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Haptics in learning to read with children from low socio-economic status families

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This study assessed the effects of multi-sensory training on the understanding of the alphabetic principle in kindergarten children from low socio-economic status families. Two interventions were compared, called HVAM (visual and haptic exploration of letters) and VAM (visual exploration of letters). The interventions were conducted by either researchers or teachers. Results showed that performance in the letter recognition task and in the initial phoneme identification task were higher after HVAM training than after VAM training in kindergarten. Moreover, pseudo-word decoding scores improved more after HVAM training than after VAM training in first grade. This delayed effect on decoding was explained by the children's poor performance on some language skills necessary for reading acquisition. Visuo-haptic exploration enables the children first to increase performance on letter knowledge and initial phoneme awareness and then allowed better decoding skills. No differences were found between the interventions conducted by researchers and those conducted by teachers.

Numerous studies on reading acquisition have identified phonological awareness and more particularly phonemic awareness as one of the best predictors of reading success (Bus & Van Ijzendoorn, 1999; Ehri *et al.*, 2001; Gombert & Colé, 2000; Hulme *et al.*, 2002; Sprugevica & Hoien, 2003; Troia, 1999). However, this ability seems to be necessary but not sufficient in itself for acquiring phonological decoding skills (for a recent review, see Castles & Coltheart, 2004). Training in phonological awareness and letter knowledge in combination is a more effective foundation for teaching children to read than training phonological skills in isolation (Byrne & Fielding-Barnsley, 1991; Castles & Coltheart, 2004; Ehri *et al.*, 2001; Schneider, Roth, & Ennemoser, 2000).

Although this kind of training has proved to be quite efficient, the question of the optimal strategy for training children to link their emerging phonological awareness with printed knowledge (in particular letter knowledge) is still a challenge in research.

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The multi-sensory methods, which stress all the different channels (vision, hearing and haptic), seem to bring a suitable solution because they could make very explicit connections between the different activities involved in reading and spelling (Bryant & Bradley, 1985). These methods allow the child to retain at the same time, the visual image of the letter and the movement necessary for writing it, and thus is in line with Frith's (1985) claim that access to the alphabetic principle comes via spelling and writing acquisition.

Some studies have shown that multi-sensory methods are particularly suitable for the remediation of reading difficulties (Bradley, 1981; Bryant & Bradley, 1985; Hulme, 1981; Ofman & Shaevitz, 1963). According to Bryant and Bradley, backward readers, just as beginner readers, tend to treat as two separate things: what they learn about a written word's sound and what they learn about its visual appearance. Multi-sensory methods enable them to connect these two different kinds of learning.

In our recent studies, we successfully used a multi-sensory training with pre-reading kindergarten children from average socio-economic status families (Bara, Gentaz, & Colé, 2004; Gentaz, Colé, & Bara, 2003). We investigated the effects, on the understanding and use of the alphabetic principle, of adding visuo-haptic and haptic exploration of letters in training designed to develop phonemic awareness, letter knowledge and letter/sound correspondences. Two kinds of intervention, which differed in the perceptual modes they addressed, were compared. 'HVAM' training (haptic-visual-auditory-metaphonological) involved haptic, visual and auditory modes whereas 'VAM' training (visual-auditory-metaphonological) only involved visual and auditory modes. Both interventions made use of the same phonological exercises. However, whereas the work on letter identity in HVAM training was based on visuo-haptic and haptic exploration (the shapes of the raised letters were traced with the index finger), only visual exploration was involved in VAM training. Results revealed that pseudo-word decoding scores improved more after HVAM training than after VAM training. However, no difference was found between the two interventions in the letter recognition test and in the phoneme identification tests. This positive effect on decoding was explained in terms of the functional specificities of various sensory modes (Hatwell, Streri, & Gentaz, 2000; Lederman & Klatzky, 1987). In the case of sight, all the object's dimensions are perceived quasi-simultaneously. It is not the same in haptic modality because haptic exploration requires children to process letters in a more sequential and therefore in a more analytical way, something which they do not do naturally when letters are presented in a visual mode only. As a result, it might facilitate the link between letters which are processed visually and sounds which are processed auditorily. This hypothesis was investigated in another study (Bara *et al.*, 2004) by evaluating a third training called 'VAM-sequential'. In this training, the letters were explored visually and sequentially (they took shape gradually on a computer screen). Results showed that pseudo-word decoding scores were higher after HVAM training than after both VAM and VAM-sequential training. Therefore, they suggested that the sequential exploration of letters (independent of the perceptual modality involved) was not sufficient alone for explaining improvements in pseudo-word decoding. In conclusion, it is the active motor act of exploring the letter in itself that improves the children's decoding level.

Because of the number of backward readers and because children who are experiencing early difficulties in learning to read almost invariably continue to be poor readers throughout their schooling (Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996; Torgesen & Burgess, 1998), it seems of crucial importance to find ways of preventing early potential problems. In this framework, we have to deal with the manner of selecting children who need early intervention. Hatcher, Hulme, and Snowling (2004) have recently determined three variables which allow us to identify easily, at a very early stage of schooling, children who are more likely to fail in reading acquisition. Children can be considered at risk of reading failure if they show a low level of vocabulary, letter identification, rhyme and phoneme deletion, and if they are slow at acquiring these literacy skills. Although semantic abilities essentially assume importance later in the reading acquisition process, they can also affect decoding skills because they are predictive of phonological awareness (Bishop & Adams, 1990; Burgess & Lonigan, 1998; Elbro, Borstrom, & Petersen, 1998; Lonigan, Burgess, & Anthony, 2000; Lonigan, Burgess, Anthony, & Barker, 1998; Share, Jorm, Maclean, & Matthews, 1984; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wagner *et al.*, 1997) and because their growth fosters phonological segmentation (Carroll, Snowling, Hulme, & Stevenson, 2003).

This problem of reading readiness is strongly linked to family income. It has been reported that poor readers, who enter school significantly delayed in a wider range of pre-reading skills, consist largely of children from low socio-economic status families (Davie, Butler, & Goldstein, 1972; Duncan, 2000; Jantz, 1974; Raz & Bryant, 1990; Stuart, 1998; Wedge & Prosser, 1973). To explain this poor reading level, a number of preschool factors have been identified, such as low frequency of shared reading activities at home (Adam, 1990; Britto, Fuligni, & Brooks-Gunn, 2002; Hewinson & Tizard, 1980), limited material for promoting letter knowledge (Stuart, Dixon, Masterson, & Quinlan, 1998), low average development of language (Quigley, 1973) and low phonological awareness level (Bowey, 1995; Lonigan *et al.*, 2000; Raz & Bryant, 1990). These children show difficulties in understanding and applying the alphabetic principle (Torgesen & Burgess, 1998) and in learning to use the regular patterns of correspondence between letters and sounds as an aid for identifying new words (Siegel, 1989). These difficulties should be avoided by an explicit and systematic phonemic and alphabet letter instruction (Cardoso-Martins, 1991; Hatcher *et al.*, 2004; Roberts, 2003). Moreover, at-risk children benefit more from phonological training than normally developing children and reading delayed children (Ehri *et al.*, 2001).

Positive results obtained with readers in difficulty and with pre-readers in kindergarten lead us to think that the multi-sensory method should be quite suitable for reading difficulty prevention. Thus, the present study evaluates the effects of incorporating visuo-haptic and haptic exploration of letters in a preparatory reading intervention with kindergarten children from low socio-economic status families. This study had three main objectives:

(1) To compare two ways of improving decoding skills in children at risk of reading failure, who were selected by their family income. For this purpose, we compared two interventions, one with a visuo-haptic and haptic exploration of letters (called HVAM; experimental group) and the other with only a visual exploration of letters (called VAM, control group). We chose the VAM training as a control group because the goal was not to evaluate the effects of VAM training *per se*, but to evaluate the effects of the addition of haptics in such training. Several studies (e.g. Byrne & Fielding-Barnsley, 1991) have already compared the effects of this kind of training (which develops phonemic awareness and letter knowledge) with the effects of other control training (with only phonological exercises or semantic exercises).

(2) To examine training effects in children from low socio-economic status families. Because of the children's characteristics (low level in vocabulary, letter knowledge

and phonological awareness), it is possible that the training effects on the decoding level would be delayed until a certain level of necessary language skills was acquired. Therefore, we evaluated the long-term effects of the interventions by testing the children twice, first immediately after training (at the end of kindergarten) and then at the beginning of first grade.

(3) To assess the 'ecological validity' of the interventions. The interventions were conducted by either experimenters or classroom teachers. A few studies in which training was led by teachers have shown that they were effective in teaching phonemic awareness; however, the effect on reading was smaller than for the interventions led by researchers (Ehri *et al.*, 2001). Nevertheless, it seems that the intervention efficiency results from the training attended by teachers. Blachman, Tangel, Wynne-Ball, Black, and McGraw (1999) showed that after giving teachers-specific training on the goals and the procedure of the intervention, no difference remained between teachers and researchers. Consequently, in our study, teachers and researchers received equivalent training.

If the experiment shows the same pattern of results as the previous studies, we should observe an improvement in the pseudo-word decoding task, following HVAM and VAM training, but with higher amplitude after HVAM training than after VAM training. Moreover, we should observe a similar improvement in the letter knowledge test and in the phoneme identification tests. Because of the children's characteristics (low level in vocabulary, letter knowledge and phonological awareness), an alternative hypothesis may be that the training effect on the decoding level would be delayed until some necessary language skills were acquired (that is letter knowledge and phonemic awareness). Regression analyses should permit us to address this question. Considering the fact that teachers and experimenters were equally trained, we expected no differences between the interventions led by teachers and those led by experimenters.

Method

Participants

One hundred and thirty-two French children (77 girls and 55 boys) selected from a sample of 230 children, with a mean age of 5 years 5 months (5 years to 6 years 1 month), took part in this study. These children were attending 14 different kindergarten classes at schools in Chambéry (Savoie, France). They were all schooled in a 'Priority Education Area' (called ZEP in France) which is defined as a low socio-economic catchment area exhibiting a variety of social difficulties such as lower socio-economic status and unemployment. Thus, these children belonged to low socio-economic status families which can be described, according to the Government criteria, as families where unemployment is high or for whom low income is the predominant situation. Moreover, many of these are single parent families and are very frequently non-francophone.

We included in the experimental sample only the children who participated in the three test sessions (one pre-test and two post-tests after training) and who participated in all the training sessions (consequently, 98 children were removed from the sample). In each classroom, children in the two training groups were matched on each of the following criteria: age, vocabulary level (EVIP; Dunn, Thériault-Whalen, & Dunn, 1993), non-verbal performance level (square from WPPSI), metaphonological abilities (a rhyme identification test, an initial phoneme identification test and a final phoneme identification test), knowledge of the alphabet and pseudo-word decoding (Table 1; all $p > .5$). There were 66 children in each training group.

Table 1. Characteristics of children in each group before the interventions

	Training	
	HVAM	VAM
Age: M (σ)	67.2 (3.0)	65.8 (3.3)
Vocabulary (EVIP): M (σ)	57.0 (17.5)	54.1 (13.6)
Kohs block: M (σ)	24.9 (5.7)	24.0 (5.2)
Letter knowledge: M (σ)	11.4 (6.6)	10.7 (6.6)

Student t tests were performed in order to compare the scores obtained by children from low and average socio-economic status families (from the study of Bara *et al.*, 2004). The results revealed that children from low socio-economic status families showed lower level of vocabulary [$t(190) = 5.48$, $p < .001$], letter knowledge [$t(190) = 3.83$, $p < .001$] and rhyme identification [$t(190) = 4.8$, $p < .001$]. Thus, these children could actually be considered at risk of reading failure (Hatcher *et al.*, 2004).

The mean scores (and standard deviations) in pre-test, for children from two different socio-economic status families, are presented in Table 2.

Table 2. Mean scores (and standard deviation) obtained in vocabulary, Kohs block, letter recognition and phonological tests, for children from low and average socio-economic status families, before the interventions (scores coming from Bara *et al.*, 2004)

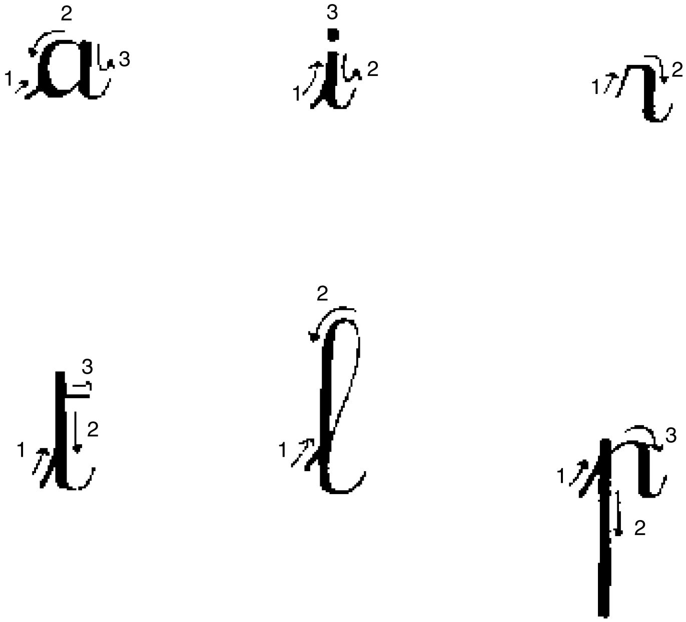
Social status	Vocabulary (EVIP)	Kohs block	Letter recognition	Rhyme	Initial phoneme	Final phoneme
Low ($N = 132$)	55.7 (15.6)	24.6 (5.5)	11.1 (6.6)	3.9 (1.6)	3.5 (1.6)	3.2 (1.7)
Average ($N = 60$)	69.0 (15.8)	25.2 (4.8)	14.9 (6.3)	5.1 (1.2)	3.1 (1.6)	3.3 (1.3)

Materials and procedure

For the training sessions, the selection of the phonemes and the order in which they were studied were based on their frequency of appearance in the French language (Rondal, 1997). Thus the sessions started with the study of the sounds /a/ and /i/ (amongst the most frequent), continued with sounds /r/ and /l/, and terminated with the sounds /t/ and /p/ (less frequent). The typography of each letter resembled lowercase handwriting (Figure 1).

Pre-test and post-test 1 in kindergarten

Each child's understanding and use of the alphabetic principle and his or her metaphonological abilities were individually evaluated between 1 and 2 weeks before and after the interventions which took place between the months of February and May.



Note: The numbers inscribed above the arrows indicated the exploration order of each letter.

Figure 1. The typography of each letter.

These evaluations were carried out by four experimenters, who remained blind to the training assignments of each child.

(a) The letter recognition test. The experimenter said the name of a letter and the child had to indicate on a presentation card (composed of six written letters) the letter he or she had heard. Each correct response was scored 1. Before the training, all of the 26 letters were tested (score out of 26), whereas in the post-tests only the six letters involved in each training session were tested (score out of 6).

(b) The children's metaphonological abilities were measured using three tests. A rhyme identification test, an initial phoneme identification test and a final phoneme identification test. In these three tests, pictures corresponding to familiar, easily depicted words were presented and pronounced by the experimenter (in order to avoid an effect of verbal memory) and children were asked to perform a specific task. In phoneme identification tests, children were asked to look for the six phonemes, which had been included in the training sessions. Each test consisted of three training trials, during which we made sure that the child had correctly understood the task, and six trials on the basis of which a score out of 6 was obtained. In the rhyme test, the child saw three pictures and had to indicate those corresponding to the two words 'that sound the same at the end' (e.g. *bulle* [bubble], *pull* [jumper], *four* [furnace]). In the test requiring the identification of phonemes in initial position, four pictures were presented in each trial. The experimenter chose a first picture and said the word. This first word was then used by the child to find, among the others three pictures, the one corresponding to the word 'that starts with the same sound' (e.g. *bague* [ring] was the

first word and the child had to choose between *bouée* [buoy], *chemise* [shirt], *stylo* [pen]). In the test requiring the identification of phonemes in final position, we used the same principle with the difference that the child had to find the word 'that ends with the same sound' (e.g. *lit* [bed] was the first word [in French, the last letter /t/ is not pronounced] and the child had to choose between *toupie* [spinning top], *pomme* [apple], *clé* [key]). In each test, the order of picture presentation was controlled; in each trial, we changed the position of the target word with reference to the word that acted as the starting-point in order to prevent the establishment of retrieval strategies based on the order of picture presentation.

(c) The pseudo-word decoding test. The experimenter told the child that the words were made-up and meant nothing in our language. To succeed the child had to associate the corresponding sounds with the letters. Two of these pseudo-words consisted of two letters, three out of three letters and one out of four letters (score out of 6). These pseudo-words consisted only of the alphabet letters studied during the training sessions.

Post-test 2 in first grade

The children were retested in November, in first grade. They were evaluated by means of four tests, similar to those used in post-test 1: a pseudo-word decoding test, a letter recognition test and two metaphonological tests. In the pseudo-word decoding test, they had to decode 11 pseudo-words made of the 6 letters trained. Six of the pseudo-words were the same as those in post-test 1 and five were added in order to make the task more difficult. Among the five new pseudo-words, one consisted of three letters, one of four letters and three of six letters. In the letter recognition test, the children had to recognize the six letters trained among all the alphabet letters. The final and initial phoneme identification tests were the same as in kindergarten.

Training sessions

Two equivalent groups of 66 children each were formed from eight criteria: age, vocabulary level (EVIP), non-verbal performance level (Kohs block from the WPPSI), three metaphonological tests, letter recognition and pseudo-word decoding. A specific training was administered to each group of children: 'HVAM' (experimental group) or 'VAM' (control group). Each program consisted of 12 training sessions, each of which was conducted in the same way (the same exercises were performed in the same order). Each training session lasted 25 min approximately. Foorman and Torgesen (2001) insisted on the fact that instruction for at-risk children must be more intensive than for other children. These children learn more slowly and will thus require more repetition in order to solidly establish critical decoding skills. Thus, each sequence of training was reproduced twice and two sessions were conducted each week. A different sound (and the corresponding letter) was learned each week during two training sessions. In consequence, each training program took 7 weeks (12 training sessions and 2 review sessions). By the end of the 12 sessions, children were familiar with the sounds/letters -a-, -i-, -r-, -l-, -t- and -p-.

The context in which the different groups were asked to work was identical. Each training session took place in an acoustically insulated room in order to optimize the children's attention. The children sat in-groups of five or six around a table in order to encourage their interactions. The experimenter involved each of them during the different exercises. The interventions were led for about half of the children by their classroom teacher and for the other half by experimenters. Teachers and experimenters were equally trained for 2 days to learn to lead the training sessions.

The two types of intervention used the same metaphonological exercises, which included nursery rhyme, posters and card games (see below). The basic difference between the two interventions lays in the sensory modes that were mobilized for exploring letters. Thus, 'HVAM' training mobilized haptic, visual and auditory modes, whereas 'VAM' training only mobilized visual and auditory modes.

HVAM training sessions

(a) Letter identification exercise. At the start of each session, the experimenter gave a small, moveable letter (made of foam 5 mm thick) to each child and showed the correct orientation of the letter. The experimenter asked them to guess its identity. The small letters -a-, -i- and -r- were 2.5 cm high, while the letters -t-, -l- and -p- were 4.8 cm high. The children held the letter in their hands during the two following activities (nursery rhyme and posters) and were free to touch it during this period.

(b) Nursery rhyme. After the first identification exercise, the experimenter recited a nursery rhyme. The rhyme contained many examples of the sound on which children were required to concentrate during the session. Its aim was to sensitize the children to sound by means of short, playful stories, which children found easy to remember and fun to repeat. During this rhyme, the children attempted to detect the sound that corresponded to the target letter. Then, they repeated the rhyme sentence by sentence. Repeating the rhyme enabled them to say the target sound a large number of times and to familiarize themselves with it. These two first exercises (letter identification and nursery rhyme) encouraged awareness of letter/sound correspondence, because it is the first stage in training where the letter is explicitly linked with a sound in words.

(c) Poster exercises. Children then started working on two posters (40 cm high × 60 cm wide). The first contained pictures corresponding to words starting with the learned sound and distractor words. Among the six words presented (three target words and three distractors), each child had to find a word starting with learned sound and to whisper the answer to the experimenter. Each child's answer was then revealed to the group and discussed in order to determine whether or not it was correct. We then moved on to the poster containing pictures corresponding to words which ended with the learned sound and repeated the above exercise accordingly.

(d) Visuo-haptic and haptic exercises. Large letters (fixed to a 20 cm × 25 cm board) made with foam were then handed out. The letters -a-, -i- and -r- were 5 cm high and the letters -t-, -l- and -p- were 10 cm high. Children were told to explore the relief letter with their fingers and run their index finger along its contours in a fixed exploratory order corresponding to its writing (Figure 1). The experimenter observed and checked the way that each child handled the letter. Once this exercise was finished, haptic exploration of the letter continued under a cover, which was placed above the board. The children slid their hands below the cover and were told to think of the letter while exploring it haptically. The same exercise was then used with the small letters (the same

as those used in the letter identification exercise), which were fixed to a board 10 × 13 cm. It should be noted that we used two letter sizes in order to facilitate learning and exploration of letters. Indeed, we know that medium amplitude movements are easier to control with precision than low amplitude movements. Thus large letters, which induced medium amplitude movements, helped children to succeed in this visuo-manual tracking task and gave them the idea of exploring letters. Therefore, this facilitated exploration of small letters, which induce low amplitude movements.

Once the haptic exploration training was finished, the child performed a recognition test using the small fixed letters. He or she had to distinguish between the letter learned during the session and a 'distractor letter' which physically resembled it. Thus, we associated the training letter (TL) -a- with the distractor letter (DL) -e-, the TL -i- with the DL -u-, the TL -r- with the DL -n-, the TL -l- with the DL - t-, the TL -t- with the DL -b-, and the TL -p- with the DL -q-. The two foam letters were arranged under a cover where children again had to slide their hands in order to handle them. Their task was to explore both letters and to identify the target letter. If children had correctly identified the letter, they were allowed to remove the cover and check for themselves. However, if they failed to identify the correct letter, the experimenter advised them to take their time and explore the two letters again.

(e) Card game exercises. The final stage of the session took the form of two card games. Pictures representing target and distractor words were spread out on the table. In the first game, children had to take turns to choose a picture, which corresponded to a word starting with the target sound. In the second game, the chosen picture had to represent a word, which ended with the learned sound. This game ended when no further target pictures remained.

VAM training sessions

(a) Letter identification exercise. Visual exploration boards were distributed. Each letter, printed on a sheet of paper, was glued to a small board. Each letter was the same size as the foam letters used in letter identification exercise in HVAM training. These boards displayed the handwritten letter to be learned and remained visible throughout the session. They helped children in the task of observing the letter. First, children tried to name the letter that was presented to them, after which the experimenter pronounced the sound corresponding to it.

(b) Nursery rhyme. The nursery rhyme exercise was the same as in the HVAM training sessions.

(c) Poster exercises. The two poster exercises were the same as in the HVAM training sessions.

(d) Visual exercises. The letter was then explored visually. The experimenter asked children to follow the drawing of the letter with their eyes and drew their attention to its shape and the lines and curves it contained. This information allowed them to subdivide the letter into organized elements and track its contour visually in a fixed exploratory order. When children had explored the letter for long enough, we distributed the sheets containing a visual recognition test. Children were asked to cross out the target letter

presented together with a number of distractors. The target letter was the letter studied during the training session, while the distractors were letters sharing physical characteristics with it. This test was presented on a sheet of paper (A4 format) containing 4 lines out of 12 letters each (with a small size). Each line of letters contained two types of 'distractor letters' and a variable number of instances of the target letter in order to prevent children from using a strategy based on the number of items to be crossed out. It should be noted that, for this training, we selected two distractor letters (instead of one in the haptic task) in order to increase the difficulty of the exercise (the use of a single letter makes the visual task too simple). The training letter (TL) -a- was associated with the distractor letters (DL) -o- and -e-, the TL -i- with the DL -j- and -u-, the TL -r- with the DL -n- and -s-, the TL -t- with the DL -b- and -d-, the TL -l- with the DL -t- and -h-, and the TL -p- with the DL -q- and -g-.
In order to equalize the two interventions length, we proposed an additional card game. A different card game was used in each session since the games were designed specifically for each training letter. Each game consisted of 12 cards amongst which there were 4 cards corresponding to the training letter, and 4 cards of each of the two distractor letters which shared physical characteristics with the target letter. The cards were spread on the table and each child had to take one. The distractor letters used for each target letter were the same as those used in the crossing-out task. Children had to judge whether the letter they had taken corresponded to the target letter or to a distractor by placing it in one out of the two boxes in front of them (one for target letters and one for distractor letters as specified by the experimenter or the teacher).

(e) Card game exercises. The two card game exercises were the same as in the HVAM training sessions.

Review session

A review session was planned for each group at the end of the six training sessions. First of all, we summarized the work done during the sessions and reminded children of the six letters they had studied together with the corresponding sounds. In HVAM training, children were told to explore each relief letter with their index finger. In VAM training, children were asked to explore each letter visually. The purpose of this session was to reactivate the knowledge acquired by children during the training sessions and then to get them to work with dominos. Dominos formed part of the metaphonological training. They consisted of two pictures placed side by side. All these pictures represented words which started (or ended) with one out of the six sounds learned during the training sessions. The children's task was to match the dominos in such a way that the different pictures, when put together, corresponded to words which started or finished with the same sound. We constructed two sets of dominos. The first game contained pictures corresponding to words, which started with the learned sounds; while the second contained pictures corresponding to words which finished with these sounds. The dominos also made it possible to check the children's knowledge of the different sounds they had learned.

Results

Five ANOVAs were performed on the scores in letter recognition, rhyme identification, phoneme identification tests and pseudo-word decoding. In each analysis, three variables were taken into account: training (HVAM or VAM), trainer (teacher or researcher) and period (pre-test, post-test 1 in kindergarten and post-test 2 in first grade). Because the inclusion of trainer factor in the analyses did not produced significant effects and for the purpose of clarity, we chose not to include this factor in figures.

Recognition of the six target letters

The mean number (and standard deviation) of correctly recognized target letters (maximum 6) before and after each of the two interventions in kindergarten and in first grade are presented in Figure 2.

The main effect of period [$F(2, 256) = 172.16$, $p < .001$] and of training type [$F(1, 128) = 5.8$, $p < .05$] were significant. These main effects were tempered by a significant training × period interaction [$F(2, 256) = 6.48$, $p < .01$]. The *post hoc* Newmans–Keuls comparisons showed that the difference between the two training types was not significant in pre-test, but was significant in post-test 1 in kindergarten children and in post-test 2 in first graders. The number of recognized letters was higher after HVAM training than after VAM training at the end of kindergarten ($M = 4.5$ vs. $M = 3.5$) and in first grade ($M = 5.6$ vs. $M = 5.2$).

The trainer effect [$F(1, 121) = 0.2$, $p > .25$], the trainer × training interaction [$F(14, 128) = 2.56$, $p > .25$] and the trainer × period interaction [$F(1, 256) = 0.55$, $p > .25$] were not significant.

Metaphonological abilities

The mean scores (and standard deviations) obtained in the three metaphonological tests before and after each of the two trainings in kindergarten and in first grade are presented in Table 3.

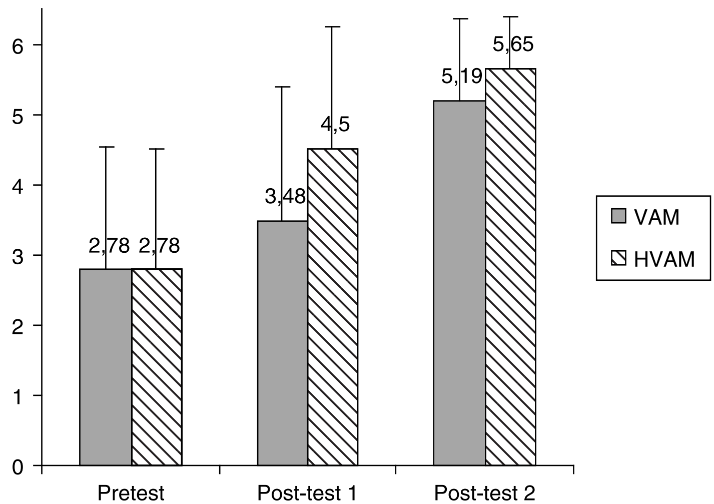


Figure 2. Mean number (and standard deviation) of recognized letters (maximum 6) before and after each of the two interventions in kindergarten and in first grade.

Table 3. Mean scores (and standard deviations) obtained in the three metaphonological tests before and after each intervention in kindergarten and in first grade

	Kindergarten		First grade
	Pre-test *M* (*SD*)	Post-test 1 *M* (*SD*)	Post-test 2 *M* (*SD*)
Rhyme			
HVAM	3.9 (1.5)	4.6 (1.4)	
VAM	3.9 (1.7)	4.7 (1.6)	
Initial phoneme			
HVAM	3.6 (1.6)	4.6 (1.3)	4.8 (1.2)
VAM	3.5 (1.6)	3.9 (1.7)	4.7 (1.3)
Final phoneme			
HVAM	3.1 (1.6)	4.5 (1.4)	4.8 (1.1)
VAM	3.2 (1.8)	3.8 (1.5)	4.5 (1.4)

(a) Rhyme test (score out of 6). The effect of period was significant [$F(1, 128) = 27.13$, $p < .001$], the scores in kindergarten were higher after the training sessions ($M = 4.6$) than before ($M = 3.9$). The effect of training type [$F(1, 128) = 0.09$, $p = .76$], the effect of trainer [$F(1, 128) = 0.10$, $p = .75$], the trainer × period interaction [$F(1, 128) = 0.12$, $p > .25$), the training × period interaction [$F(1, 128) = 0.08$, $p > .25$] and the trainer × training interaction [$F(1, 128) = 0.56$, $p > .25$] were not significant.

(b) Initial phoneme test (score out of 6). The main effect of period was significant [$F(2, 256) = 38.7$, $p < .001$]. This main effect was tempered by a significant training × period interaction [$F(2, 256) = 3.27$, $p < .05$]. The improvement of performances was higher after HVAM training than after VAM training. The *post hoc* Newmans–Keuls comparisons showed that the difference between the two interventions was not significant in pre-test and in first graders (post-test 2). It was significant in post-test 1, the scores were higher after HVAM training ($M = 4.6$) than after VAM training ($M = 3.9$). The trainer effect [$F(1, 128) = 0.005$, $p > .25$], the training type effect [$F(1, 128) = 1.8$, $p > .25$], the trainer × period interaction [$F(2, 256) = 1.02$, $p > .25$) and the trainer × training interaction [$F(1, 128) = 1.44$, $p > .25$] were not significant.

(c) Final phoneme test (score out of 6). The effect of period was significant [$F(2, 256) = 53.3$, $p < .001$]. The Newmans–Keuls comparisons showed that the performances were higher in post-test 1 ($M = 4.1$) than in pre-test ($M = 3.1$) and were higher in first grade ($M = 4.6$) than at the end of kindergarten. The trainer × period interaction was significant [$F(2, 256) = 3.4$, $p < .05$]. The Newmans–Keuls comparisons showed that the differences between the groups trained by teachers ($M = 2.81$) and the groups trained by experimenters ($M = 3.5$) were significant in pre-test. These results were explained by the fact that the sharing out in the groups was not equivalent concerning this measure. The training effect [$F(1, 128) = 3.26, p = .07$], the trainer effect [$F(1, 128) = 1.18$, $p = .17$], the trainer × training interaction [$F(1, 128) = 1.75$, $p = .18$] and the training × period interaction [$F(2, 256) = 2.44$, $p = .08$] were not significant.

Pseudo-word decoding

The mean number (and standard deviation) of correctly decoded pseudo-words before and after each training in kindergarten and in first grade are presented in Figure 3.

The main effects of period [$F(2, 256) = 165.6$, $p < .001$] and training type were significant [$F(1, 128) = 4.54$, $p < .05$]. These main effects were tempered by a significant period × training interaction [$F(2, 256) = 15.99$, $p < .001$]. The improvement of performances was more important after HVAM training than after VAM training. The planned comparisons showed no differences between the two interventions in pre-test and post-test 1 in kindergarten. The effect of training type was significant only in first grade [$F(1, 121) = 23.4$, $p < .001$]: the performances on the six pseudo-words was higher in HVAM training ($M = 3.7$) than in VAM training ($M = 2.2$).

The effect of trainer [$F(1, 128) = 0.62$, $p > .25$], the trainer × training interaction [$F(1, 128) = 0.21$, $p > .25$] and the trainer × period interaction [$F(2, 256) = 0,29$, $p > .25$] were not significant.

T Tests performed on the score obtained on the five new pseudo-words showed a significant effect of training type [$t(130) = 3.5$, $p < .001$]. The performances were higher after HVAM training ($M = 2.8$, $SD = 1.87$) than after VAM training ($M = 1.7$, $SD = 1.84$).

Correlation and regression analyses

In order to have a global understanding of the results and to better understand the link between verbal abilities, phonological awareness, letter knowledge and decoding skills, we performed correlation and regression analyses. These analyses were performed on the 132 children for whom pre-test and first grade data were available.

Table 4 shows the correlations between the pre-test scores in Kohs block, vocabulary, letter recognition, rhymes and phoneme identification and the scores in pseudo-word decoding in first grade. All correlations were significant.

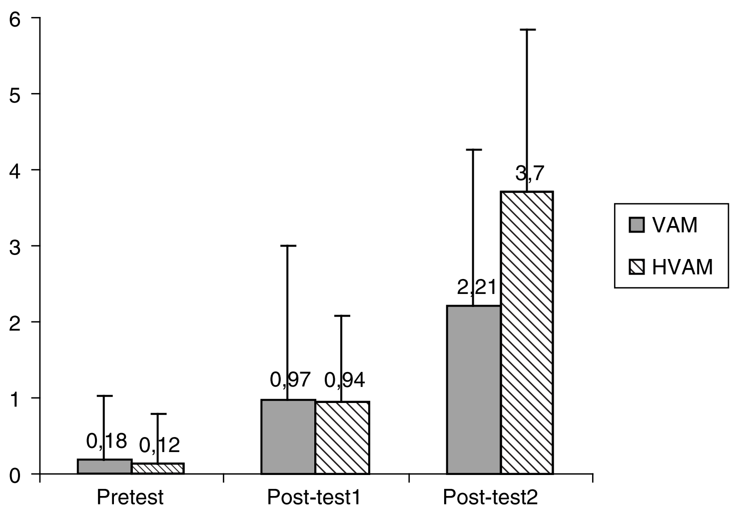


Figure 3. Mean number (and standard deviation) of correctly decoded pseudo-words before and after each of the two interventions in kindergarten (pre-test and post-test 1) and in first grade (post-test 2).

Table 4. Correlations between vocabulary, non-verbal IQ (Khos Block), rhyme test, phoneme identification tests and letter recognition (measured in pre-test in kindergarten) and pseudo-word decoding (measured post-test 2 in first grade) ($N = 132$)

	1	2	3	4	5	6	7
1. Vocabulary	–	.29**	.24**	.33**	.34**	.20*	.28**
2. Khos block		–	.31**	.29**	.42**	.31**	.36**
3. Rhyme			–	.33**	.49**	.39**	.35**
4. Initial phoneme				–	.60**	.32**	.47**
5. Final phoneme					–	.51**	.43**
6. Letter recognition						–	.63**
7. Pseudo-word decoding							–

* $p < .05$; ** $p < .01$.

Regression analyses were performed in order to find, among pre-test scores in kindergarten, the variables that better predict pseudo-word decoding in first grade. The aim of this analysis was to better understand the role of literacy skills on decoding acquisition.

Table 5 presents regression analyses that were computed with pseudo-word decoding in first grade as the dependant variable and pre-test scores as predictors.

Table 5. Hierarchical regression analyses with pseudo-word decoding in first grade at first assessment as the dependant variable and pre-test scores in, Kohs block, vocabulary, letter recognition, rhyme and phoneme identification as predictors ($N = 132$)

	Pseudo-word decoding	
Steps 1 to 6	R^2	R^2 change
1. Kohs block	.13	.13
2. Vocabulary	.16	.03*
3. Rhyme	.21	.05*
4. Final phoneme identification	.25	.04*
5. Initial phoneme identification	.30	.05**
6. Letter recognition	.49	.19**
5. Letter recognition	.44	.19**
6. Initial phoneme identification	.49	.05**

* $p < .05$; ** $p < .01$.

Taken together, the measurements in pre-test in kindergarten accounted for 49% of variance in pseudo-word decoding scores. Only letter recognition and initial phoneme identification accounted for a significant part of variance. When entered at the last step, letter recognition accounted for 19% of variance and initial phoneme identification accounted for 5% of variance.

Discussion

The aim of this study was to assess the effects of a multi-sensory intervention on understanding of the alphabetic principle in kindergarten children from low socio-economic status families. Two interventions, which differed in the way of exploring letters (haptic or visual), were compared. Children were tested three times, before and after the interventions in kindergarten and at the beginning of first grade. This research focused on a better way of teaching children at risk of reading failure about alphabetic letters and letter-sound relationships. We assumed that visuo-haptic and haptic exploration of letters (HVAM intervention) would improve the decoding level more than exclusively visual exploration (VAM intervention). In order to test this hypothesis, we compared children's performance in tests of letter recognition, phoneme identification and pseudo-word decoding.

At the end of kindergarten, we found that performance in letter recognition and initial phoneme identification improved more after HVAM training than after VAM training. Results in letter recognition were in line with those obtained by Hulme (1979, 1981), who found that haptic exploration resulted in more improvement of memorization of abstract graphical figures and alphabet letters than visual exploration only. Performance obtained on the initial phoneme identification test was more surprising. Indeed performances on this test were better after HVAM training than after VAM training. Actually, the two interventions proposed the same phonological activities, thus we expected no differences between the two training groups. However, this unpredicted result could be explained by the fact that letter knowledge and phonemic awareness are interactively linked (Burgess & Lonigan, 1998; Morais, Alegria, & Content, 1987). Previous studies show that letter knowledge is associated with some aspects of phonological awareness (Bowey, 1994; Stahl & Murray, 1994) and growth in these skills (Burgess & Lonigan, 1998; Wagner, Torgesen, & Rashotte, 1994; Wagner *et al.*, 1997). Johnston, Anderson, and Holligan (1996) reported that children who knew no letters never succeeded in phoneme segmentation or deletion tasks. Phonemic awareness is rarely observed in children prior to them having any alphabetic skills (Stahl & Murray, 1994; Wimmer, Landerl, Linortner, & Hummer, 1991) and children who do not know alphabet letters cannot learn to which sounds those letters relate (Bond & Dykstra, 1967). Treiman, Tincoff, Rodriguez, Mouzaki, and Francis (1998) found that children used their letter knowledge in the acquisition of letter sounds. Explicit awareness of a particular sound seems to be gained only when its connection with a particular letter is formed. Thus, because haptic exploration improved letter knowledge, phonemic awareness was more easily acquired.

Linguistic awareness and letter knowledge seem to be strongly interrelated and linked to reading acquisition (Lonigan *et al.*, 2000; Wagner *et al.*, 1997; Whitehurst & Lonigan, 1998). Reading consists of translating print units into sound units. Consequently, this task requires knowing the letters and being able to discriminate language units. The ability to link orthographic and phonological knowledge can be assessed specifically using the pseudo-word decoding task. Pseudo-word decoding is a phonological recoding task, which requires the ability to blend the individual phonemes and to combine them. Thus, success in this task lies in knowledge of both sound and letter. Pseudo-word decoding seems to be a suitable task for children at that age, in the sense that beginner readers are always confronted with unknown real words, which are equivalent for them to pseudo-words. Inasmuch as the training develops phonemic awareness and letter knowledge, it should improve children's alphabetic skills and thus their decoding level.

It is only in the first grade that pseudo-word decoding scores were significantly higher after HVAM training than after VAM training. This result is quite different from that obtained in our previous studies conducted with children from average socio-economic status families. In this latter group, as soon as the end of kindergarten, pseudo-word decoding improved more after HVAM training than after VAM training (Bara *et al.*, 2004; Gentaz *et al.*, 2003). In the present study, the training effect on pseudo-word decoding appears delayed. It was only at the first grade entry, when formal instruction had begun, that the expected effect on decoding was observed. This difference between our previous studies and the present one could be explained by the fact that the two kinds of population, from two different social backgrounds, differed on numerous aspects. If we compare results obtained in our previous study, with middle class children and those obtained in the present study, we can see that low-income children have a lower level in vocabulary, letter knowledge and rhyme identification. According to Hatcher *et al.*'s (2004) criteria, our selected population could be considered at risk of reading failure. However, no differences were found concerning the two phonemic awareness tests (initial and final phoneme identification). This could be explained by the fact that activities that develop phonemic awareness are typically presented at school, whereas rhyme sensitivity can be easily developed by some activities practiced at home. For example, sharing book reading and learning nursery rhymes is a good way for developing rhyme sensitivity (Bryant, Bradley, Maclean, & Crossland, 1989; Maclean, Bryant, & Bradley, 1987) and is a more common activity in average socio-economic status families. Raz and Bryant (1990) also reported that differences between the two social groups on phonological scores (phoneme detection) emerge only after children go to school. Therefore, phonemic awareness is more the product of their experience at school rather than home practice. It is also noticeable that score differences between the two socio-economic statuses concerned only the verbal abilities, while there was no difference on the non-verbal IQ (Kohs block test). In that sense, some studies have shown that a low IQ level is not related to a low reading level as far as decoding skills are concerned (Jimenez & Rodrigo-Lopez, 2000; Siegel, 1988; Siegel, 1989). Therefore, these results suggest that before reading instruction, low-income children already suffer from gaps on some language skills that are necessary for reading acquisition. These gaps seem to influence the speed of the alphabetic principle understanding. As language skills (letter knowledge and phonemic awareness) are less developed in low income children at the beginning of the interventions, the training effect on decoding skills is not immediate and is only shown when formal schooling has begun.

Haptic exploration first improved children's level in letter knowledge and initial phoneme identification. At the end of kindergarten, children had better performance after HVAM training than after VAM training in two domains necessary for the alphabetic principle acquisition (letter knowledge and phonemic awareness). Regression analyses showed that, among all factors measured before training, only letter recognition and initial phoneme identification were predictors of pseudo-word decoding. These results are in line with those obtained by Hulme *et al.* (2002), who showed that initial phoneme accounted for 10% of the variance in reading, whereas final phoneme did not account for variance. The ability to identify the first phoneme was a better predictor of reading level than the ability to identify onsets, rhymes or final phonemes. According to Treiman, Tincoff, and Richmond-Welty (1996) and Treiman, Weatherston, and Berch (1994), letter knowledge is the first stage of reading acquisition. Letter names help children to connect print and speech by noticing the links between letters in printed words and letters names in the corresponding spoken words.

Thus, the alphabetic process is interactively linked to the development of these two skills (letter knowledge and phonemic awareness) and both are needed to allow children to understand it. At the end of kindergarten, children trained with HVAM training possessed the necessary knowledge on alphabet letters and phonemic awareness to enable them to better understand the alphabetic principle. However, even if these skills were developed, their decoding level showed a ‘floor effect’ in kindergarten (children were able to decode less than one pseudo-word). We can consider that these emergent literacy abilities were not yet strong enough to show a measurable effect on decoding. The connection between letters and sounds was first developed in an implicit way by the multi-sensory training, and then this implicit knowledge was reactivated and became available when formal reading instruction had begun.

Another goal of this research was to test teachers’ ability to conduct training. As indicated previously, no difference between the interventions conducted by experimenters or those conducted by teachers was found. Teachers were able to successfully manage this kind of intervention, provided that they were equally trained to the method as researchers. These results replicate those obtained by Blachman *et al.* (1999): when teachers received a suitable training, the effect on the decoding level was observed. It seems that this kind of training can be offered in the classroom and can be included in the classic school programs used in kindergarten.

In summary, a preparatory reading intervention, which develops phonemic awareness, knowledge of letters and of letter-sound correspondences, is suitable and beneficial for children from low socio-economic status families. This kind of intervention is more effective when the exploration of letters is made by haptic modality in addition to visual modality. Haptic exploration increases letter knowledge and phonemic awareness and then, because it makes the link between letters and sounds more explicit, it improves decoding skills. Our results suggest that children from low income families, who are delayed in the acquisition of some necessary language skills, could benefit from an intervention which offers phonological and letter knowledge activities. Therefore, it seems that multi-sensory training can be successfully used for both remediation of reading difficulties and prevention of these difficulties. Finally, this kind of multi-sensory training can be conducted effectively by trained classroom teachers.

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References

Adam, M. J. (1990). *Beginning to read: Thinking and learning about print*. Cambridge, MA: MIT 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.

Bara, F., Gentaz, E., & Colé, P. (2004). The visuo-haptic and haptic exploration of letters increases the kindergarten-children’s reading acquisition. *Cognitive Development*, *19*, 433–449.

Berger, C., & Hatwell, Y. (1993). Dimensionnal and overall similarity classifications in haptics: A developmental study. *Cognitive Development*, *8*, 495–516.

Berger, C., & Hatwell, Y. (1996). Developmental trends in haptic and visual free classifications: Influence of stimulus structure and exploration on decisional processes. *Journal of Experimental Child Psychology*, *63*, 447–465.

Bishop, D. V. M., & Adams, J. (1990). A prospective study of the relationship between specific language impairment, phonological disorders and reading retardation. *Journal of Child Psychology and Psychiatry*, *31*, 1027–1050.

Blachman, B. A., Ball, E. W., Black, R. S., & Tangel, D. M. (1994). Kindergarten teachers develop phonemic awareness in low-income inner-city classrooms; Does it makes a difference? *Reading and Writing: An Interdisciplinary Journal*, *6*, 1–18.

Blachman, B. A., Tangel, D. M., Wynne-Ball, E., Black, R. S., & McGraw, C. K. (1999). Developping phonological awareness and word recognition skills: A two year intervention with low-income, inner city children. *Reading and Writing: An Interdisciplinary Journal*, *11*, 239–273.

Bond, G. L., & Dykstra, R. (1967). The cooperative research program in first grade reading instruction. *Reading Research Quarterly*, *2*, 5–142.

Bowey, J. A. (1994). Phonological sensitivity in novice readers and nonreaders. *Journal of Experimental Child Psychology*, *58*, 134–159.

Bowey, J. A. (1995). Socioeconomic status differences in preschool phonological sensitivity and first grade reading achievement. *Journal of Educational Psychology*, *87*, 476–487.

Bowey, J. A., & Francis, D. J. (1991). Phonological awareness as a function of age and exposure to reading instruction. *Applied Psycholinguistics*, *12*, 91–121.

Bradley, L. (1981). A tactile approach to reading. *British Journal of Special Education: Forward Trends*, *8*, 32–36.

Britto, P., Fuligni, A., & Brooks-Gunn, J. (2002). Reading, rhymes, and routines: American parents and their young children. In N. Halfon & K. McLearn (Eds.), *Child reading in America: Challenges facing parents with young children* (pp. 117–145). New York: Cambridge University Press.

Bryant, P., & Bradley, L. (1985). *Children's reading problems: Psychology and education*. Blackwell: Oxford, Oxfordshire, New York, NY.

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

Bryant, P. E., Bradley, L., Maclean, M., & Crossland, J. (1989). Nursery rhymes, phonological skills and reading. *Journal of Child Language*, *16*, 407–428.

Burgess, S. R., & Lonigan, C. J. (1998). Bidirectional relations of phonological sensitivity and prereading abilities: Evidence from a preschool sample. *Journal of Experimental Child Psychology*, *70*, 117–141.

Bus, A. G., & Van Ijzendoorn, M. H. (1999). Phonological awareness and early reading: A meta-analysis of experimental training studies. *Journal of Educational Psychology*, *91*, 403–414.

Byrne, B., & Fielding-Barnsley, R. (1991). Evaluation of a program to teach phonemic awareness to young children. *Journal of Educational Psychology*, *83*, 451–455.

Byrne, B., & Fielding-Barnsley, R. (1995). Evaluation of a program to teach phonemic awareness to young children: A 2 and 3 years follow-up and a new preschool trial. *Journal of Educational Psychology*, *87*, 488–503.

Cardoso-Martins, C. (1991). Awareness of phonemes and alphabetic literacy acquisition. *British Journal of Educational Psychology*, *61*, 164–173.

Carroll, J. M., Snowling, M., Hulme, C., & Stevenson, J. (2003). The development of phonological awareness in preschool children. *Developmental Psychology*, *39*, 913–923.

Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to sucess in learning to read? *Cognition*, *91*, 77–111.

Davie, R., Butler, N., & Goldstein, H. (1972). *From birth to seven: A report of the national child development study*. London: Longman.

De Jong, P. F., & Olson, R. K. (2004). Early predictors of letter knowledge. *Journal of Experimental Child Psychology*, *88*, 254–273.

Duncan, L. G., & Seymour, P. H. (2000). Socio-economic differences in foundation-level literacy. *British Journal of Psychology*, *91*, 145–166.

Dunn, L. M., Thériault-Whalen, C. M., & Dunn, L. M. (1993). *Echelle de vocabulaire en images Peabody*. Toronto: Editions Psycan.

Ehri, L. C., Nunes, S. R., Willows, D. M., Schuster, D. M., 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.

Elbro, C., Borstrom, I., & Petersen, D. K. (1998). Predicting dyslexia from kindergarten: The importance od distinctness of phonological representations of lexical items. *Reading Research Quaterly*, *33*, 36–60.

Foorman, B. R., Francis, D. J., Shaywitz, S. E., Shaywitz, B. A., & Fletcher, J. M. (1997). The case for early reading intervention. In B. A. Blachman (Ed.), *Foundations of reading acquisition and dyslexia: Implications for early intervention*. Mahwah, NJ: Erlbaum.

Foorman, B. R., & Torgesen, J. K. (2001). Critical elements of classroom and small-group instruction promote reading success in all children. *Learning Disabilities Research and Practice*, *16*, 203–212.

Francis, D. J., Shaywitz, S. E., Stuebing, K. K., Shaywitz, B. A., & Fletcher, J. M. (1996). Developmental lag versus deficit models of reading disability: A longitudinal, individual growth curves analysis. *Journal of Educational Psychology*, *90*, 37–55.

Gentaz, E., Colé, P., & Bara, F. (2003). Evaluation d'entraînements multisensoriels de préparation à la lecture chez les jeunes enfants de grande section maternelle: étude sur la contribution du système haptique manuel.[Evaluation of multisensoriel reading training in kindergarten children: The role of haptic exploration]. *L'Année Psychologique*, *104*, 561–584.

Gombert, J. E., & Colé, P. (2000). Activités métalinguistiques, lecture et illettrisme. In M. Kail & M. Fayol (Eds.), *L'acquisition dur langage: Le langage en développement au delà de trois ans* (Vol. 2, pp. 117–150). Paris: PUF.

Hatcher, J., Hulme, C., & Ellis, A. W. (1994). Ameliorating early reading failure by integrating the teaching of reading and phonological skills: The phonological linkage hypothesis. *Child Development*, *65*, 41–57.

Hatcher, P. J., Hulme, C., & Snowling, M. J. (2004). Explicit phoneme training combined with phonic reading instruction helps young children at risk of reading failure. *Journal of Child Psychology and Psychiatry*, *45*, 338–358.

Hatwell, Y., Streri, A., & Gentaz, E. (2000). *Toucher pour connaître. Psychologie cognitive de la perception tactile manuelle*. Paris: PUF.

Hewinson, J., & Tizard, J. (1980). Parental involvement and reading attainment. *British Journal of Developmental Psychology*, *50*, 209–215.

Hulme, C. (1979). The interaction of visual and motor memory for graphic forms following tracing. *Quarterly journal of Experimental Psychology*, *31*, 249–261.

Hulme, C. (1981). *Reading retardation and multisensory teaching*. Londres: Routledge & Kegan Paul.

Hulme, C., Hatcher, P. J., Nation, K., Brown, A., Adams, J., & Stuart, G. (2002). Phoneme awareness is a better predictor of early reading skill than onset-rime awareness. *Journal of Experimental Child Psychology*, *82*, 2–28.

Jantz, R. K. (1974). The effects of sex, race, IQ and SES on the reading scores of sixth graders for both levels and gains in performance. *Psychology in the Schools*, *11*, 90–94.

Jimenez, J. E., & Rodrigo-Lopez, M. R. (2000). IQ vs phonological recoding skill in explaining differences between poor readers and normal readers in word recognition: Evidence from a naming task. *Reading and Writing: An Interdisciplinary Journal*, *12*, 129–142.

Johnston, R., Anderson, M., & Holligan, C. (1996). Knowledge of the alphabet and explicit awareness of phonemes in pre-readers: The nature of the relationship. *Reading and Writing: An Interdisciplinary Journal*, *8*, 217–234.

Lederman, S. J., & Klatzky, R. L. (1987). Hand movements: A window into haptic object recognition. *Cognitive Psychology*, *19*, 342–368.

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.

Lonigan, C. J., Burgess, S. R., Anthony, J. L., & Barker, T. A. (1998). Development of phonological sensitivity in 2- to 5-year old children. *Journal of Educational Psychology*, *90*, 294–311.

Lundberg, I., Frost, J., & Petersen, O. (1988). Effects of an extensive program for stimulating phonological awareness in preschool children. *Reading Research Quarterly*, *23*, 263–284.

Maclean, M., Bryant, P., & Bradley, L. (1987). Rhymes, nursery rhymes and reading in early childhood. *Merrill-Palmer Quaterly*, *33*, 255–282.

Morais, J., Alegria, J., & Content, A. (1987). The relationships between segmental analysis and alphabetic literacy: An interactive view. *Cahiers de Psychologie Cognitive*, *7*, 415–438.

Nicholson, T. (1997). Closing the gap on reading failure: Social background, phonemic awareness, and learning to read. In B. A. Blachman (Ed.), *Foundations of reading acquisition and dyslexia: Implications for early intervention* (pp. 381–407).

Ofman, W., & Shaevitz, M. (1963). The kinesthetic method in remedial reading. *Journal of Experimental Education*, *3*, 317–320.

Orton, S. T. (1928). Specific reading disability – Strephosymbolia. *Journal of the American Medical Association*, *90*, 1095–1099.

Quigley, H. (1973). The pre-reading vocabulary of children leaving nursery school. *Educational Research*, *16*, 28–33.

Raz, I. S., & Bryant, P. (1990). Social background, phonological awareness and children's reading. *British Journal of Developmental Psychology*, *8*, 209–225.

Roberts, T. A. (2003). Effects of alphabet letter instruction on young children'sword recognition. *Journal of Educational Psychology*, *95*, 41–51.

Rondal, J. A. (1997). *L'évaluation du langage*. Liège: Mardaga.

Roth, F. P., Speece, D. L., & Cooper, D. H. (2002). A longitudinal analysis of the connection between oral language and early reading. *Journal of Educational Research*, *95*, 259–272.

Schneider, W., Küspert, P., Roth, E., & Visé, M. (1997). Short- and long-term effects of training phonological awareness in kindergarten: Evidence from two German studies. *Journal of Experimental Child Psychology*, *66*, 311–340.

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., Jorm, A. F., Maclean, R., & Matthews, R. (1984). Sources of individual differences in reading acquisition. *Journal of Educational Psychology*, *76*, 1309–1324.

Siegel, L. S. (1988). Evidence that IQ scores are irrelevant to the definition of learning disability. *Canadian Journal of Psychology*, *42*, 201–215.

Siegel, L. S. (1989a). IQ is irrelevant to the definition of learning disabilities? *Journal of Learning Disabilities*, *22*, 469–478.

Siegel, L. S. (1989b). IQ is irrelevant to the definition of learning disabilities. *Journal of Learning disabilities*, *22*, 469–479.

Snowling, M., Gallagher, A., & Frith, U. (2003). Family risk of dyslexia is continuous: Individual differences in the precursors of reading skills. *Child Development*, *74*, 358–373.

Sprugevica, L., & Hoien, T. (2003). Early phonological skills as a predictor of reading acquisition: A follow-up study from kindergarten to the middle of grade 2. *Scandinavian Journal of Psychology*, *44*(2), 119–124.

Stahl, S. A., & Murray, B. A. (1994). Defining phonological awareness and its relationship to reading. *Journal of Educational Psychology*, *76*, 466–477.

Stuart, M., Dixon, M., Masterson, J., & Quinlan, P. (1998). Learning to read at home and at school. *British Journal of Developmental Psychology*, *68*, 3–14.

Torgesen, J. K., & Burgess, S. R. (1998). Consistency of reading-related phonological processes throughout early childhood: Evidence from longitudinal correlational and instructional studies. In J. L. Metsala & L. C. Ehri (Eds.), *Word recognition in beginning reading* (pp. 161–188). Hillsdale, NJ: Erlbaum.

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

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.

Treiman, R., Weatherston, S., & Berch, D. (1994). The role of letter names in children learning of phoneme-grapheme relations. *Applied Psycholinguistics*, *15*, 97–122.

Troia, G. A. (1999). Phonological awareness intervention research: A critical review of the experimental methodology. *Reading Research Quarterly*, *34*, 28–52.

Tunmer, W. E., Herriman, M. L., & Nesdale, A. R. (1988). Metalinguistic awareness abilities and beginning reading. *Reading Research Quarterly*, *23*, 134–158.

Wagner, R. K., Torgesen, J. K., Laughon, P., Simmons, K., & Rashotte, C. A. (1993). Development of young readers' phonological processing abilities. *Journal of Educational Psychology*, *85*, 83–103.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1994). Development of reading related phonological processing abilities: New evidence if bidirectional causality from a latent variable longitudinal study. *Developmental Psychology*, *30*, 73–87.

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., Burgess, S. R., *et al.* (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: A 5-year longitudinal study. *Developmental Psychology*, *33*, 468–479.

Wedge, P., & Prosser, H. (1973). *Born to fail*. London: Arrow Books.

Whitehurst, G. J., & Fischel, J. E. (2000). Reading and language impairments in conditions of poverty. In D. V. M. Bishop & L. B. Leonard (Eds.), *Speech and language impairments in children: Causes, characteristics, intervention and outcome* (pp. 57–71). Philadelphia: Psychology Press.

Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. *Child Development*, *69*, 848–872.

Wimmer, H., Landerl, K., Linortner, R., & Hummer, P. (1991). The relationship of phonemic awareness to reading acquisition: More consequence than precondition, but still important. *Cognition*, *40*, 219–249.

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