound. Typically, beginning reading instruction postpones the teaching of complexities. However, findings here showed that even novice beginners process and remember complexities involving visually based orthographic patterns in specific words when they learn to read them. Remembering doubled-letter orthographic patterns may be especially easy when the letters function together to represent single phonemes already associated with the constituent letters. This may be why they are learned early.

Results carry practical implications. Because doubled consonants are easy for beginners to learn and remember, they can be taught early during phonics instruction along with single-letter–sound correspondences rather than saved until later when multiletter patterns are introduced. They may even prove useful in disabusing children of the belief that the English alphabetic system consists of one-letter one-sound mappings. As a result, this may better prepare beginners to distinguish and learn more complex two-letter graphemes such as SH and NG, as well as larger units such as rime spellings. A number of preprimer and primer level words contain doubled consonants as well as doubled vowels, for example, *all, little, funny, happy, look,* and *see.* Knowing about the doublet pattern will help children grasp how these spellings are regular. Recognizing the regularity should improve their memory for the doubled letters when they spell these words. In addition, present findings suggest that it is not necessary for teachers to teach explicitly all the regularities of the writing system. Exposure to words may be sufficient to make even the least mature beginners aware that words begin with single letters but not doubled letters, and to teach them doubled letter consonants such as those studied here.

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