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Integrated pictorial mnemonics and stimulus fading: Teaching kindergartners letter sounds

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Background. The conclusion from a vast literature on literacy acquisition is that letter knowledge is one of the best predictors of literacy development. The question of the best way to teach children letter sounds has not, as yet, been answered satisfactorily.

Aims. The aim of this study was the evaluation of a computer training program using integrated-picture mnemonics combined with a fading procedure to teach children letter sounds.

Sample. Thirty-nine kindergartners attending mainstream primary education participated in this study.

Method. A within-subject design was used. Each kindergartner learned letters under three conditions: (a) a fading condition in which letters are taught using a picture-supported first-sound mnemonics procedure in combination with a fading procedure; (b) an embedded condition in which letters are taught using the picture-supported first-sound-mnemonics procedure only and (c) a without-picture condition in which letters are taught using a first-sound procedure without-picture support. Dependent measures included a productive and receptive letter-sound test, and a first-sound isolation task.

Results. Productive letter-sound knowledge in the fading condition was better than in the other two conditions. In addition, kindergartners with good and those with poor first-sound isolation ability performed equally well in the fading condition. However, in the embedded and in the without-picture conditions, the kindergartners with good first-sound isolation ability outperformed those with poor isolation ability.

Conclusion. These findings indicate that an integrated-picture mnemonics procedure combined with a fading procedure is effective in teaching kindergartners letter sounds and that the success of such a procedure does not depend on their initial first-sound isolation ability.

Letter knowledge is, in addition to phonological awareness, an important correlate of beginning literacy. Evidence for this notion comes from intervention studies

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(Ball & Blachman, 1991; Bradley & Bryant, 1983; Ehri *et al.*, 2001; Schneider, Roth, & Ennemoser, 2000) and longitudinal research (Caravolas, Hulme, & Snowling, 2001; Lonigan, Burgess, & Anthony, 2000; McBride-Chang, 1999).

Bradley and Bryant (1983) demonstrated that the effect of a sound-categorization training on literacy skills is enhanced when the sounds are practised in the presence of the letters of the alphabet. Ball and Blachman (1991) also showed that phoneme-segmentation instruction in conjunction with letter-name and letter-sound instruction has an immediate effect on early reading and spelling. A phonological-awareness training combined with a letter-sound training for kindergartners at risk for dyslexia had strong positive effects on their reading and spelling performance in Grades 1 and 2 (Schneider *et al.*, 2000). Moreover, in a meta-analysis of phonemic-awareness instruction, Ehri *et al.* (2001) concluded that phonemic-awareness instruction is more effective when it is taught with letters. This conclusion is supported by Byrne and Fielding-Barnsley (1989) who argue that a combination of phonemic awareness and grapheme–phoneme knowledge is actually needed for the acquisition of the alphabetic principle.

Evidence for the importance of letter-sound knowledge also comes from longitudinal research that targeted predictors for reading and spelling. McBride-Chang (1999) showed that although letter-naming and letter-sound knowledge are both predictive of reading-related skills, letter-sound knowledge is a far better predictor of reading-related skills than letter-naming. Lonigan *et al.* (2000), who studied the significance of emergent literacy skills for reading, also found letter knowledge to be a unique predictor of word decoding. These findings are in accordance with results reported by Caravolas *et al.* (2001) who showed, by means of path analysis, that letter-sound knowledge is a precursor of early phonological-spelling ability.

Experimental studies by Treiman and Rodriguez (1999) also show the relevance of letter knowledge to the development of literacy. They had pre-readers and novice readers who learned to pronounce three made-up spellings. In the name condition, the printed stimulus, for example BT, was pronounced 'beet', thus providing a letter-name and a letter-sound cue for the letter B. In the sound condition, BT was pronounced 'bait', thus only providing a letter-sound cue for the letter B. In the visual condition, BT was pronounced as 'ham', thus providing no cue at all. Pre-readers as well as novice readers found it easier to pronounce a novel word in the letter-name condition than in the letter-sound condition. Only novice readers took advantage of letter-sound cues because they performed better in the sound condition than in the visual condition. This pattern of earlier development of letter-name knowledge and earlier use of this information in reading novel words, and later development of letter-sound knowledge and later use of this information in reading novel words, is also found in Hong Kong Chinese kindergartners despite their more extensive experience with logographic methods in learning to read novel words (McBride-Chang & Treiman, 2003).

Factors involved in learning letter names and letter sounds have been examined in a number of other studies (Share, 2004; Treiman & Broderick, 1998; Treiman & Kessler, 2004; Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998). An important factor is that the experience children have with their first name (Treiman & Broderick, 1998). Children showed superior performance with respect to the initial letter of their first name on tests for letter-name knowledge but not for letter-sound knowledge. Treiman and Kessler showed that this advantage appeared for upper case as well as lower case initial letters.

Treiman *et al.* (1998) also demonstrated that the contingency between a letter sound and its letter name is predictive of the acquisition of letter-sound knowledge. In addition, the position of the sound in the letter name is also important: children perform better on sounds that are at the beginning of the letter name than at the end. This so-called 'name-to-sound-facilitation' effect was also tested by Share (2004). He had Hebrew-speaking kindergartners learn English letter names for letter-like symbols. Sometimes, the corresponding letter sound occurred in the letter name, and sometimes it did not. His conclusion was similar to that of Treiman *et al.*: children found it easier to learn letter sounds if they were already familiar with a letter name containing that sound.

Although there is ample evidence for the relevance of learning letter sounds regarding literacy acquisition, it is less clear how the relationships between visual and phonological representations should be acquired. For preliterate children, letter symbols and their corresponding sounds are usually unrelated and therefore hard to learn. Mnemonics, techniques to improve one's memory, have proven to be effective in teaching associations between otherwise unrelated items and are therefore widely used in educational settings. A number of studies have been conducted using mnemonics to learn the writing systems of foreign languages (Gruneberg & Sykes, 1996; Lu, Webb, Krus, & Fox, 1999). The effectiveness of mnemonics can be explained, as suggested by Higbee (1987), by the fact that it uses the basic psychological principles of learning and memory, that is, association, organization, meaningfulness, attention and visual imagery. Gleitman, Fridlund, and Reisberg (1999) also used these principles to explain why mental images are an effective memory aid. They argued that images of two unrelated items might be chunked in memory to form a coherent whole. When one of the items is presented, it functions as a retrieval cue for the entire chunk. Coherence appears to be an important condition for recall. Wollen, Weber, and Lowry (1972) found that unified mental images result in better recall than non-unified images. For example, recall performance was better when the participants imagined the noun-noun pair 'flag-doll' as the doll waving the flag than when the participant imagined the two nouns as a set of merely adjacent, not interacting constituents.

Ehri, Deffner, and Wilce (1984) used unified or integrated pictures that supported a first-sound mnemonics procedure to establish meaningful relationships between letters and sounds. In this procedure, the shape of the letter is embedded in a drawing and serves as a salient visual feature because the name begins with the target sound (e.g. the letter 'l' is embedded in a drawing of a lamp). Ultimately, the letter is supposed to function as a retrieval cue for the mnemonic picture's name which will in turn retrieve the corresponding sound of the letter. Thus, information is encoded in both a verbal and a non-verbal manner. According to dual-coding theory, memory is better for information that is encoded both verbally and non-verbally than for information that is encoded only one way (Sadoski & Paivio, 2001).

Prior to the letter training in Ehri *et al.*'s (1984) study, children were trained in phonemic segmentation to ensure that they could segment first sounds in picture names. To make the children pay attention to the letters during the letter training, the children were instructed to write the letters in the pictures. This study showed that this mnemonics procedure was effective in teaching letter sounds to pre-readers. However, the possibility that rote rehearsal was in fact responsible for the learning effects could not be ruled out completely because children in the no-picture control condition spent less time on trials than those in the experimental condition. Moreover, in their experiment, the effect of the integrated pictures and drawing practice could not be disentangled because the design did not include a condition in which children were trained by means of integrated pictures without drawing the letters. The training might have been less effective if children were only exposed to the integrated pictures. Since the main goal of their study was to demonstrate that the use of integrated pictures is essential for a mnemonics procedure, this is a problem. Earlier, Marsh and Desberg (1978) showed that first-sound mnemonics as well as action mnemonics facilitated performance during training, without causing a transfer effect to a task where letters were shown without pictures. Ehri *et al.*'s interpretation was that the pictures used were inadequate and therefore proposed the use of integrated mnemonics. Their final proposition for future research was to investigate whether drawing letters as part of the training could be replaced by other procedures without losing effectiveness, which is what we would like to pursue.

Hoogeveen, Smeets, and Lancioni (1989) also tested an integrated-picture mnemonics procedure to teach letter sounds to children with mild mental retardation. They combined this procedure with a stimulus-fading procedure that served as an alternative for the drawing activity described by Ehri *et al.* (1984). In general terms, stimulus fading is a procedure to establish transfer of stimulus control from a prompt (an additional facilitating stimulus) to a discriminative stimulus (Miltenberger, 1997). In the study of Hoogeveen *et al.*, the prompts were the mnemonic pictures in which the letters were embedded as discriminative stimuli. The pictorial elements of the drawings faded out gradually in response to correct answers of the child, causing the letter to become more salient so that stimulus control was transferred from pictures to letters. Although this training was also effective, it still remains unclear whether mere rote rehearsal of letter-sound relations would have resulted in the same findings as the first-sound mnemonics procedure. Hoogeveen *et al.*'s study was set up as a multiple-baseline design and did not include a control condition without a fading procedure, which precludes a definite answer to the question of whether fading can be seen as a relevant aspect in these types of training.

The present study aims at answering questions that remained unanswered in the studies of Ehri *et al.* (1984) and Hoogeveen *et al.* (1989). Our main question was whether an integrated-picture first-sound mnemonics procedure combined with a fading procedure is effective in teaching kindergartners letter sounds. In order to investigate the relevance of fading, we wanted to know whether integrated pictures alone are effective in teaching kindergartners letter sounds. We also wanted to rule out the possibility that mere rote rehearsal is responsible for the training effects. To answer these questions, we designed an experiment with three training conditions. In the first condition, letters were taught with the support of pictures in combination with a fading procedure. In the second condition, the letters were taught only with support of pictures. The effects of the integrated pictures and the effect of a procedure to make children pay attention to the letters, in this case a fading procedure, could thus be disentangled. In the third condition, letters were taught without-picture support to rule out the possibility that mere rote rehearsal is responsible for possible effects in the fading condition. The pictures were designed following the principles given by Ehri *et al.*: the shape of the first letter is a salient visual feature of the picture and the first sound of the picture name is the sound that needs to be learned.

We examine two additional questions in this study. The first additional question pertains to the influence of pre-existing letter-sound knowledge and age on training success. Because the age range was rather large (5–7 years old), performance on the training can be different for the younger than for the older children due to differences in working memory. According to Baddeley's memory model (Baddeley, 1997), working memory involves three components: The central executive, the phonological loop and the visuospatial sketchpad. Evidence exists that all three components function better when children grow older. Older children have an increased capacity to conduct complex operations, a function that is associated with the central executive.

The phonological loop, specialized for the retention and manipulation of information in a phonological form, also develops rapidly through the early and middle childhood years. For example, 4-year-old children could recall about 1.5 items on an auditory serial recall task, whereas 7-year-olds recalled more than two items (Gathercole, 1998). Finally, the visuospatial sketchpad, involved in remembering and mentally manipulating the physical features and dimensions of events, also shows development during childhood. For example, 5-year-olds had a mean pattern span of about four blocks, whereas 7-years-olds reached twice as high values on a test for visual-memory span.

The second additional question is whether extensive segmentation training is needed prior to letter training, as in the study by Ehri *et al.* (1984). Fulk, Lohman, and Belfiore (1997) raised the same question in their study on the effectiveness of integrated-picture mnemonics for letter-sound acquisition by first grade students with special needs. Despite the fact that they did not administer a segmentation training prior to their training, they reported improvement in letter-sound recall. However, the participants were not tested on segmentation ability before the training. If this ability was already present in the participants, this might have been partly responsible for the success of the training. In our study, prior to the training, children were tested on first-sound isolation ability to determine whether the training program is equally beneficial for children who are able to isolate first sounds in words and for children who are less able to do this.

In the experiments by Ehri *et al.* (1984) and Hoogeveen *et al.* (1989), the training program was conducted by human teachers. In the present study, we implemented all three training conditions in a computer program. A useful advantage of computers is that various skills can be trained intensively and individually in classrooms without too much involvement of teachers. Moreover, computers may contribute to the reliability of an experimental study. After all, computers always provide the same feedback irrespective of the student or training condition, which promotes treatment integrity. A specific advantage of the computer in this experiment was that the stimulus-fading procedure could be implemented relatively easily. Despite the advantages of instruction by the computer, not all feedback could be given by the computer. Human monitoring was necessary to evaluate the sounds produced by the children, because speech recognition software has not yet reached the precision required for performing this task properly.

Method

Participants

Ninety-two kindergartners were recruited from two mainstream kindergartens. In the Netherlands, children enter kindergarten when they are 4 years old. Kindergartens follow a 2-year program in which the children's beginning literacy is stimulated by language games, nursery rhymes and so forth. All 92 children were in their second year of kindergarten. From this group, 39 children were selected for participation in the experiment. Only children who knew, both productively and receptively, fewer than 22 letters or graphemes, leaving at least 12 letters to be learned, were admitted. The productive and receptive letter-sound pre-tests are described below (see Table 1 for descriptives). The group of participants consisted of 19 girls and 20 boys with a mean age of 72 months ($SD = 4$; minimum = 62; maximum = 84). The mean age of the participants was identical to that of the group of 92 kindergarteners from which they were selected. All children were native Dutch speakers, except one boy who spoke Vietnamese at home, and all came from middle-class backgrounds with parents who had middle to higher levels of education and professions.

Table 1. Mean scores, standard deviations, minimum and maximum scores on the pre-tests productive letter-sound knowledge, receptive letter-sound knowledge[3] and first-sound isolation ability

Pre-tests	*M*	*SD*	Minimum	Maximum
Productive letter-sound knowledge				
All children	4.79	2.56	0	34
Children below group mean	2.74	1.20	0	4
Children above group mean	6.75	1.86	5	11
Receptive letter-sound knowledge				
All children	11.87	3.17	0	34
Children below group mean	8.64	2.34	0	11
Children above group mean	13.68	1.87	12	20
First-sound isolation ability				
All children	11.18	7.98	0	20
Children with good ability	16.64	2.60	10	20
Children with poor ability	0.69	1.32	0	9

Material and procedure

Pre-tests

Three pre-tests were administered individually in two separate sessions. In the first session, all 92 children were tested on productive and receptive letter-sound knowledge. To determine their productive letter-sound knowledge, children were presented with cards containing 34[1] lower case graphemes (in Arial font with a point size of 200). The graphemes were presented in random order. The child was asked to pronounce the sound of each letter. If the child pronounced the letter name, he or she was also asked to produce the letter sound. To determine their receptive letter-sound knowledge, a six-alternative forced-choice measure was used. Children were presented with 3 sheets containing 34 rows of 6 different graphemes. After oral presentation of a letter sound, for example, 'Where do you see the/d/from "door"?', the child had to point to the correct grapheme in the row of 6 graphemes. The distracters were in the same phonological class as the targets: vowels were contrasted with vowels and consonants with consonants. Two contrasts showed visual resemblance to the target and two showed auditory resemblance. The final distracter letter was chosen arbitrarily. The tests for productive and receptive letter-sound knowledge yielded Cronbach's α values of .94 and .89, respectively, indicating a high internal consistency. In the second session, a first-sound isolation task[2] measuring phonemic awareness was administered to the 39 participating children only (see Table 1 for the descriptives). Their task was to isolate and pronounce the first sound of 10 CVC words and 10 CCVC words after the oral presentation, for example, 'Which sound do you hear at the beginning of "cat"?'. The test items were preceded by four practice items for which corrective feedback was provided. Next, all 20 test items were administered in a fixed order, first the CVC items and after that the CCVC items, without corrective feedback. The cut-off point was four consecutive errors in the CVC or in the CCVC section. This test was also highly reliable (Cronbach's $\alpha = .97$).

[1] *Dutch has 34 graphemes: 5 vowels, 12 digraphs and 17 consonants.*
[2] *This test was developed by Dr. R. Irausquin, Department of Special Education, Radboud University, Nijmegen, The Netherlands.*
[3] *Note that during pre-test, children were questioned about all 34 Dutch graphemes, whereas during the post-tests and the retention test, they were only questioned about the 12 (4 per condition) trained letters.*

Post-tests

Each training session, except the first one (see below), was preceded by two short tests: a six-alternative forced-choice receptive letter-sound test and a computerized productive letter-sound test, testing the knowledge of all 12 letters that were practised. In the former test, children were presented with the same three sheets that were used for the receptive letter-sound test of the pre-test. However, this time they were only questioned about the letters that they had practised during the training. In the latter test, children had to pronounce the sounds of letters presented on the computer screen. The day following the last training session, while performing the productive letter-sound test, the children were asked whether they could remember the mnemonic word for each letter.

Retention tests

Four weeks after the last training session, the computerized productive letter-sound test and the six-alternative forced-choice receptive letter-sound test were administered again. When administering the productive letter-sound test, we again asked each child whether he/she remembered the mnemonic word.

Training procedure

The training program contained three conditions: (a) The fading condition in which letters are taught using a picture-supported first-sound mnemonics procedure in combination with a fading procedure; (b) the embedded condition in which letters are taught using the picture-supported first-sound mnemonics procedure only and (c) the without-picture condition in which letters are taught using a first-sound procedure without the picture support. The training was set up as a within-subject design, because performance variability is large in kindergartners. In a within-subject design, between-subjects variability is removed from the error term, which enhances the statistical power of the within-subject comparisons. Thus, each participant learned four letters in each of the three conditions.

The training program was executed on a portable computer under the guidance of the first author and an assistant during the spring of the school year. For each child, we determined which letters they had not mastered yet. Of this set, we chose 12 letters to be trained in the computer program. Each of the letters was assigned to a condition such that letters were equally divided over the three conditions and each condition contained one vowel, one digraph and two consonants. For 28 children, this requirement could not be met, because the set of 12 letters that still needed to be mastered did not consist of three digraphs, three vowels and six consonants. However, the distribution of digraphs, vowels and consonants over the three conditions was very similar. The number of digraphs in each condition was 44, 42 and 43, respectively; the number of vowels was 27, 27 and 28, respectively; the number of consonants was 85, 87 and 85, respectively. In the results section, analyses are presented investigating a potential difference in performance between these 28 children and the remaining group of children, as well as potential differences among children learning vowels, consonants and digraphs.

The training program consisted of two repetitions of each condition, resulting in six sessions per child, distributed over a 2-week period. In each session, the child practised all four letters assigned to that condition. Each training condition was presented once in the first week and once in the second week to each child. To control for differential carry-over effects, the order of the training conditions was counterbalanced. Six different sequences were specified and implemented in the computer program. Each child received one sequence, such that all six sequences were equally divided among the participants.

The training procedure consisted of six phases and is best explained in the fading condition. The phases in the other two conditions are constructed by analogy to the fading condition. Thus, in all three conditions, children received exactly the same feedback following correct as well as incorrect answers. The procedure of the fading condition is described below, with the letter ‘m’ as example (see Figure 1 for a screen example).

The child is presented with the letter ‘m’ on the computer screen embedded in a drawing of a mouth. The experimenter asked the child to pronounce the sound of the letter and provided feedback: ‘Very good’ in case of a correct answer and ‘That is not correct’ in case of an incorrect answer. Then, the child was invited to look for the correct sound by listening to sounds produced by four buttons on the computer screen, each representing a different sound, and was asked to click on the correct button. When correct, the child was complimented by the computer and heard the following feedback: ‘This is the/m/from mouth,/m/-outh, mouth’. If the answer was incorrect, the computer asked the child to try again. If the child failed again, the computer provided the correct answer: ‘This is the/m/from mouth,/m/-outh, mouth.’ After one correct or two incorrect choices, a new letter was presented to the child and the same procedure repeated. If the response of the child was correct, the letter passed to a new phase. With respect to the fading condition, this meant that each time a letter passed to a new phase, the pictorial elements of the drawing faded out gradually. In phases five and six, the pictorial elements had disappeared completely (see Figure 2). In case of an incorrect answer, the letter remained in the phase it was presented in. After six consecutive incorrect choices, the letter was eliminated from the letter set.

In the embedded and the without-picture condition, the computer program had the same underlying structure: each letter was presented in six phases. However, in the embedded condition, the picture remains visible throughout all six phases and in the without-picture condition, no picture support was available.

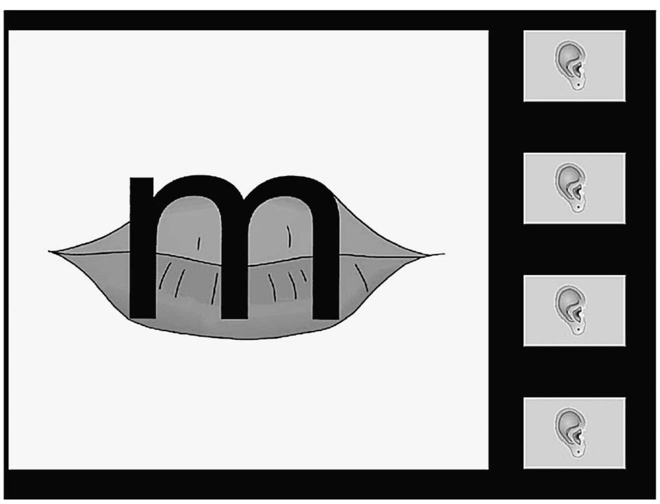


Figure 1. Screen example.

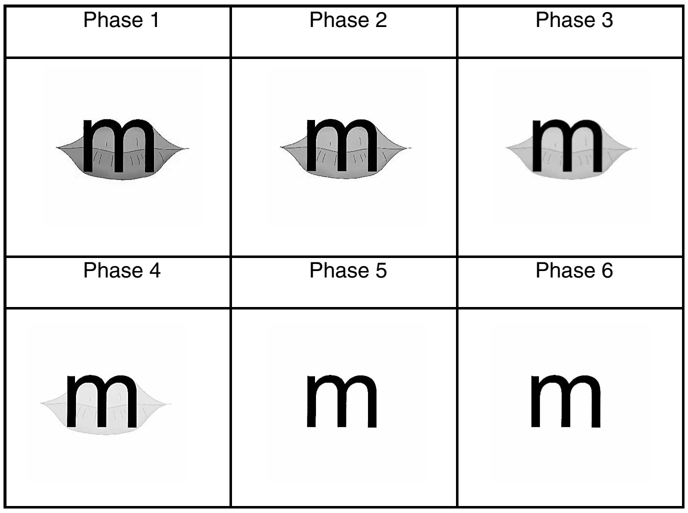


Figure 2. Six training phases in the fading condition for the letter 'm'.

Results and conclusions

First, we focus on training effectiveness and analyse the effect of the training in the three experimental conditions pertaining to productive and receptive letter-sound knowledge. Next, we analyse the training characteristics: mean number of trials per session per condition and the elimination of letters during the training. Then, learning curves are presented in which the relation between percentage correct of sound-button selection and percentage correct of sound production is shown, revealing learning patterns during training. Finally, we analyse the strategy used by the children through assessment of recall of mnemonic words. For all these variables, with the exception of training characteristics, within-subjects repeated measures analyses were conducted to assess the main effect of time. Changes between different assessment sessions were assessed by repeated contrasts. To assess differences between experimental conditions on all these variables, tests of simple within-subject contrasts were conducted: the fading condition was first compared with the embedded condition and then compared with the without-picture condition. Only these two contrasts were required to answer the research questions. Each contrast was tested with $\alpha = .025$ (Bonferroni correction). In case of significant differences between experimental conditions, the corresponding effect sizes, represented by the differences in means divided by the pooled standard deviations (Cohen's *d*, 1988), are reported as well.

Two additional questions will be examined. First, we focus on the influence of pre-existing productive letter-sound knowledge, pre-existing receptive letter-sound knowledge and age on training effectiveness, the mean number of trials during training, the number of eliminated letters and on recall of mnemonic words. These three variables were entered as between-subject factors in the analyses. Each variable was dichotomized: A-level containing children performing above the mean and a-level containing those who performed below the mean. No significant interactions were found between the between-subject factors and the three experimental conditions (see Table 2). Therefore, simple contrasts are presented originating from the analyses without between-subject factors to maintain the maximum of degrees of freedom.

Table 2. Results from Repeated Measures Interactions Between the dichotomized factors age, pre-existing productive letter-sound knowledge (PPLSK) and pre-existing receptive letter-sound knowledge (PRLSK), and experimental condition with as dependent variables productive letter-sound knowledge (PLSK), receptive letter-sound knowledge (RLSK), recall of mnemonic word, number of trials and letter elimination

	Factors								
	Age			PPLSK			PRLSK		
Tests	*F*	*df*	*p*	*F*	*df*	*p*	*F*	*df*	*p*
Post-test I									
PLSK	0.18	2,36	.84	0.22	2,36	.80	0.25	2,36	.78
RLSK	0.15	2,36	.86	1.89	2,36	.17	0.10	2,36	.91
Post-test II									
PLSK	0.81	2,36	.45	0.24	2,36	.79	0.04	2,36	.97
RLSK	0.44	2,36	.65	0.41	2,36	.67	3.03	2,36	.06
Mnemonic recall	1.53	2,35	.23	0.32	2,35	.73	0.47	2,35	.63
Retention test									
PLSK	0.82	2,36	.45	0.17	2,36	.85	1.25	2,36	.30
RLSK	0.76	2,36	.48	0.62	2,36	.54	0.90	2,36	.42
Mnemonic recall	1.27	2,36	.29	0.22	2,36	.80	1.15	2,36	.33
Number of trials	1.13	2,36	.33	0.49	2,36	.62	0.65	2,36	.53
Letter elimination	2.45	2,36	.10	1.21	2,36	.31	0.20	2,36	.82

Second, we focused on the relation between first-sound isolation ability before the training and training outcome, that is, we investigated whether the training program is more beneficial for children who were already able to isolate first sounds in words.

Training effectiveness

Letter-sound knowledge

A repeated measures design was used to investigate the effects of the training on productive and receptive letter-sound knowledge. Only test results collected after the first training week (Post-test I), the second training week (Post-test II), and 4 weeks after the last training session (retention test) are presented. The independent variables were time of test (Post-test I, Post-test II and retention test) and experimental condition (fading vs. embedded vs. without picture). The dependent variables were the number of correct answers on the productive letter-sound test and the number of correct answers on the receptive letter-sound test. The mean number of correct answers and standard deviations of these tests are shown in Table 3.

Productive letter-sound test

The main effect of time was significant, children in all three conditions progressed throughout the training, $F(2, 37) = 36.45$, $p < .001$ (two-tailed). A repeated contrast showed that progress took place between Post-test I and Post-test II, $F(1, 38) = 65.10$, $p < .001$ (one-tailed). The comparison between Post-test II and the retention test was not significant, indicating that letter-sound knowledge was stable, $F < 1$.

Next, the main effect of experimental condition was examined. At Post-test I, children recalled more letter sounds in the fading condition than in the embedded

Table 3. Mean sum scores, standard deviations and results of simple contrast tests for productive letter-sound knowledge (PLSK) and receptive letter-sound knowledge (RLSK), and recall of mnemonic word as a function of training condition and time of testing

	Training condition						
	Fading		Embedded		Without Picture		
Tests	*M*	*SD*	*M*	*SD*	*M*	*SD*	Contrast tests
Post-test I							
PLSK	1.28	1.08	0.74	0.85	1.15	1.11	F > E; F = WP
RLSK	0.90	0.80	0.85	0.95	0.66	0.81	F = E; F = WP
Post-test II							
PLSK	2.38	1.02	1.36	1.16	1.95	1.03	F > E; F = WP
RLSK	0.89	0.81	0.86	0.85	0.92	1.01	F = E; F = WP
Mnemonic recall	2.05	1.25	1.08	1.19	1.47	1.13	F > E; F > WP
Retention test							
PLSK	2.31	1.13	1.36	1.22	1.85	1.09	F > E; F > WP
RLSK	1.48	0.89	1.17	1.15	1.09	1.18	F = E; F = WP
Mnemonic recall	2.31	1.17	1.38	1.12	1.28	1.05	F > E; F > WP

Note. Maximum score for all tests is 4. F, fading; E, embedded; WP, without-picture. The mathematical sign = can be interpreted as 'not different'.

condition, $F(1, 38) = 6.75$, $p = .01$ (one-tailed), $d = .56$. No differences were found between the fading and the without-picture condition, $F < 1$. At Post-test II, children recalled more letter sounds in the fading condition than in the embedded condition ($F(1, 38) = 25.57$, $p < .001$ (one-tailed), $d = .93$). No differences were found between the fading and the without-picture condition, $F(1, 38) = 3.83$, $p = .03$ (one-tailed). At the retention test, children recalled more letter sounds in the fading condition than in the embedded condition ($F(1, 38) = 18.55$, $p < .001$ (one-tailed), $d = .81$) and in the without-picture condition ($F(1, 38) = 4.28$, $p = .02$ (one-tailed), $d = .41$). In short, children recalled more letter sounds in the fading condition than in the embedded condition in all assessment sessions. The comparison between the fading and the without-picture condition showed superior performance at the retention test only.

To investigate whether other factors were responsible for these effects, we performed two further analyses. First, to examine whether there were differences in children's learning of vowels, consonants and digraphs, we performed chi-squared analyses for each assessment session and each condition with productive letter-sound knowledge as the dependent variable. No differences in learning of vowels, consonants and digraphs were found.

Second, to examine whether the performance of the 28 children who did not have the standard set of letters (see Methods section) differed from the performance of the other children, we performed a series of one-way ANOVAs for all three training conditions in all three assessment sessions with productive letter-sound knowledge as the dependent variable. The results are shown in Table 4. The only significant difference between children with the standard and other sets of letter types was found in the fading condition at Post-test I. It is difficult to interpret this finding other than to note the possibility of a Type-I error.

Table 4. Performance differences between the standard vs. other distributions of letter types as a function of training condition and time of testing

	Standard		Other				
Conditions	*M*	*SD*	*M*	*SD*	*F*	*df*	*p*
Post-test I							
Fading	0.64	0.67	1.54	1.11	6.30	1, 37	.02
Embedded	0.64	0.92	0.79	0.83	0.24	1, 37	.63
Without picture	1.09	0.94	1.18	1.19	0.05	1, 37	.83
Post-test II							
Fading	1.91	0.70	2.57	1.07	3.58	1, 37	.07
Embedded	1.00	1.00	1.50	1.20	1.49	1, 37	.23
Without picture	1.91	1.14	1.96	1.00	0.02	1, 37	.88
Retention test							
Fading	2.55	1.21	2.21	1.10	0.68	1, 37	.42
Embedded	1.00	1.18	1.50	1.23	1.33	1, 37	.26
Without picture	1.55	1.04	1.96	1.10	1.17	1, 37	.29

In addition to analyses across participants, we performed analyses across letters and their supporting mnemonics to examine whether similar patterns between conditions were apparent. Table 5 shows how often each letter was taught in each condition and the proportion correct in the productive letter-sound test on Post-test II. This pattern was similar to the one obtained through analyses across participants. The comparison between the fading and embedded conditions revealed that letter-sound recall was better in the fading condition for 22 out of the 29 letters. For five letters, no difference was found, and for two letters recall was better for letters practised in the embedded condition. The comparison between the fading and without-picture conditions revealed that letter-sound recall in the fading condition was better for 15 out of the 29 letters. For 4 letters, no difference was found, and for 10 letters recall was better for letters practised in the without-picture condition. In short, letters practised in the fading condition show superior recall when compared with the embedded condition, whereas the comparison between fading and the without-picture condition is less clear-cut.

Receptive letter-sound test

Because this test was set up as a six-alternative forced-choice task, the scores were corrected for chance[4] prior to conducting the repeated measures analyses. The main effect of time was significant, $F(2, 37) = 9.15$, $p = .001$ (two-tailed). A repeated contrast test showed that an increase in performance between Post-test II and the retention test was responsible for this time effect, $F(1, 38) = 13.77$, $p = .001$ (two-tailed). There was no significant change between Post-test I and Post-test II, $F < 1$. Next, we tested the main effect of experimental condition. At Post-test I, no differences were

[4] *To correct scores for chance, we used the following formula: C-W/(A-1), in which C represents the number of correct answers, W the number of wrong answers and A the number of alternatives in the receptive letter-sound test. In this way, chance correction has been adapted to the number of errors that a child has made, best reflecting the true score of each child. In case of a sum score of 0, application of this formula would have led to a nonsensical value of −.80, therefore we left these values untouched.*

Table 5. Letters and mnemonics: frequency taught and proportion correct on the productive letter-sound test on Post-test II as a function of training condition

		Frequency taught			Proportion correct			Pattern	
Letter	Dutch mnemonic word	F	E	WP	F	E	WP	F vs. E	F vs. WP
m	mond	4	4	4	.50	.50	.50	=	=
s	Slang	2	2	2	1	1	1	=	=
p	Pauw	6	6	5	.67	.67	.40	=	>
r	regenboog	4	5	4	.75	.40	.75	>	=
oo	Oog	1	1	1	0	1	1	<	<
n	nagel	6	6	6	.50	.17	.50	>	=
k	kikker	0	1	1	–	0	1	–	–
t	tak	5	6	6	.60	.17	.83	>	<
aa	aap	6	6	6	.83	.67	.50	>	>
ee	eenden	6	6	7	.67	.50	.57	>	>
l	lolly	6	6	6	.83	.17	.67	>	>
z	zwaan	6	6	6	.33	.33	.67	=	<
i	indiaan	5	5	5	1	.20	.40	>	>
o	onweer	2	2	2	.50	.50	1	=	<
B	buik	6	6	5	.67	.50	.80	>	<
G	garnaal	6	6	5	.50	.17	0	>	>
A	appel	7	6	6	.71	.17	.83	>	<
D	dinosaurus	6	5	6	.50	.40	.17	>	>
E	emmer	6	6	6	.50	.33	.33	>	>
W	wigwam	6	6	5	.50	.17	.20	>	>
Ie	ieniemienie	6	6	6	.17	0	.33	>	<
H	hond	6	5	6	.17	0	.33	>	<
Ij	ijs	6	4	5	.67	.50	.80	>	<
F	fietspomp	5	6	6	0	.50	.67	<	<
Ui	uier	6	7	6	.83	.29	.33	>	>
J	jurk	6	5	6	.83	.40	.33	>	>
U	ukkie	7	8	9	.57	.38	.33	>	>
Ei	ei	6	6	6	1	.33	.17	>	>
Au	auto	7	6	6	.71	.33	.67	>	>
V	vogel	5	6	6	.40	.33	.17	>	>

Note. F = fading; E = embedded; WP = without picture. The mathematical sign = can be interpreted as 'not different'.

found between the fading condition and the embedded condition ($F < 1$), or between the fading condition and the without-picture condition, $F(1, 38) = 2.41$, $p = .06$ (one-tailed). At Post-test II, there was no significant difference between the fading condition and the embedded condition ($F < 1$), or between the fading condition and the without-picture condition ($F < 1$). At the retention test, no differences were found between the fading condition and the embedded condition, $F(1, 38) = 2.26$, $p = .07$ (one-tailed), or between the fading condition and the without-picture condition, $F(1, 38) = 3.90$, $p = .03$ (one-tailed). In short, none of the assessment sessions yielded significant differences between the fading condition and the two other conditions.

Training characteristics

Two training characteristics were assessed: mean number of trials per condition per session and the number of letters eliminated during the training. The former refers to the number of trials that children needed to go from Phase 1 to Phase 6 in a training session. Each click on a sound button constituted a trial. Elimination of letters from the letter set occurred after six consecutive incorrect choices for a sound button. These training characteristics entered the analyses as dependent variables and experimental condition as independent variable; means and standard deviations are shown in Table 6.

Table 6. Means and standard deviations of the training characteristics mean number of trials per condition per session and elimination of letters during the training

	Training condition						
	Fading		Embedded		Without picture		
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	contrast tests
Number of trials[a]	32.10	5.41	31.19	6.48	35.42	6.47	F = E; F < WP
Letter elimination[b]	0.41	0.75	0.67	1.16	1.31	1.22	F = E; F < WP

Note. [a]Minimum is 24 and maximum is 144; [b]Minimum is 0 and maximum is 4. The mathematical sign = can be interpreted as 'not different'.

Number of trials per condition per session

There was no significant difference in the mean number of trials between the fading condition and the embedded condition, $F < 1$. However, a clear difference was visible between the fading and the without-picture condition: children needed fewer trials in the fading condition than in the without-picture condition, $F(1, 38) = 14.52$, $p < .001$ (one-tailed), $d = .56$.

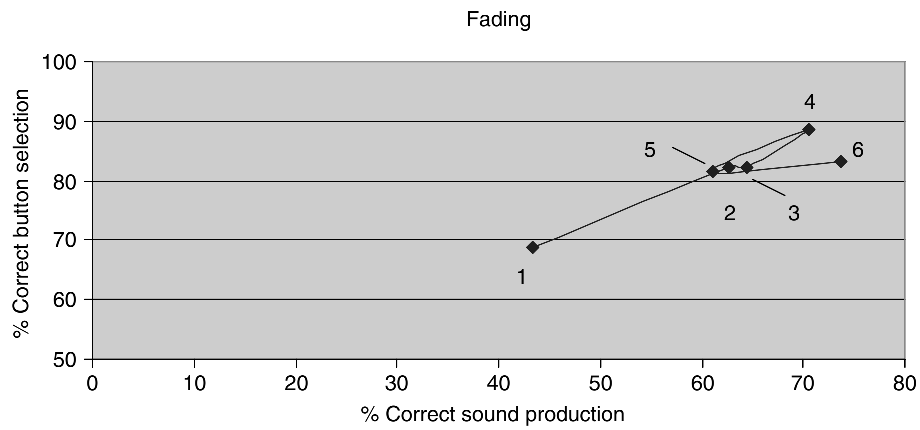
Elimination of letters during the training

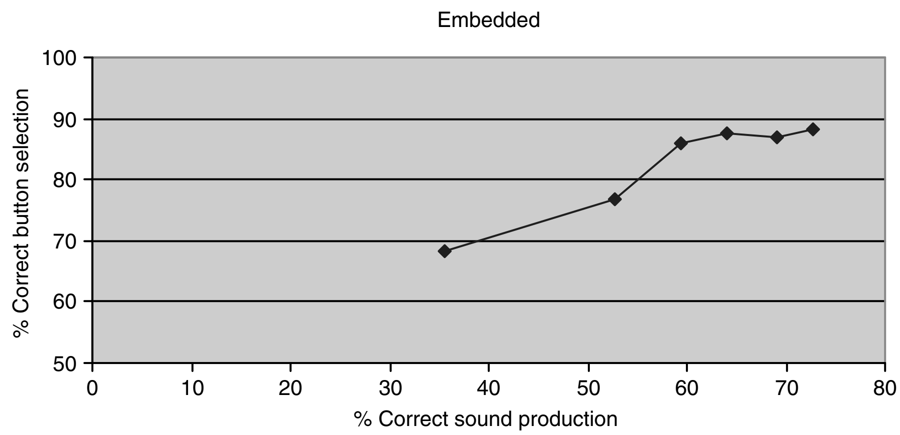
In the without-picture condition, more letters were eliminated from the letter set than in the fading condition, $F(1, 38) = 15.79$, $p < .001$ (one-tailed), $d = .89$. Between fading and embedded no such difference was found, $F(1, 38) = 1.11$, $p = .30$ (one-tailed).

Note that if the elimination rule had not been adopted in the computer program, the difference in mean number of trials between the fading condition and the without-picture condition would have been even more pronounced. Relating these findings to the outcome measures, particularly productive letter-sound knowledge, it can be concluded that children learned more letters in the fading condition than in the without-picture condition, but needed fewer trials to do so. Moreover, children made an equal number of errors in the fading condition and in the embedded condition, because there were no differences between these conditions on the variables number of trials and elimination of letters. Apparently, performance during the training was equally facilitated by the fading and the embedded conditions.

Patterns of learning during training

The learning curves presented in Figure 3 reveal the relationship between the percentage correct of sound-button selection and that of sound production during





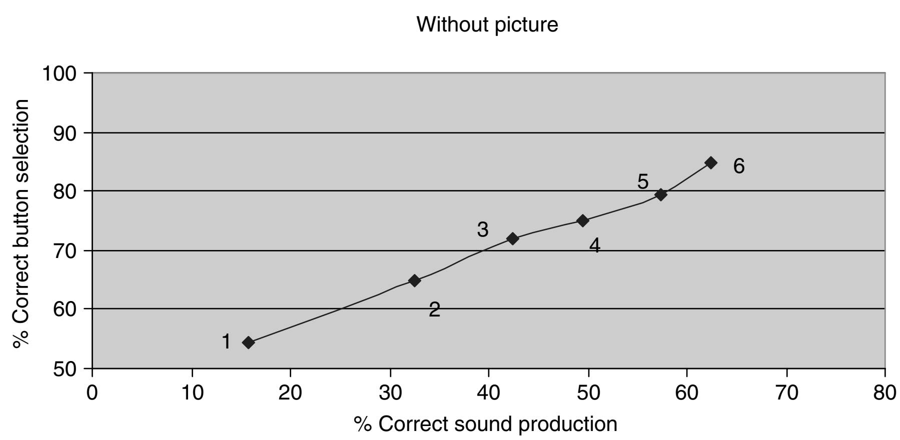


Figure 3. Learning curves showing the relation between percentage correct of sound button selection and the percentage correct of sound production during training in the fading condition (a), the embedded condition (b) and the without-picture condition (c).

training in each of the three conditions. In the embedded condition, the relationship appeared to be linear, but levelled off in Phase 3. In the without-picture condition, a clear linearly increasing relationship emerged between sound-button selection and correct sound production. In the fading condition, up until Phase 4, a similar linear trend was visible, but in Phase 5, the relationship became unstable (i.e. drops) and re-established itself in Phase 6. Recall that in the fading procedure the picture gradually faded out and became completely invisible in Phase 5, hence the destabilization of the children's behaviour.

Strategy use: recall of mnemonic word

To test whether children really used the strategy that was proposed to them, that is, linking a sound to a letter by means of a mnemonic word, we asked them at Post-test II and at the retention test whether they could recall the mnemonic word associated with a letter. The independent variables are time of test (Post-test II vs. retention test) and experimental condition (fading vs. embedded vs. without picture). The dependent variable is recall of mnemonic word; mean sum scores and standard deviations are shown in Table 3.

Although Table 3 suggests that children recalled more words at the retention test than at Post-test II, this main effect of time was not significant, $F(1, 37) = 1.69$, $p = .20$ (two-tailed). Regarding the differences between the experimental conditions, it appeared that at Post-test II children recalled more mnemonic words for letters trained in the fading condition than in the embedded and in the without-picture condition, $F(1, 37) = 23.40$, $p < .001$ (one-tailed), $d = .79$ and $F(1, 37) = 7.01$, $p = .01$ (one-tailed), $d = .49$, respectively. At the retention test, a comparable difference was visible: children recalled more mnemonic words for letters trained in the fading condition than in the embedded condition and in the without-picture condition, $F(1, 38) = 18.36$, $p < .001$ (one-tailed), $d = .81$ and $F(1, 38) = 29.43$, $p < .001$ (one-tailed), $d = .93$, respectively. In short, recall for mnemonic words was superior for letters trained in the fading condition than for letters trained in the other two conditions in all assessment sessions.

First-sound isolation ability and training outcome

The mean sum score on the first-sound isolation task was 11.2 ($SD = 8.0$). A frequency distribution showed that scores on this task were not uni-modally but bimodally distributed. It was therefore decided to distinguish between children who have good first-sound isolation skill, that is a score ≥ 10 ($N = 25$) on the task and children who have poor or no first-sound isolation skill, a score < 10 ($N = 13$). Because training effectiveness was more clear-cut for performance on the productive letter-sound test, we related first-sound isolation ability to this task only. Mean sum scores and standard deviations of letter-sound knowledge as a function of first-sound isolation ability and of time of testing are shown in Table 7. To determine whether children with good and poor first-sound isolation skill differed in letter-sound recall, we performed a series of one-way ANOVAs for all three training conditions in all three assessment sessions. An alpha-level of .05 was used for all statistical tests. In case of significant differences, Cohen's *d* effect size measures are reported. In case of non-homogeneous standard deviations, the largest standard deviation was used rather than the pooled-standard deviation.

In the fading condition in all three assessment sessions, children with good first-sound isolation ability did not recall more letter sounds than children with poor first-sound isolation ability, Post-test I: $F(1, 36) = 1.41$, $p = .12$ (one-tailed); Post-test II: $F < 1$

Table 7. Mean sum scores and standard deviations on the test for productive letter-sound knowledge as a function of first-sound isolation ability, training condition and time of testing

	First-sound isolation ability			
	Good		Poor	
Conditions	*M*	*SD*	*M*	*SD*
Post-test I				
Fading	1.44	1.08	1.00	1.08
Embedded	1.00	0.91	0.31	0.48
Without picture	1.40	1.19	0.69	0.86
Post-test II				
Fading	2.44	0.92	2.15	1.14
Embedded	1.60	1.32	0.85	0.56
Without picture	2.20	1.00	1.54	0.97
Retention test				
Fading	2.44	1.08	2.08	1.26
Embedded	1.60	1.41	0.85	0.55
Retention test	2.20	1.08	1.23	0.83

and retention test: $F < 1$. In the embedded condition, the two groups differed significantly at Post-test I, $F(1, 36) = 6.48$, $p = .01$ (one-tailed), $d = .95$, at Post-test II, $F(1, 36) = 3.83$, $p = .03$ (one-tailed), $d = .57$[5] and at the retention test, $F(1, 36) = 3.39$, $p = .04$ (one-tailed), $d = .53$[4]. Children with good first-sound isolation ability recalled more letter sounds than those with poor first-sound isolation ability. In the without-picture condition, we again found significant differences at Post-test I, $F(1, 36) = 3.61$, $p = .03$ (one-tailed), $d = .68$, at Post-test II, $F(1, 36) = 3.83$, $p = .03$ (one-tailed), $d = .67$ and at the retention test, $F(1, 36) = 7.97$, $p = .004$ (one-tailed), $d = 1.01$. In all cases, children with good first-sound isolation ability recalled more letter sounds.

To put it short, the fading condition showed no difference in letter-sound recall between good and poor performers on the first-sound isolation task, whereas in the embedded and the without-picture condition, significant differences emerged between the two groups of children in favour of children with good first-sound isolation skill.

General discussion

Claims of the effectiveness of integrated, pictorial mnemonics with stimulus fading (Hoogeveen *et al.*, 1989) or without stimulus fading (Ehri *et al.*, 1984) to promote letter-sound knowledge are confirmed by this study. The strongest evidence comes from the productive letter-sound test results. Children's performance on letter sounds trained in the fading condition was better than in the embedded condition. It appears that the fading procedure helped the children to pay attention to the relevant visual features of the letters and establish transfer of stimulus control from the picture to the letter. The without-picture condition was included in this study to establish whether possible effects were due to mere rote rehearsal. Only at the retention test did children perform better in the

[5] *Cohen's d is based on the largest standard deviation.*

fading condition than in the without-picture condition. Similar findings showed up when we performed analyses across letters and their supporting mnemonics. Superior recall for letters practised in the fading condition is particularly evident when compared with the embedded condition. The comparison between the fading and the without-picture condition is less clear-cut. Although this finding does not completely rule out rote rehearsal as an explanation for the training effects, the fact that children learned more letters in the fading condition than in the without-picture condition, but needed fewer trials (i.e. made fewer errors) to do so, makes rote rehearsal an unlikely explanation. Thus, also in terms of efficiency the fading condition is superior to the other two conditions. This finding is in accordance with a word-reading training study by Corey and Shamow (1972). They showed that a fading procedure resulted in a lower error rate than a procedure in which words were shown along with pictures, but without fading.

The interesting pattern that emerged from the three learning curves, relating percentage correct of sound-button selection and percentage correct of sound production during training, suggests that the transition from a vague picture to no picture in the fading procedure is an important aspect. Although the transition from Phase 4 to Phase 5 caused a decrease in the stability of the children's correct behaviour, they partially recovered from this in the next and last phase. This effect combined with the fact that the fading condition led to better transfer than the embedded condition regarding productive letter-sound performance again provides evidence for the superiority of the fading procedure. The latter finding is in accordance with results reported by Marsh and Desberg (1978) who also found that a first-sound mnemonics procedure facilitated performance during the training, but they found no transfer to a letter-sound task without pictures. It seems that an integrated-picture procedure alone does not guarantee training effectiveness. To enable transfer, an additional procedure, in this study the fading procedure, appears essential to make children pay attention to the letter characteristics.

The training had no effect on receptive letter-sound knowledge. No gains were found in receptive letter-knowledge between Post-test I and Post-test II and no differences were found between the conditions in these assessment sessions. Children improved between Post-test II and the retention test. However, no differences between conditions were found at the retention test. The improvement between Post-test II and the retention test is probably due to exposure to letters in the classroom during the period of 4 weeks that took place between these two assessments. How can we explain this weak transfer to the six-alternative forced-choice receptive letter test? One possibility, suggested by experimenter experience, is that the children got confused by the test. The cue words in the six-alternative forced-choice receptive letter test were not the same as the mnemonic words used in the training. For example, in the test they were instructed to point to the/d/from door, whereas the mnemonic word for the 'd' in the training was dinosaur. When we incidentally used the mnemonic word after a wrong answer in the receptive letter test, children were often better able to point to the correct letter.

Another explanation is that in the training the only direction in which the letters were taught to the child was from letter to sound, whereas in the receptive letter test the reverse direction, from sound to letter, was tested. A similar finding is reported by Ehri *et al.* (1984). In their training, children were instructed to say the sounds of letters. When they were tested in the reverse direction, that is writing the letters of the sounds they heard, performance was also poorer.

More evidence for the effectiveness of pictorial mnemonics and stimulus fading comes from the variable mnemonic-word recall. This variable was included to establish whether the children really used the strategy that was intended, namely, linking the sound to the letter by means of a mnemonic. The finding that children recalled more words from letters trained in the fading condition than in the other two conditions provides evidence for this.

We examined two additional questions in this study. The first additional question pertained to the influence of pre-existing letter-sound knowledge and age on training success. No interactions between these variables and training condition were found indicating that children from different age groups and with varying degrees of letter knowledge profited equally from the training. The second additional research question was whether the segmentation training that Ehri *et al.* (1984) used prior to the letter training was necessary. We related good and poor performance on a first-sound isolation task to productive letter-sound knowledge. In the embedded and in the without-picture conditions, children with good first-sound isolation skill outperformed children without this skill, but in the fading condition no such difference occurred. As was shown earlier, the fading procedure facilitated the recall of the mnemonic word. The feedback procedure integrated in the training itself, in which children repeatedly heard mnemonic words with the first sound pronounced distinctly, apparently enabled them to learn to isolate the first sounds of these specific words. This finding suggests that a segmentation training prior to a letter training with a fading procedure is not required. However, we need to be cautious because differences in the fading condition between children with good and poor first-sound isolation skill were in the expected direction. The absence of a significant effect might be due to a lack of power, indicating that a segmentation training also facilitates learning in the fading condition.

In their study, Ehri *et al.* (1984) asked whether drawing letters as part of the training could be replaced by other procedures without losing effectiveness. Comparing letter-sound recall of children in the present study with recall of children in Ehri *et al.*'s study, showed superior recall in the Ehri *et al.*'s study (60% and 92%, respectively). At least three reasons can be put forward to explain this difference. The first is that, in fact, the current fading procedure is less effective than Ehri *et al.*'s drawing practice. A second reason concerns the number of letters practised. In the present study, children practised 12 letters, whereas in Ehri *et al.*'s study, children practised only 5 letters. It is probably harder to discriminate 12 different letter-sound relations than 5, causing a lower score in our study. A third reason pertains to the amount of time spent on the task. The children in Ehri *et al.*'s study spent more time on practising one letter (11.3 minutes) than the children in the present study (6.41 minutes). None of these explanations can be ruled out based on the present experiment, which paves the way for future research to find out whether the fading or the drawing procedure is more effective for learning letters.

The fact that recall of letter sounds is always better in the fading condition than in the embedded condition carries an important implication for practice. Simple exposure to mnemonics (e.g. posting mnemonic alphabet pictures on classroom walls) is not enough for children to make the connection between letters and their corresponding sounds. An additional procedure is needed.

Although children performed better in the fading condition than in the two other conditions, we believe that there are possibilities to optimize the general effectiveness of the training program. First of all, changing the internal feedback structure of the program may result in stronger gains. For example, in addition to stimulus fading in response to a correct answer, pictorial elements can be reintroduced after a number of consecutive errors. This titration procedure prevents letters from being eliminated in an early stage, providing the child with more practice trials, which in-turn, enhances the possibilities for success. Furthermore, teaching letters in both directions, that is, from letter to sound as well as from sound to letter, may benefit transfer to other tasks as well.

In sum, an integrated-pictorial mnemonics and stimulus-fading procedure has proven to be effective for teaching children letter sounds. Our computer-assisted training program not only holds important promises regarding the inducement and/or enhancement of the development of beginning literacy in kindergartners, but may be equally useful for children in Grade 1 who experience problems acquiring literacy. Moreover, our program may also be useful for children with mild physical impairments, because it does not require specific fine motor skills.

References

Baddeley, A. (1997). *Human memory. Theory and practice* (Rev. ed.). Hove and New York: Psychology Press.

Ball, E. W., & Blachman, B. A. (1991). Does phoneme awareness training in kindergarten make a difference in early word recognition and developmental spelling? *Reading Research Quarterly*, *26*, 49–66.

Bradley, L., & Bryant, P. E. (1983). Categorizing sounds and learning to read – a causal connection. *Nature*, *301*, 419–421.

Byrne, B., & Fielding-Barnsley, R. (1989). Phonemic awareness and letter knowledge in the child's acquisition of the alphabetic principle. *Journal of Educational Psychology*, *81*, 313–321.

Caravolas, M., Hulme, C., & Snowling, M. J. (2001). The foundations of spelling ability: Evidence from a 3-year longitudinal study. *Journal of Memory and Language*, *45*, 751–771.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Corey, J. R., & Shamow, J. (1972). The effects of fading on the acquisition and retention of oral reading. *Journal of Applied Behavior Analysis*, *5*, 311–315.

Ehri, L. C., Deffner, N. D., & Wilce, L. S. (1984). Pictorial mnemonics for phonics. *Journal of Educational Psychology*, *76*, 880–893.

Ehri, L. C., Nunes, S. R., Willows, D. M., Valeska Schuster, B., Yaghoub-Zadeh, Z., & Shanahan, T. (2001). Phonemic awareness instruction helps children learn to read: Evidence from the national reading panel's meta-analysis. *Reading Research Quarterly*, *36*, 250–287.

Fulk, B. M., Lohman, D., & Belfiore, P. J. (1997). Effects of integrated picture mnemonics on the letter recognition and letter-sound acquisition of transitional first-grade students with special needs. *Learning Disability Quarterly*, *20*, 33–42.

Gathercole, S. E. (1998). The development of memory. *Journal of Child Psychology and Psychiatry*, *39*, 3–27.

Gleitman, H., Fridlund, A. J., & Reisberg, D. (1999). *Psychology*. New York: W.W. Norton & Company.

Gruneberg, M., & Sykes, R. (1996). The use of mnemonic strategies in the learning of non roman foreign language alphabets. *Language Learning Journal*, *13*, 82–83.

Higbee, K. L. (1987). Process mnemonics: Principles, prospects, and problems. In M. A. McDaniel & M. Pressley (Eds.), *Imagery and related mnemonic processes: Theories, individual differences, and applications* (pp. 407–427). New York: Springer-Verlag.

Hoogeveen, F. R., Smeets, P. M., & Lancioni, G. E. (1989). Teaching moderately mentally retarded children basic reading skills. *Research in Developmental Disabilities*, *10*, 1–18.

Lonigan, C. J., Burgess, S. R., & Anthony, J. L. (2000). Development of emergent literacy and early reading skills in preschool children: Evidence from a latent-variable longitudinal study. *Developmental Psychology*, *36*, 596–613.

Lu, M., Webb, J., Krus, D. J., & Fox, L. S. (1999). Using order analytic instructional hierarchies of mnemonics to facilitate learning Chinese and Japanese kanji characters. *Journal of Experimental Education*, *67*, 293–311.
Marsh, G., & Desberg, P. (1978). Mnemonics for phonics. *Contemporary Educational Psychology*, *3*, 57–61.
McBride-Chang, C. (1999). The ABC's of the ABCs: The development of letter-name and letter-sound knowledge. *Merrill-Palmer Quarterly*, *45*, 285–308.
McBride-Chang, C., & Treiman, R. (2003). Hong Kong Chinese kindergartners learn to read English analytically. *Psychological Science*, *14*, 138–143.
Miltenberger, R. G. (1997). *Behavior modification: Principles and procedures*. Pacific Grove, CA: Brooks/Cole Publishing Company.
Sadoski, M., & Paivio, A. (2001). *Imagery and text: A dual coding theory of reading and writing*. Mahwah, NJ: Lawrence Erlbaum Associates.
Schneider, W., Roth, E., & Ennemoser, M. (2000). Training phonological skills and letter knowledge in children at risk for dyslexia: A comparison of three kindergarten intervention programs. *Journal of Educational Psychology*, *92*, 284–295.
Share, D. L. (2004). Knowing letter names and learning letter sounds: A causal connection. *Journal of Experimental Child Psychology*, *88*, 213–233.
Treiman, R., & Broderick, V. (1998). What's in a name: Children's knowledge about the letters in their own names. *Journal of Experimental Child Psychology*, *70*, 97–116.
Treiman, R., & Kessler, B. (2004). The case of case: Children's knowledge and use of upper- and lowercase letters. *Applied Psycholinguistics*, *25*, 413–428.
Treiman, R., & Rodriguez, K. (1999). Young children use letter names in learning to read words. *Psychological Science*, *10*, 334–338.
Treiman, R., Tincoff, R., Rodriguez, K., Mouzaki, A., & Francis, D. J. (1998). The foundations of literacy: Learning the sounds of letters. *Child Development*, *69*, 1524–1540.
Wollen, K. A., Weber, A., & Lowry, D. H. (1972). Bizarreness versus interaction of mental images as determinants of learning. *Cognitive Psychology*, *3*, 518–523.

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