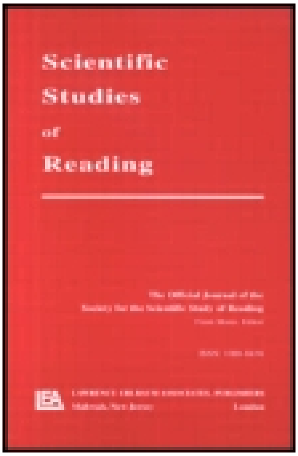

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English-speaking preschoolers who knew letters but were nonreaders ($M = 4$ years 9 months; $n = 60$) were taught to segment consonant–vowel (CV), VC, and CVC words into phonemes either with letters and pictures of articulatory gestures (the LPA condition) or with letters only (the LO condition). A control group received no treatment. Both trained groups outperformed controls on phoneme segmentation, spelling, word reading, and nonword repetition posttests. LPA training enhanced children's ability to learn to read words with practice more than LO training. The favored explanation, consonant with the motor theory of speech perception, is that LPA training activated the articulatory features of phonemes in words as children practiced reading them so that grapheme-phoneme connections were better secured in memory. Results also suggested that phoneme segmentation training with letters improved phonological short-term memory.

An important challenge for young children when they begin reading instruction is grasping the alphabetic principle (National Early Literacy Panel, 2008; Snow, Burns, & Griffin, 1998). Learning how graphemes in written words systematically represent phonemes in spoken words provides the foundation for acquiring word reading and spelling skills. Mastery of the alphabetic system requires phonemic awareness (PA), which involves the ability to attend to and manipulate phonemes in spoken words (Adams, 1990; Byrne & Fielding-Barnsley, 1989; Liberman,

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Shankweiler, Fischer, & Carter, 1974; Snow et al., 1998). Research has consistently demonstrated the important role that PA plays in reading development (Juel, 1988; Juel, Griffith, & Gough, 1986; Share, Jorm, Maclean, & Mathews, 1984). Meta-analyses of experimental studies have shown that instruction in PA benefits students' decoding, spelling, and comprehension skills (Bus & Van Ijzendoorn, 1999; Ehri et al., 2001; National Reading Panel, 2000). Among the various forms of PA, segmenting words into phonemes is among the strongest predictors of reading and spelling abilities, particularly in less transparent orthographies such as English (Nation & Hulme, 1997).

PHONEMIC SEGMENTATION INSTRUCTION

Children acquire spoken language easily, but the same is not true of phonemic awareness. Speech is perceived as an unbroken flow of sound with no pauses between phonemes in words. Adjacent phonemes are coarticulated making it even harder to detect them as separate sounds (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967). Most children require explicit instruction to learn how to segment and blend phonemes in words. Because of PA's foundational role in learning to read, the most effective techniques of teaching PA to beginners are important to identify. One purpose of the present study was to examine experimentally the effects of instruction that enhances children's awareness of the articulatory constituents of phonemes in words.

Previous studies have shown that teaching children to use letters to distinguish phonemes in words is an effective way to teach PA (Ball & Blachman, 1991; Bradley & Bryant, 1983; Byrne & Fielding-Barnsley, 1989; Ehri & Wilce, 1987; Hohn & Ehri, 1983; Tangel & Blachman, 1992; Uhry & Shepherd, 1993). Letters are thought to facilitate learning because they provide visible, concrete representations of phonemes that are transient and disappear as soon as they are spoken or heard. Letter markers allow children to hold phonemic segments in memory and to inspect and manipulate them during training. Letters facilitate the transfer of phoneme segmentation skill to reading and spelling tasks that require letter knowledge (Blaiklock, 2004).

Another approach to PA instruction involves teaching children to attend to their own articulators. Concrete markers in the form of articulatory pictures depicting positions of the mouth, lips and tongue are manipulated to reflect the sequence of phonemes in words (Castiglioni-Spalten & Ehri, 2003; Ehri & Sweet, 1991; P. Lindamood & Lindamood, 1998; Wise, Ring, & Olson, 1999). The effectiveness of teaching segmentation based on articulation is suggested by the motor theory of speech perception. According to Liberman (1998, 1999), the individual phonemes that occur during speech production are created by a series of linguistically specialized articulatory movements that represent the only invariants of the phonemes that make up speech. Phoneme perception is based on these movements rather than on the sounds that result (Liberman et al., 1967; Liberman & Mattingly, 1985). The claim of invariance has been challenged by Massaro and Chen (2008), who presented evidence that articulatory movements associated with phonemes do vary as much as their acoustic features. However, an experiment by D'Ausilio et al. (2009) showed that stimulating parts of the motor cortex facilitated the perception of targeted phonemes, thus supporting the view that articulatory movements contribute to the perception of phonemes.

Two experiments have examined whether teaching phoneme segmentation with articulatory gestures is more effective than teaching without this focus. Wise et al. (1999) examined whether phonics-based reading instruction helped second- through fifth-grade struggling readers improve their reading when instruction included articulatory awareness compared to instruction without articulation. Although the students in both conditions gained substantially in PA, decoding, and word reading compared to students not receiving these treatments, no advantage was provided by the articulatory awareness component.

The second experiment was conducted by Castiglioni-Spalten and Ehri (2003) with younger kindergartners who received only phonemic segmentation instruction, not any reading instruction as part of the treatment. One group was taught PA by segmenting words with articulatory pictures. Another group was taught PA with blank markers. Letters were not part of training, but children already knew the names of the letters that symbolized the sounds being manipulated, so transfer of PA training to word reading and spelling could be examined. Consistent with the Wise et al. (1999) study, the two treatment groups made greater gains following training than a no-treatment control group, but no benefit of articulation beyond that of blank markers was observed in acquiring PA or its transfer to spelling. The present study was conducted to improve on the previous two studies. Younger nonreading preschoolers rather than older struggling readers were the participants. The comparison group was taught to segment with letters rather than blank markers, and the articulation group was taught segmentation with both mouth pictures and letters.

EARLY READING AND SPELLING DEVELOPMENT

Learning to read words from memory entails a process of forming connections between letters in spellings and phonemes detected in pronunciations, storing these connections in memory, and accessing them to read the words the next time they are seen. Phonemic awareness is needed to read words in this way, to remember their spellings, and to spell unfamiliar words by detecting and writing the phonemes in spoken words. According to Ehri's (2005) phase theory of reading development, even very young children are able to learn to read words in this way. Once they acquire letter knowledge and some phonemic awareness, they move from the *pre-alphabetic* phase to the *partial alphabetic* phase. They can read words from memory, that is, by accessing partial connections between some of the letters and sounds that were formed when the words were read previously. They can also invent partial spellings by writing some of the letters whose names contain their sounds and whose sounds are detected in words. However, they lack the ability to decode unfamiliar words.

Simplified word reading and spelling tasks have been used to reveal what prereaders and novice beginners are able to do even before they have received formal reading instruction in school. Studies of young children's writing have shown that they can use letter-name or letter-sound relations to invent partial spellings of words, for example, YL (*while*), MFN (*muffin*), KAK (*cake*), TNS (*tennis*) (Read, 1971, 1975; Treiman, 1985, 1993). Studies have also shown that children in the partial alphabetic phase can use their letter name or letter sound knowledge and phonemic awareness to remember how to read simplified phonemic spellings of words when given practice reading the words with corrective feedback over several trials, for example, AP (*ape*), DK (*duck*), LN (*lunch*), JRF (*giraffe*) (Castiglioni-Spalten & Ehri, 2003; Ehri & Wilce, 1985; Roberts, 2003; Scott & Ehri, 1990; Shmidman & Ehri, 2010). Children do this by forming connections between letters they see and sounds they detect in the words, storing them in memory, and accessing the connections to read the words. One purpose of the present study was to examine whether both forms of PA instruction would facilitate performance in simplified word reading and spelling tasks.

THE PRESENT STUDY

The present study was conducted with preschoolers in the pre-alphabetic phase to determine whether PA instruction would move them into the partial alphabetic phase and enable them to read and spell words. Tasks and procedures used by Castiglioni-Spalten and Ehri (2003) were improved. Segmentation was taught with letters only rather than blank markers in one treatment condition (LO) and with letters and articulatory pictures in the other condition (LPA). LPA training involved teaching children how eight pictures depicting different mouth positions corresponded to one or another of 15 phonemes and how to use these pictures as well as letters to segment spoken words into phonemes. LO training was conducted identically but without the articulation component. A no-treatment control group was included. Children were given several posttests to assess whether training was effective in teaching phonemic segmentation and whether training transferred to simplified word reading and spelling and to nonword repetition tasks.

The posttest of particular interest involved giving children practice over several trials so they could remember how to read a set of words. In the Castiglioni-Spalten and Ehri (2003) study, this task proved difficult because the words all began with the same letter, causing children to mix up the words based on partial cues. When their readings were scored to include partially correct responses, that is, words containing at least two phonemes spelled in the written words, children trained with mouth pictures statistically outperformed the control group ($d = 1.25$), whereas children trained with blank markers did not ($d = 0.38$). In the present study, the same task was used but words were spelled with fewer letters and with different initial letters.

Two possible explanations for the salutary effects of articulation on word reading were addressed. One was that articulation training helped to secure the attachment of graphemes to phonemes in memory by activating the articulatory features of phonemes in pronunciations during the word learning trials. To strengthen these connections in the present study, letters were added to segmentation training with mouth pictures. A second reason is that articulation training may have enhanced children's phonological memory for the words being read. This was examined by including an oral nonword repetition task (Gathercole, 2006). The question of interest was whether PA training with articulatory pictures and letters would improve word reading and phonological memory more than PA training with letters only.

METHOD

Participants

The participants were 60 children (35 female, 25 male), ranging in age from 4.1 to 5.8 years ($M = 4.9$ years) whose parents gave written consent. They were enrolled in two private, middle-class to upper middle-class preschools in New York State. They were proficient speakers of English without any apparent hearing loss, neurological disorders, uncorrected vision, or severe emotional or behavioral problems. To enter the study, they had to know 15 target letter names, segment no more than three consonant–vowel (CV), VC, or CVC words into phonemes, neither read nor spell more than one nonword, read no target words used in posttests, read no more than three preprimer words, and score no more than 1 standard deviation below the mean for their age on the Peabody Picture Vocabulary Test (PPVT–4; Dunn & Dunn, 2007). Fourteen children were dropped. One refused to be pretested. Seven could not name enough target letters. Two segmented too many words into phonemes. Two read too many nonwords. Two could not be matched to form a triplet.

Children enrolled in the same school were matched to form triplets based on similar scores on several pretests (segmentation, word reading and spelling, vocabulary). Triplet members were randomly assigned to the three experimental conditions: LO, LPA, and no-treatment control.

The literacy curriculum in the preschools was focused on the joys of books and letters. Each day, teachers read and discussed themed storybooks. Each week a different letter and its sound were taught, but no formal reading instruction involving word and text reading or writing was provided.

Materials and Procedures

Children in the LO condition received instruction in letter–phoneme correspondences and phonemic segmentation with letters. Children in the LPA condition received the same instruction and in addition were taught to segment words into phonemes with pictures of articulation gestures. Children in the control condition remained in their classrooms and received no special instruction. Children in the three conditions completed one pretest session, a posttest session 1 day after training ended, and another posttest 7 days later, each session lasting about 30 min. Children in the LO completed 4 to 9 training sessions, and children in the LPA condition completed from 4 to 11 training sessions, as many as were necessary to reach criterion segmenting the CV/VC and CVC word sets. Each training session lasted between 10 and 20 min. The average time between pretest and posttest was 40 days for each of the groups. Vacations and absences lengthened the time for some students. All testing and training were conducted individually by one experimenter (the first author).

Pretests

The following pretests were administered in the order listed.

1. *Naming Letters.* Children named 15 capitalized target letters representing the phonemes to be segmented during training: A, B, D, E, F, K, L, M, N, O, P, S, T, V, Z. These letters were chosen because each letter name contains a target phoneme (e.g., B named "bee" contains /b/). The remaining uppercase letters and all lowercase letters were tested as well. Letters were shown on four cards. If children erred on any uppercase target letter, the experimenter pointed to the letter and asked for its name. If children still erred, they were asked to write the letter. If still in error, a card displaying several letters was presented, the missed letter was named, and children pointed to it. To qualify for the study, children had to show knowledge of all 15 uppercase target letters by the final task. Letter naming accuracy was scored.
2. *Segmenting Words into Phonemes.* Children segmented 10 words constructed from the 15 target phonemes: 2 VC, 2 CV, and 6 CVC words. The words were *aid, eat, foe, nay, bowl, cope, phase, seam, take, veal.* The task was Mrs. Magic

Mouth (Uhry & Ehri, 1999). A drawing of a woman's face with five blank tiles placed on her open mouth was presented. Children were told "Look at Mrs. Magic Mouth. She has sounds in her mouth and you can see them." For practice, the experimenter demonstrated and had the child copy how to segment a VC, a CV, and a CVC word with corrective feedback. The segmentation procedure involved removing a tile from the mouth as each phoneme in the word was spoken. After this practice, children heard, repeated, and segmented the 10 target words without any feedback. Two measures were distinguished: the number of words (10 maximum) and the number of phonemes (26 maximum) segmented correctly. Credit was given for consonant phonemes that were followed by a schwa (e.g., "buh" for /b/) but not for consonants followed by the vowel in the word (e.g., "bo" for /b/ in "bowl"). Any child who segmented more than 3 words correctly was excluded from the study.

3. *Reading Nonwords.* The nonword reading task was given to screen children for their phase of word reading. According to Ehri (2005), readers in the partial alphabetic phase lack the ability to decode nonwords. Children who read more than one nonword were excluded from the study. The nine nonwords included three VC, three CV, and three CVC words constructed from the 15 training sounds and printed in uppercase letters on a card: AF, EB, OS, PO, TA, VE, DEM, NAK, ZOL. Children were told that these were made-up words without any meaning but still readable. The experimenter modeled how to sound out the nonword, ZED, pronounced /zid/ with long E before the test began. Credit was given for either long or short vowel pronunciations.
4. *Reading Preprimer and Target Words*. The word reading task was given to assess children's development as readers and to eliminate those who could read any target words to be taught in the word learning posttest. Children were shown 22 preprimer words mixed with 12 target words and eight pictures to provide some success. No child read any target words.
5. *Spelling Nonwords.* Children's ability to generate phonemic spellings of nonwords was assessed. Three VC, three CV, and three CVC nonwords were constructed from the 15 target phonemes: AN, EP, OL, KO, VA, ZE, BOS, MEF, TAD. Children were given 26 capital letter tiles. The experimenter spoke nonwords using the long vowel pronunciation. Children repeated and selected letters to spell them. Responses scored were the number of nonwords (9 maximum) and the number of sounds (21 maximum) spelled phonemically (e.g., spelling of /k/ as K or C was accepted). Children writing more than one nonword correctly were excluded from the study.
6. *Recognizing Vocabulary Word Meanings.* The PPVT–4 (Dunn & Dunn, 2007) was given to assess children's English proficiency. Children pointed to one of four pictures depicting the meaning of each word spoken by the experimenter. According to the manual, the reliability varies from .89 to .97. No child scored below a standard score of 99 ($M = 100$).

7. *Nonword Repetition.* The Children's Test of Nonword Repetition (CNRep), developed by Gathercole and Baddeley (1996), was given to measure short-term phonological memory. Before beginning the test, children practiced repeating a nonword until they succeeded. Then they listened to nonwords on a tape recorder and were told to repeat each word as soon as they heard it. The total number of correct repetitions (40 maximum) was scored. The split half reliability was 0.85.

Experimental Conditions

LPA condition. Children in the LPA condition used 8 tiles displaying mouth pictures and 15 tiles displaying uppercase letters to learn to segment and spell CV, VC, and CVC words and nonwords. The children used a hand mirror to examine their mouth movements during the articulation part of the training, which consisted of several steps described next.

1. *Teaching Correspondences between Mouth Pictures and Phonemes.* Children were taught to associate pictures of eight mouth positions with one or another of 15 phonemes. These associations are shown in Figure 1. Each picture depicted from 1 to 4 phonemes. Lips closed represented /p/, /b/, and /m/. Mouth open and tip of tongue lifted to the roof of the mouth depicted /t/, /d/, /l/ and /n/. Mouth open and back of tongue lifted depicted /k/. Teeth resting on lower lip with air escaping represented /f/ and /v/. Teeth together with air escaping depicted /s/ and /z/. The lips and mouth ranging from a smile to a rounded position represented the three long vowel sounds. The 15 associations were taught in four successive sets: Set 1: /p/, /t/, /f/, long a; Set 2: /b/ d/ /v/ long e; Set 3: /m/ /l/ /k/ /s/; Set 4: /z/ /n/ long o.

   First the experimenter demonstrated how the mouth moves when words are pronounced, and children examined their mouth movements in a mirror. Then they were taught to associate pictures of mouth positions with phonemes, one set at a time. The experimenter explained each mouth picture. Children practiced viewing the pictures, hearing and repeating each phoneme presented in random order, pointing to the mouth picture that matched that phoneme, and receiving corrective feedback. The children learned each set to a criterion of two perfect successive trials. This was followed by a review of all 15 picture–phoneme associations until children reached a criterion of two perfect trials in a row.
2. *Teaching Segmentation of VC and CV Words with Mouth Pictures.* Children were presented with 13 mouth picture tiles, 3 long-vowel pictures, and two copies of each of the 5 consonant pictures. Tiles were placed in front of children along with a drawing of two squares arranged horizontally. The experimenter demonstrated the procedure of moving each of 2 correct pictures

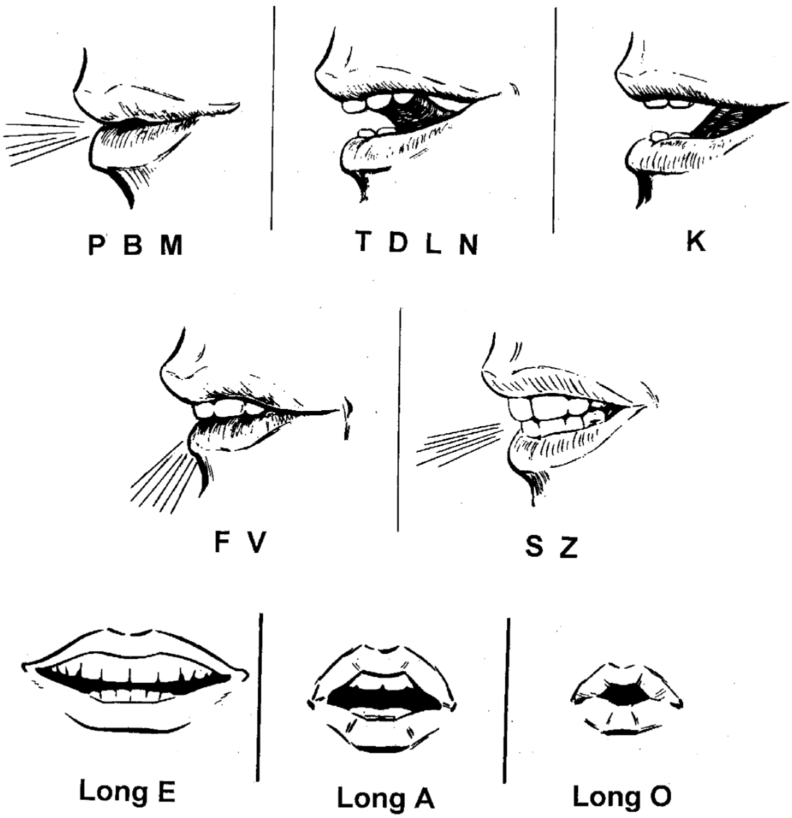

FIGURE 1 Pictures of articulation gestures and their associations to phonemes in letter names. *Note.* Drawings of mouth taken from C. Lindamood and Lindamood (1975). Copyright 1975 by C. & P. Lindamood. Reprinted by permission.

into its square from left to right as she spoke each of two segments in a word. Children copied her to practice the procedure. Then they segmented VC and CV words constructed from the 15 target sounds. They heard and repeated each word and then pronounced each phoneme as they moved its picture into a square. A mirror was available if children needed it. Corrective feedback was provided. The experimenter cycled through the list of 24 words until children reached a criterion of 8 successive words segmented correctly.

3. *Teaching Correspondences between Phonemes and Letters.* Children were taught associations between phonemes and the 15 target letters. The experimenter explained how each phoneme can be heard in the letter's name, which they already knew, as determined during pretesting. Then children were

taught successively the same four sets of phonemes used in Step 1. The children heard each phoneme, repeated it, and pointed to the corresponding letter. Children continued until reaching a criterion of two perfect successive trials on each set. This was followed by a review of all 15 phoneme–letter relations practiced to a criterion of two perfect successive trials.

4. *Teaching Segmentation of VC and CV Words with Letters.* The 15 letter tiles were placed in front of children along with the drawing of two horizontal squares. The experimenter demonstrated and had children copy the procedure for segmenting CV and VC words by moving letter tiles into the squares as phonemes were pronounced. Then they segmented the same VC and CV words taught in Step 2. Children repeated each word and then pronounced each phoneme as they moved its corresponding letter tile into a square. Corrective feedback was provided. The experimenter cycled through the list of 24 VC/CV words until children reached a criterion of 8 successive words segmented correctly.
5. *Teaching Segmentation of CVC Words with Mouth Pictures.* The eight mouth pictures were presented along with the horizontal drawing of three squares. Children segmented CVC words constructed from the 15 target sounds. The procedure was identical to that used in Step 2. The experimenter cycled through the list of 24 CVC words until children reached a criterion of 8 successive words segmented correctly.
6. *Teaching Segmentation of CVC Words with Letters. C*hildren segmented the same CVC words, this time by moving letter tiles into three squares. The procedure was the same as that in Step 4. The experimenter cycled through the list of 24 CVC words until children reached a criterion of 8 successive words segmented correctly.
7. *Teaching Segmentation of CV/VC Words Mixed with CVC Words Using Mouth Pictures and Letters.* The same VC/CV and CVC words were segmented, this time by positioning mouth pictures in one row of three squares followed by letters in a second row of three squares displayed beneath the first row. The words were randomly mixed. The experimenter no longer told children how many segments to find in each word. The mouth pictures and letter tiles were arrayed separately on the table. The letter tiles were covered while children heard and repeated a word, counted the number of phonemes, selected the mouth picture that corresponded to each phoneme as they pronounced it, and placed the picture in a square. Then the experimenter uncovered the letter tiles; children repeated the word again, selected a letter tile as they pronounced each phoneme, and placed it in a square. Corrective feedback was provided. The experimenter cycled through the word list until children reached a criterion of eight successive words segmented correctly with both markers.

Children were taught and reminded to use the mirror to examine their mouth movements as part of both the correspondence and segmentation training with articulatory pictures. When incorrect responses occurred, children were instructed to use the mirror as part of corrective feedback. Every LPA child used the mirror as he or she completed correspondence and segmentation test trials. However, use of the mirror faded as children became more successful. None of the LPA children needed to use the mirror during the final segmentation word review.

LO condition. Children in the LO condition learned to use the same 15 letter tiles to segment words, but no attention was drawn to articulation, and mouth pictures were not taught. The steps were nearly identical to those involving letters in the LPA training condition. Corrective feedback was provided.

1. *Teaching Correspondences between Phonemes and Letters.* (Same as Step 3 of LPA training just described.)
2. *Teaching Segmentation of VC and CV Words with Letters.* (Same as Step 4 of LPA training just described.) Because each word was segmented twice in the LPA condition, once with mouth pictures and then with letters, children in the LO condition segmented each word twice as well. After the first segmentation, the letters selected were placed back in the larger array, and children performed the segmentation again before moving to the next word.
3. *Teaching Segmentation of CVC Words with Letters.* (Same as Step 6 of LPA training just described.) The LO children segmented each word twice with letters.
4. *Teaching Segmentation of CV/VC Words Mixed with CVC Words Using Letters.* The same procedures in Step 7 of LPA training were followed, except that only one row of squares was displayed and only letter tiles were used to segment VC/CV and CVC words. The LO children segmented each word twice with letters.

No treatment control condition. Children in the no treatment control condition remained in their classrooms and received no special training.

One-Day Posttest

Several posttests were administered 1 day after training ended and 7 days later. Words and nonwords included in posttests were not those taught during training. Each session lasted about 30 min. The tasks were given in the order listed next.

1. *Segmenting Words into Phonemes.* The Mrs. Magic Mouth pretest was repeated as a posttest to assess whether PA training was effective and whether

both treatments enhanced PA to the same extent, replicating Castiglioni-Spalten and Ehri's (2003) finding. Seven new words constructed from the 15 target phonemes were added: *bean, date, gnome, blow, old, steak, peeks.* There were 2 VC, 2 CV, 9 CVC, and 1 each of CCV, VCC, CCVC, and CVCC words. Words with consonant clusters were included to assess for transfer. Procedures differed from those used during segmentation training in that no diagram of squares was provided and children segmented with blank tiles rather than mouth pictures or letters. Word-level and phoneme-level scores were calculated. The alpha reliability on the word-level score was 0.88.

2. *Spelling Nonwords.* This task was the same as the pretest and was included to assess the effectiveness of segmentation training with letters and to see whether both forms of training enhanced spelling performance to the same extent, as Castiglioni-Spalten and Ehri (2003) found. Three nonwords constructed from target phonemes were added—EF, ZA, PON pronounced with long vowels. Responses scored were nonwords (12 maximum) and phonemes (28 maximum) spelled phonemically. The alpha reliability on the nonword measure was 0.91.
3. *Learning to Read Phonemic Spellings of Words.* The word learning task assessed children's ability to remember how to read words. Children practiced reading phonemic spellings of six words, three CV and three CVC, constructed from the target letters: *BO* (*bow*), *SA* (*say*), *TE* (*tea*), *BEK* (*beak*), *SOP* (*soap*), *TAL* (*tail*). The set included two words beginning with B, S, and T, and two words containing the same long-vowel phoneme.

   Each word was printed on a card. During the first study trial, the experimenter showed each word, spoke a meaningful sentence containing the word, pointed to the word, and said "This says ________," and had children repeat the word. The study trial was followed by several test trials. On each, the six words were presented one by one in random order, children tried to read each and were corrected if necessary. Children completed a minimum of 5 trials and a maximum of 8 trials if they failed to reach a criterion of 3 perfect successive trials. Responses scored were the number of words read correctly on each trial and the total number across 8 trials (48 maximum). If children completed fewer than 8 trials because they reached criterion, they were given credit for 8 trials of correct performance. The alpha reliability on the total word measure was 0.94.
4. *Recalling the Phonemic Spellings of Words.* At the end of the word learning task, children recalled spellings of the 6 words that were taught. An array of 26 letter tiles was displayed, and they were told to remember the letters they saw in the words. Two measures were calculated: words spelled (6 maximum) and letters spelled (15 maximum) as taught. The alpha reliability on the word-level measure was 0.89.

5. *Reading Nonwords.* To assess whether segmentation training impacted decoding skill, the nonword pretest was repeated as a posttest. Procedures were identical. The alpha reliability was 0.92.
6. *Nonword Repetition*. The CNRep pretest was repeated as a posttest with the same items and procedures (Gathercole & Baddeley, 1996). The number of correctly repeated nonwords (40 maximum) was scored. The split-half reliability calculated on the posttest was 0.91.
7. *Recalling Letter–Phoneme Correspondences.* To assess whether the 15 target letter-sound correspondences had been learned, children were shown the 15 uppercase target letters in mixed up order and pronounced each sound.
8. *Recognizing Correspondences between Mouth Pictures and Phonemes*. This multiple-choice task assessed whether children who received LPA training had learned the picture–sound correspondences. The eight articulation pictures were displayed in mixed up order, each of the 15 target sounds was pronounced, children repeated each sound, and pointed to its picture. Chance-level performance was 1.88 items correct (i.e., one eighth correct by chance on each item multiplied by 15 items).

Seven-Day Posttest

Some of the earlier posttests were readministered 7 days later in the order listed next during a session lasting about 30 min.

1. *Reading Words Previously Taught.* To determine whether children remembered how to read the words they had been taught on the 1-day posttest (see Task 3 just presented), they were shown the six CV and CVC words and asked to read them. The alpha reliability was 0.61.
2. *Segmenting Words into Phonemes*. Children segmented 14 words constructed from the target sounds: *ate, oak, doe, see, dean, fees, foam, lobe, paid, vane, aches, plea, dotes, bleat.* The Mrs. Magic Mouth procedures and scoring were identical to the previous tests but the words were new. The alpha reliability on the word measure was 0.87.
3. *Spelling Nonwords*. The same items and procedures used in the earlier posttest were repeated. The alpha reliability on the nonword measure was 0.91.
4. *Learning to Read Phonemic Spellings of Words*. The procedures and scoring were identical to the previous posttest (Task 3) but the words were new: KE (*key*), LO (*low*), PA (*pay*), KAV (*cave*), LEF (*leaf*), POL (*pole*). The alpha reliability on the total word measure (maximum of 48 correct) was 0.93.
5. *Recalling the Phonemic Spellings of Words*. Children used letter tiles to recall spellings of the words taught in Task 4. The procedures were the same as in the earlier pretest. The alpha reliability on the word measure was 0.91.

Design and Statistical Analyses

The experiment was a pretest–posttest control group design. The independent variable was phoneme segmentation training with three levels: LO, LPA, and no-treatment control. Children were matched to form triplets based on similar scores on some of the pretests, and members were randomly assigned to one of the three conditions. The dependent measures were drawn from the training tasks and posttests. Matched subjects were analyzed as independent observations.

To compare the three groups on pretests, analyses of variance (ANOVAs) were used except when measures included excessive floor or ceiling effects necessitating binomial logistic regressions (see next). Because the groups differed significantly on the phoneme segmentation pretest, this variable was included as a covariate in statistical analyses of posttest performance. Because the control group exhibited floor effects on many of the posttests, binomial logistic regression analyses were conducted (see next) to determine whether the control group differed significantly from either treatment group. To compare the two treatment groups on outcomes, ANOVAs were employed on training session measures and analyses of covariance (ANCOVAs) on posttest measures.

Treatment-control group comparisons were analyzed using a generalized linear model (GLM) conducted with SPSS on posttests where the same items were given to all participants. This analysis was necessitated by the presence of excessive low scores which created substantial skew in the no-treatment control group. GLM does not require the assumption of normality in the distribution of scores. In addition, GLM allows the inclusion of a covariate, which was necessitated by unequal performance of the three groups on the phoneme-level segmentation pretest despite random assignment. The type of GLM model used was the binomial logistic regression (BLR) model (Agresti, 1996). With this model we examined whether the independent variable predicted a binomial outcome variable, in this case, the number of correct and incorrect responses on a fixed number of items. We used the model to test whether the log (odds) probability of correct responses of each of the two treatment groups differed statistically from the control group. "Odds" refers to the odds ratio, that is, the ratio of the odds of an event occurring in one group to the odds of it occurring in another group. Individual regression coefficients were compared to determine whether performance in the control condition treated as the baseline differed significantly from performance in each of the treatment conditions. In SPSS, the Hosmer-Lemeshow test assesses the goodness of fit for the model. Estimation procedures (i.e., robust covariance matrix and the Pearson scale parameter method) were employed to address any lack of fit. The Wald chi-square statistic tested effects of conditions in the model.

RESULTS

Characteristics of Participants

Characteristics, mean performance of the three experimental groups on pretests, and test statistics are given in Table 1. Because most children scored zero on all but the vocabulary measure, the latter score was the primary basis for forming triplets. As evident in Table 1, statistical analyses revealed that the three groups did not differ on most pretests. However, by chance, two of the groups differed significantly on the phoneme segmentation and uppercase 26-letter naming tasks, with the LO group outperforming the control group. Because children had to know the 15 target letters to qualify for the study, differences in letter knowledge centered on knowledge of nontarget letters. To take account of pretest differences, phoneme segmentation performance was included as a covariate in the statistical analyses of posttests.

TABLE 1
Characteristics of Children, Means, Standard Deviations, and Test Statistics for the Letter Plus Articulation (LPA) Group, the Letter Only (LO) Group, and the Control (C) Group on the Pretests

		Treatment Group			
Characteristics and Pretests	*LPA M (SD)*	*LO M (SD)*	*C M (SD)*	*Test Stat*	*Post Hoc*
Age[a]	4;9 (.31)	4;9 (.39)	4;7 (.38)		
Gender	14F; 6M	10F; 10M	11F; 9M		
Segmentation					
Phonemes (26)	4.10 (4.8)	4.95 (3.4)	2.30 (3.4)	*W*: 0.42 *ns*	LPA = LO
% Zero	40%	15%	45%	*W*: 2.00 *ns*	LPA = C
				W: 4.90*	LO > C
Letters					
Uppercase (26)	24.3 (2.1)	25.1 (1.4)	23.3 (1.7)	*W*: 2.31 *ns*	LPA = LO
				W: 2.15 *ns*	LPA = C
				W: 8.83**	LO > C
Lowercase (26)	17.8 (4.3)	18.1 (3.4)	17.4 (4.1)	*F*: 0.18 *ns*	
Spell phonemes (21)	6.05 (4.1)	5.90 (3.7)	4.90 (3.0)	*F*: 0.59 *ns*	
% Zero	15%	15%	10%		
Nonword repetition (40)	24.7 (6.2)	24.6 (8.4)	22.8 (7.3)	*F*: 0.41 *ns*	
Vocabulary (SS)	119.2 (7.1)	118.8 (6.9)	118.7 (7.1)	*F*: 0.03 *ns*	

Note. There were 20 children in each group. W = Wald chi-square values in the binomial logistic regression analyses; F = F statistic in analyses of variance with $df = 2, 57$; LPA = letters and pictures of articulatory gestures; LO = letters only; C = no-treatment control; SS = standard score.

[a]Years, months.

*$p < .05$. **$p < .01$. *ns* = not statistically significant.

Table 1 reveals the extent of these preschoolers' development in literacy and language. They were able to segment and to spell some single phonemes, but few if any spelled entire words or nonwords. They knew the names of most uppercase letters and 69% of lowercase letters on average. They had vocabularies that were well above average. They could repeat on average some four-syllable nonwords. However, they performed poorly reading words and nonwords and segmenting and spelling whole words (i.e., 90–100% received zero scores across groups on these measures). This indicates that these preschoolers were prereaders but had letter knowledge.

Performance During Training

The two segmentation treatment groups were compared in their performance during training. As evident in Table 2, the LO group took significantly less time to complete all the phases of training than the LPA group, not surprisingly because LO children were taught to segment only with letters, whereas LPA children were taught with both mouth pictures and letters.

As shown in Table 2, the LO group practiced using letters to segment significantly more CV, VC, and CVC words to reach criterion than the LPA group did.

TABLE 2
Means, Standard Deviations, and Test Statistics for the Letter Plus Articulation (LPA) Group and the Letter Only (LO) Group During the Training Sessions

	Training Group			
Training Measures	*LPA M (SD)*	*LO M (SD)*	*F Stat*[a]	*Post Hoc*
Minutes of training	149.0 (34.2)	111.8 (33.5)	12.14**	LPA > LO
Range (min)	80–210	65–195		
Letter segmentation[b]				
VC/CV words	11.75 (3.6)	15.95 (6.1)	7.07*	LO > LPA
CVC words	9.85 (2.5)	15.15 (5.7)	14.52**	LO > LPA
Articulation segmentation[b]				
VC/CV words	12.35 (4.8)	—	—	
CVC words	13.60 (5.2)	—	—	
Segmentation of mix[b]	11.70 (2.9)	13.65 (4.5)	2.65 *ns*	

Note. There were 20 children in each group. V = vowel; C = consonant.

[a]$df = 1, 38$. [b]Number of words attempted in order to reach a criterion of eight successive words segmented correctly.

$^{*}p < .05$. $^{**}p < .01$. *ns* = not statistically significant.

This occurred because the LPA group had prior experience segmenting words with mouth pictures before they segmented with letters. However, in the final review phase, the groups did not differ significantly in the trials to reach criterion. It was interesting to note that despite achieving mastery on earlier phases when two- and three-phoneme words were taught separately, children needed substantial additional practice to master segmenting a mix of the two word types.

Performance on Posttests

Effectiveness of segmentation instruction. Several 1-day posttests confirmed that children learned what they were taught. In recalling associations between mouth pictures and phonemes, all children in the LPA condition recognized at least 13 of the 15 associations. In contrast, children in the other two groups performed at a chance level: $M = 1.95$ for LO; $M = 1.30$ for controls; chance = 1.88. Memory for the 15 letter–sound associations taught during training revealed mastery levels as well. Among LPA and LO trained children, 39 of 40 received perfect scores, whereas only 1 control child performed this well: *M*s = 15.00 (LPA), 14.95 (LO), and 7.50 (no-treatment control).

Performance on the 1- and 7-day spelling posttests showed that both forms of PA training enabled children to spell better than controls. This task differed from the training task in that all 26 letter tiles rather than just 15 target letters were provided, and no squares were displayed for positioning the letters. Table 3 reveals that the log (odds) probability of correct responses was significantly greater in the two training conditions than in the control condition on both nonword- and phoneme-level spelling measures. In fact, most control students scored zero on the nonword level measure.

Students who received LPA training spelled nonwords significantly better than LO trained students, but this difference was short lived. Results of ANCOVAs revealed significant effects on both nonword-level and phoneme-level measures on the 1-day posttest, but the difference diminished and was nonsignificant after 7 days (see Table 3).

Phoneme segmentation on the posttests was conducted with blank markers rather than letters. Comparison of each treatment group to the control group using BLR analyses revealed significant differences favoring the treatment conditions on both word-level and phoneme-level measures on both 1-day and 7-day posttests (see Table 3). The majority of control children (90%) were unable to segment any words correctly. ANCOVAs revealed that the LPA group segmented significantly more words and phonemes on the 1-day posttest and significantly

TABLE 3
Means, Standard Deviations, Test Statistics, Post Hoc Pairwise Tests, and Effect Sizes to Compare the Letter Plus Articulation (LPA), Letter Only (LO), and Control (C) Groups on One-Day and Seven-Day Posttests

	Experimental Conditions							
Posttest Measures	*LPA*	*LO*	*C*	*Wald*[a] *LPA vs. C*	*Wald*[a] *LO vs. C*	*F (1, 37)*[a] *LPA vs. LO*	*M*	*Effect Size d and CI for (LPA vs. LO)*[b]
One-day posttests								
Spelling								
Nonwords (12)	8.45 (3.1)	6.00 (2.8)	0.50 (1.1)	54.90**	32.38**	7.39**	0.85	0.20 *to* 1.50
% Zero	0%	5%	80%					
Phonemes (28)	24.30 (3.3)	21.15 (3.9)	7.15 (5.1)	96.83**	59.11**	7.77**	0.88	0.23 *to* 1.52
Phoneme segmentation								
Words (17)	5.45 (3.9)	3.10 (2.5)	0.20 (0.6)	30.20**	16.49**	8.04**	0.79	0.15 *to* 1.44
% Zero	10%	25%	90%					
Phonemes (49)	26.70 (7.5)	22.50 (7.7)	4.85 (5.8)	72.31**	41.84**	4.58*	0.62	−0.01 *to* 1.25
% Zero	0%	5%	40%					
Word learning								
Total read (48)	40.65 (5.1)	31.40 (10.4)	10.60 (8.1)	120.03**	39.04**	12.69**	1.12	0.46 *to* 1.79
Memory for spellings								
Words (6)	5.00 (1.6)	4.15 (1.6)	0.70 (1.3)	32.28**	26.73**	2.67 *ns*	0.52	−0.11 *to* 1.15
% Zero	5%	0%	65%					
Phonemes (15)	13.55 (3.4)	12.70 (2.2)	6.00 (3.6)	17.37**	37.39**	0.93 *ns*	0.30	−0.32 *to* .93
Nonword reading (9)	3.00 (3.4)	0.80 (1.3)	—	—	—	W[a]: 9.39**	0.87	0.23 *to* 1.52
% Zero	35%	65%	100%					
Nonword repetition (40)	27.75 (5.0)	27.10 (8.2)	18.65 (5.8)	27.00**	9.59**	0.10 *ns*	0.10	−0.52 *to* 0.72
Seven-day posttests								
Spelling								
Nonwords (12)	7.10 (3.2)	6.20 (3.6)	0.40 (1.0)	35.98**	27.52**	0.98 *ns*	0.30	−0.32 *to* 0.93

(*Continued*)

TABLE 3
(Continued)

Posttest Measures	*Experimental Conditions* *LPA*	*LO*	*C*	*Wald*[a] *LPA vs. C*	*Wald*[a] *LO vs. C*	*F (1, 37)*[a] *LPA vs. LO*	*M*	*Effect Size d and CI for (LPA vs. LO)*[b]
% Zero	0%	0%	85%					
Phonemes (28)	22.75 (3.8)	21.30 (4.6)	7.20 (4.3)	100.05**	63.14**	1.63 *ns*	0.39	−0.24 *to* 1.02
Phoneme segmentation								
Words (14)	5.10 (3.5)	3.60 (2.3)	0.10 (0.3)	42.48**	31.13**	4.02*	0.58	−0.05 *to* 1.21
% Zero	20%	15%	90%					
Phonemes (40)	22.80 (6.8)	20.20 (6.9)	4.50 (4.6)	76.73**	50.46**	2.35 *ns*	0.45	−0.18 *to* 1.07
% Zero	0%	0%	40%					
Word learning								
Read from Day 1 (6)	4.25 (1.3)	2.45 (1.6)	0.80 (1.1)	44.43**	10.15**	15.03**	1.22	0.54 *to* 1.89
% Zero	0%	15%	55%					
Total Read (48)	40.45 (5.3)	30.40 (9.9)	12.70 (12.2)	65.12**	18.61**	16.37**	1.27	0.59 *to* 1.95
Memory for spellings								
Words (6)	5.00 (1.3)	4.55 (1.6)	0.90 (1.8)	28.43**	20.73**	0.96 *ns*	0.31	−0.31 *to* 0.93
% Zero	0%	0%	65%					
Phonemes (15)	13.85 (1.5)	13.20 (2.1)	5.70 (3.2)	62.27**	50.30**	1.21 *ns*	0.35	−0.28 *to* 0.97

Note. There were 20 children in each group. Means are unadjusted for the covariate. CI = confidence interval.

[a]For binomial logistic regression analyses, Wald chi-square test statistics are reported to compare each of the treatment groups to the control group. For analyses of covariance to compare the two treatment groups, *F* values are reported except where *W* indicates a Wald statistic.

[b]Effect sizes reflect the difference between *M* (LPA) and *M* (LO) adjusted for the covariate divided by unadjusted pooled *SD* followed by Hedges and Olkin (1985) adjustment for bias. Calculations were conducted using the effect size calculator, Center for Evaluation and Monitoring website, Durham University, UK. CI = 95% confidence interval.

[c]Chance-level performance on this 8-choice picture recognition test was 1.88. The highest score in the LO and C groups was 4 correct whereas the lowest score in the LPA group was 13 correct.

$^{*}p < .05$. $^{**}p < .01$. *ns* = not statistically significant.

more words on the 7-day posttest than the LO group. However, the difference was not significant on the 7-day phoneme-level measure (see Table 3). These findings reveal that adding articulation pictures to letter segmentation training provided an advantage in teaching students to segment words into phonemes.

Students were not taught to segment words containing consonant clusters (CC) during training. The phoneme segmentation posttests included four words with CCs to assess transfer. Results indicated little success: 70% to 75% of the LPA children and 80% to 85% of the LO children segmented no CCs in words. This suggests that specific instruction in CC segmentation is needed to enable this skill.

Transfer effects of segmentation instruction. On both posttest days, a word learning task was given to assess children's ability to remember how to read words with practice. They received up to eight trials to learn to read six words, followed by a spelling memory test. BLR analyses revealed that the two treatment groups significantly outperformed the control group on all of the reading and spelling measures on both posttests (see Table 3 and Figures 2 and 3). Thus, both treatments enhanced children's word learning ability.

A central purpose of the present study was to pursue effects found in an earlier study (Castiglioni-Spalten & Ehri, 2003) suggesting that articulation segmentation training may facilitate processes underlying the ability to remember how to read words. Results were positive. ANCOVAs showed that the LPA-trained children significantly outperformed the LO-trained children on the word reading

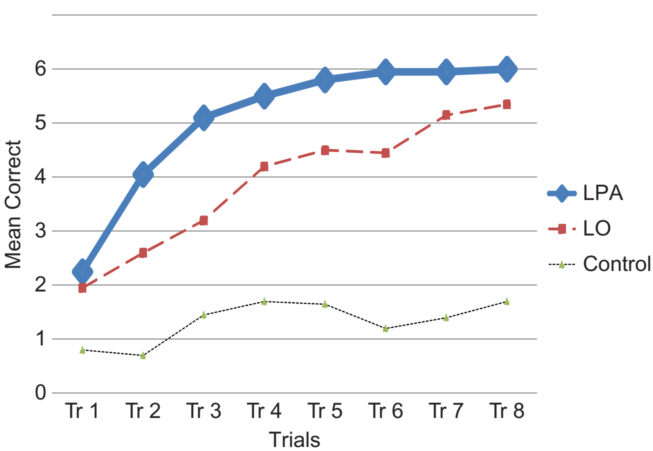

FIGURE 2 Mean number of words read correctly on each trial by Letter Plus Articulation (LPA), Letter Only (LO), and control groups as a function of condition on the one-day word learning posttest.

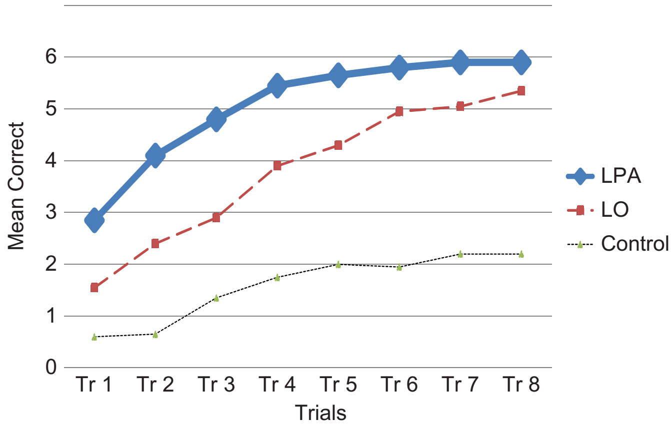

FIGURE 3 Mean number of words read correctly on each trial by Letter Plus Articulation (LPA), Letter Only (LO), and control groups as a function of condition on the seven-day word learning posttest.

measures on both posttests. As evident in Figures 2 and 3, the mean of the LPA group approached ceiling by the fifth learning trial whereas the LO group took eight trials to read the words this well. Moreover, 7 days later, the LPA group read significantly more of the words they had learned on the earlier posttest than the LO group.

After children practiced reading the words, they recalled their spellings. ANCOVAs revealed that the two groups did not differ significantly in their spellings on both word-level and phoneme-level measures on both posttests (see Table 3). Because both groups had learned to read most of the words by the final trial, and because they had both received spelling training, spelling differences might not be expected.

Children selected for the study lacked nonword decoding ability, and this skill was not taught during PA training. The nonword decoding transfer task consisted of CV, VC, and CVC units spelled with taught letters. The control group was not analyzed because 100% of the scores were zero. A BLR analysis was utilized because of the prevalence of zero scores. Results revealed that the log (odds) probability of correct responses was significantly greater in the LPA group than in the LO group (see Table 3). Whereas six LPA children read between five and nine nonwords correctly, none of the LO children decoded more than four nonwords. This reveals that letter plus articulation training did facilitate the emergence of decoding skill among some children.

The nonword repetition task was included to determine whether LPA training might enhance children's phonological memory compared to LO training, and whether this might explain their superior ability to remember how to read words. The BLR analysis revealed that the log (odds) probability of repeating nonwords correctly on the posttest was significantly greater in the two training conditions than in the control condition (see Table 3). However, the ANCOVA showed that the two treatment groups did not differ significantly in this task (see Table 3). Comparison of pretest to posttest performance with paired-sample t tests applied to each group revealed that mean scores rose significantly in the two treatment groups but fell significantly in the control group (see means in Tables 1 and 3): $t(19) = 2.63$ (LPA), and $t(19) = 2.65$ (LO), both ps $< .02$; $t(19) = -3.17$ (C), $p < .01$. These findings indicate that the detection of a significant difference favoring the treatment groups on the posttest did not result simply from depressed scores of the control group. The absence of a difference between treatment groups suggests that the ability to segment words with letters was the capability that enhanced phonological memory. Articulation training did not add to this effect.

Effect of Training Differences on Outcomes

It took longer to teach the LPA group to segment with both mouth pictures and letters than to teach the LO group with letters only. To examine whether longer training times explained the superior performance of the LPA group on posttests, ANCOVAs were conducted with total training time as the covariate, treatment group as the independent variable, and each of the posttests as the dependent measure. Results were negative. Training time contributed no significant effects in any of the analyses. Correlations between training time and the literacy posttests were low and nonsignificant, with rs ranging from $-.01$ to $.24$, all ps $> .10$.

The LPA group was taught to segment with both mouth pictures and letters and hence received more instruction in PA than the LO group. This may account for their superior performance on the PA posttests. To examine whether extra PA training might explain the LPA group's superior performance on the other posttests, performance on the PA posttest was treated as a covariate to equate the two groups statistically. Analyses were conducted on posttests showing significant differences favoring the LPA group. The independent variable was treatment (LPA vs. LO). The covariate measure was word-level phoneme segmentation on the 1-day posttest. ANCOVAs revealed that all spelling effects became nonsignificant (all ps $> .10$). A BLR analysis revealed that the nonword reading effect became nonsignificant ($p = .07$). However, all of the word reading effects remained highly significant (i.e., both Day 1 and Day 7 "total read" measures, and the Day 7 "read from Day 1" measure, all ps $< .01$). These results indicate that greater training in phoneme segmentation may explain spelling and nonword reading differences but not word reading differences favoring the LPA over the LO group.

DISCUSSION

To summarize, results of this experiment showed clearly that phoneme segmentation training conducted either with letters alone or with letters combined with articulation pictures helped preschoolers acquire phoneme segmentation and phonemic spelling skill compared to no training and that trained children's segmentation skill transferred and facilitated performance reading words and repeating spoken nonwords. The addition of articulation to letter segmentation training was found to improve children's ability to learn to read words with practice compared to letter-only training. This benefit was still evident 7 days after training. However, LPA training did not boost nonword repetition skill any more than LO training.

Although the LPA group outperformed the LO group on the phoneme segmentation, spelling, and nonword reading posttests, these differences may have arisen because the LPA group received more PA training. When the difference between groups on the PA posttest was controlled statistically, results showed that the two groups did not differ in spelling or nonword reading. The absence of differences on these measures is consistent with prior studies comparing segmentation training with and without articulation (Castiglioni-Spalten & Ehri, 2003; Wise et al., 1999). Nevertheless, because these studies differed in some respects from the present study, it remains for future research to examine the effect of equating the amount of PA training across LPA and LO treatments on these outcomes.

In the study by Castiglioni-Spalten and Ehri (2003), kindergartners were taught to segment with articulation pictures or blank markers but not letters. Their results gave a hint that articulation training might benefit children's memory for reading words. In the current study utilizing improved procedures, this possibility was confirmed even when the difference in phoneme segmentation ability between treatment groups was controlled. One explanation for the contribution of articulation segmentation training to the process of learning to read words from memory is provided by the connectionist view of word learning proposed by Ehri (2005) and others. Remembering how to read words over trials involves securing graphemes in spellings to phonemes in pronunciations and storing these connections along with meanings in memory so that sight of the words subsequently activates the grapho-phonemic connections leading to the word in lexical memory. Articulation training may have improved access to the motoric gestures that form phonemic representations of words in memory (Frost et al., 2009; Liberman & Mattingly, 1985). As a result, during the word learning trials, letters in the words became more securely attached to these motoric phonemic constituents to support word reading.

Rack, Hulme, Snowling, and Wightman (1994) and Laing and Hulme (1999) also found that articulation contributed to children's word reading. They taught youngsters to read two types of simplified phonetic *misspellings* of words over several trials, one type that contained a letter representing the voicing mate of the correct letter, for example, *f* substituted for *v* in *slfr* (*silver*), (note that voicing mates such as /f/ and /v/ are articulated in the same place in the mouth), and another type containing a letter articulated in a more distant location, for example, *z* substituted for *v* in *slzr* (*silver*). Results showed that children learned to read the words with letters that shared articulatory gestures with the spoken words more easily than those that did not. Children were not made aware of the similarities. They just practiced reading the words over trials, so the contribution provided by articulation features to the connection forming process happened spontaneously, perhaps "out of awareness." The same was true in the present study. No attention was drawn to letter-sound constituents in words and no decoding strategy was taught. Children just practiced reading the words over trials. Corrective feedback consisted of simply hearing and repeating the correct word after it was misread.

Although articulatory training effects were substantial in the word learning task, they were minimal in the spelling task. One possible explanation distinguishes between the processes used to read and spell. When children practiced reading words over trials, grapheme–phoneme connections were activated spontaneously and implicitly. Because LPA training enhanced the quality of phonemes in words by clarifying their articulatory features, graphemes may have become more securely attached to these phonemes during the connection-forming process, and hence words were better remembered. In contrast, when children spelled words, they applied a strategy of attending to speech elements in pronunciations in order to single out phonemes and select letters. This necessarily included attention to articulation. Moreover, both groups had been taught how to spell during training. The deliberate nature of this strategy and the necessary involvement of articulation may have precluded any contribution from the articulatory treatment.

We were surprised that LPA training improved some children's nonword decoding skill. Participants were selected because they lacked this skill, it was not taught, and such an effect was not observed by Castiglioni-Spalten and Ehri (2003). It may be that the mouth pictures served to clarify gestures that linked letters to phonemes so that the blending process became more transparent, particularly as children practiced reading words over trials in the task that preceded the nonword decoding task. Alternatively, superior decoding may have resulted from the more extensive PA training that the LPA group received, as indicated when this difference was controlled statistically. Which factor might explain findings awaits further study.

Participants in the present study were prereaders with little ability to read or spell words at the outset and hence were in Ehri's (2005) pre-alphabetic phase of word reading development. They could name 15 target letters and thus had the potential for moving into Ehri's partial alphabetic phase as a result of phoneme segmentation training. Simplified reading and spelling tasks served as posttests. Results showed that both forms of training did enable them to function at the partial alphabetic phase in their word reading and spelling. By the end of training, they could spell CV, VC, and CVC nonwords, they could remember how to read words with practice, and some could even decode nonwords. In contrast, children who received no training showed little ability to read or spell words on posttests and so remained at the pre-alphabetic phase. These results support Ehri's claim that letter knowledge, phoneme segmentation, and grapho-phonemic mapping skills are central in enabling children to move from the pre-alphabetic to the partial alphabetic phases of word reading development.

Effects of Segmentation Training on Speech

Another possible explanation for the contribution of LPA training to word learning was addressed. We thought that LPA training might enhance children's phonological memory and this might enable them to remember how to read words better than LO training. However, results were negative. LPA-trained children performed almost identically to LO-trained children on the nonword repetition posttest, yet the LPA group showed superior word reading ability.

Present findings indicate that teaching children to segment phonemes with letters improves their phonological memory. One possible explanation is that when children learn how to spell phonemes in words, phoneme–grapheme connections become incorporated into the phonological representational system, this serves to distinguish phonemic constituents and to prolong their duration in memory when words are heard, and hence the ability to repeat nonwords is enhanced. Recent findings using fMRI technology to study brain processes during speech and reading suggest that when children learn to read, written language engages areas of the brain originally involving speech as indicated by the processing of pseudowords (Frost et al., 2009). Perhaps our findings reveal the beginning of this development. Previous studies have been interpreted to suggest that phonological memory may contribute to children's reading achievement (Rapala & Brady, 1990; Rohl & Pratt, 1995; Snowling, Goulandris, Bowby, & Howell, 1986; Stone & Brady, 1995). Present findings along with studies by Wadsworth, DeFries, Fulker, Olson and Pennington (1995) and by Rosenthal and Ehri (2008) suggest that cause may run in the opposite direction as well.

Strengths, Limitations, and Directions for Future Research

One strength of the present study is that findings were obtained from an experiment with random assignment, thus supporting the attribution of cause to the instructional treatments that were manipulated. Sixty children were included, so there was sufficient power to test hypotheses. Both the LPA and LO groups showed mastery of segmentation during training. However, scores fell below ceiling on the segmentation and spelling posttests (see Table 3), possibly because they differed from the training tasks in ways that mattered. Nevertheless, training was sufficiently effective in teaching both forms of segmentation as both groups outperformed the control group by a wide margin. Positive effects of the two segmentation treatments on posttests persisted not only 1 day after training but also a week later.

Threats to the internal validity of the study were addressed. By chance, random assignment resulted in a control group that showed weaker performance than the LO group on the phoneme segmentation pretest. This difference was addressed in the analyses by including segmentation as a covariate.

Two other threats to internal validity were addressed as well. Segmentation training was structured to equate the LPA and LO treatments on a criterion of mastery. However, because the LPA group had more to learn, its training time was longer. When instructional time was controlled statistically, results remained unchanged, thus ruling out training time differences as an explanation of outcomes. Also, the LPA group received more PA instruction than the LO group, and this may have boosted their PA performance on posttests. When the two groups were equated statistically on this measure, spelling and nonword reading differences were eliminated, indicating no effect of training type. However, word reading differences remained strong, indicating that the effect of articulation training on word reading was not simply a result of superior PA in the LPA group.

In the earlier study by Castiglioni-Spalten and Ehri (2003), motivational differences distinguished the two segmentation conditions, with articulation-trained children more engaged and less distracted than the blank marker group. In contrast, notes and observations recorded by the experimenter in the current study revealed no motivational problems. Children paid attention and followed instructions in both treatments. Similarly children in the control group did not exhibit a lack of motivation even though they received no treatment. Their performance remained stable from pretests to posttests, a period lasting on average 40 days. Mean scores rose slightly but not significantly except in the nonword repetition task where their scores declined.

The English writing system utilized in the present study was simplified and transparent. The words and nonwords were spelled phonemically with a different letter for each phoneme. Letter-sound relations were drawn from 15 letters whose names contained the target phonemes including three long vowels (A, E, O). This writing system was used to study reading and spelling acquisition processes at the outset in learning to read. The system is consistent with the way that beginners process print, as evidenced by their spelling inventions (Read, 1971, 1975) and by the cues they use to read words from memory (Ehri & Wilce, 1985). The participants were prereaders who knew letter names but had not received formal reading instruction in school and did not know alternative, short vowel sounds of the letters. They held no expectations about variable or irregular word structure characterizing the conventional English writing system. Whether these findings apply to later phases of acquisition in learning to read and spell English awaits further research. The fact that the full English writing system lacks the transparency studied here may limit generalization of findings beyond the beginning period. Perhaps Wise et al.'s (1999) failure to detect any benefits of articulation training arose because their older struggling readers were grappling with a writing system too opaque to benefit from articulatory segmentation training.

The external validity of the present study is limited. Participants were middle-class to upper middle-class English-speaking preschoolers who had above-average vocabularies, and had already learned the names of target letters. Although this is the age when maximal effects of phonemic awareness instruction have been observed (National Reading Panel, 2000), it remains for future research to determine whether findings generalize to other ethnic groups, age levels, socioeconomic status levels, children at risk for reading disabilities, children who must be taught letters as part of the training, and children learning to read in other writing systems that vary in their orthographic transparency for reading as well as for spelling (Share, 2008).

Implications for Practice

Findings of the present study carry important educational implications. Our preschoolers had substantial letter knowledge, but their phonemic segmentation, spelling, and word reading skills were limited or nonexistent when they began the study. LPA and LO segmentation training promoted substantial growth in these skills. LPA training was especially effective in facilitating word-reading processes. Children were able to acquire phoneme segmentation with letters or mouth pictures easily, they enjoyed the training procedures, and only a limited number of training sessions was required. Thus, both LPA and LO forms of instruction are recommended to teach phoneme segmentation and its application in learning to read and spell words.

The importance of articulation to teach PA is not generally recognized. When beginners are taught to segment and blend phonemes in words, it is more common to direct their attention to the "sounds" they hear. However, acoustic stimuli do not contain the critical features needed to perform these manipulations and they are transitory. Present findings suggest the value of directing children's attention to mouth movements in addition to sounds through the use of articulatory pictures and mirrors to teach phoneme segmentation. Hatcher, Hulme, and Ellis (1994) found that nesting phonemic awareness training within beginning reading instruction exerted the strongest positive effect on beginners' literacy skills. How LPA training might be incorporated into beginning word reading instruction and whether this enhances its effectiveness is worthy of future research.

Designers of preschool curricula place a high value on the development of early literacy skills (Christie & Roskos, 2006; Scott-Little, Kagan, & Frelow, 2006) because research has identified these skills as prerequisites for future reading success. Phonemic awareness as well as letter knowledge are generally recognized as providing the foundation for young children's early reading and spelling development (National Early Literacy Panel, 2008; Snow et al., 1998). The present study showed that even preschoolers can benefit from phonemic awareness training taught with letters and articulation pictures. Although such training does not require expensive materials or lengthy instruction, it may require explicit teacher training in phonology and orthography. Previous studies have shown that teachers may lack this knowledge so they need help to understand the phoneme-grapheme system of correspondences and how articulation gestures define and distinguish among phonemes (McCutcheon et al., 2002; Moats, 1994; Piasta, Connor, Fishman, & Morrison, 2009). We recommend that educators who attempt to implement our findings make sure that instructors either have this knowledge or receive the necessary training.

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