The visuo-haptic and haptic exploration of letters increases the kindergarten-children's reading acquisition

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The visuo-haptic and haptic exploration of letters increases the kindergarten-children's understanding of the alphabetic principle

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Running title: Haptic contribution in reading acquisition

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Abstract

This study examined the effect of incorporating a visuo-haptic and haptic (tactual-kinaesthetic) exploration of letters in a training designed to develop phonemic awareness, knowledge of letters and letter/sound correspondences, on the children's (5 years old) understanding and use of the alphabetic principle. Three interventions, which differed in the work on letter identities, were evaluated. The letters were explored visually and haptically in "HVAM" training (Haptic-Visual-Auditory-Metaphonological), only visually in "VAM" training (Visual-Auditory-Metaphonological) and visually but in a sequential way in “VAM-sequential” training. The three interventions made use of the same phonological exercises. The results revealed that the improvement in the pseudo-word reading task was greater after HVAM training than after VAM and VAM-sequential training. Similar improvements in the letter recognition test and in the phonological awareness tests were observed after the three interventions. Taken together, the results show that incorporating the visuo-haptic and haptic exploration of letters has positive effects on the reading skills of young children. The sequentiality of the exploration is not sufficient alone for explaining these improvements.

Keywords: reading acquisition, multisensory, haptics

I. Introduction

This study examined the effects of incorporating a visuo-haptic and haptic (tactual-kinaesthetic) exploration of letters in a training designed to develop phonemic awareness, knowledge of letters and letter/sound correspondences, on the understanding of the alphabetic principle among pre-reading kindergarten children. Researches on reading acquisition had primarily focused on the phonological dimension involved in the understanding of the alphabetic principle. Several studies have shown that one of the factors influencing reading success lies in the development of some skills related to spoken language and broadly referred to as metaphonological abilities (for recent reviews in English, see Ehri, Nunes, Willows, Schuster, Yaghoub-Zadeh & Shanahan, 2001; Troia, 1999; for recent reviews in French, see Gombert & Colé, 2000; Sprenger-Charolles & Colé, 2003). These are defined as the abilities which allow children to identify the phonological components of linguistic units and to manipulate them intentionally (Liberman, Shankweiker, Fisher, & Carter, 1974). It appears that the metaphonemic abilities (the ability to manipulate the phonemes in spoken words) are the best predictors of reading in alphabetic systems (Ehri *& al.*, 2001).

Furthermore, if we very broadly believe the acquisition of reading to consist, on the one hand, in the development of phonological and orthographic representations and, on the other, in the establishment of connections between, or indeed the fusion of, these two types of representation (Metsala & Ehri, 1998), then the body of research devoted to the way in which these connections or this fusion come about is very slight and tends to consider that this is an "implicit" process which is triggered by the learning of letter/sound correspondences (e.g. Plaut, MacClelland, Seidenberg & Patterson, 1996). Reading training programs adhere strictly to this conception and make use of metaphonological and letter discrimination exercises which are associated with the learning of the letter/sound correspondences (Bus & van

Ijzendoorn, 1999). For example, Byrne and Fielding-Barnsley (1991) evaluated the efficiency of this kind of training program on 5-year-old pre-readers. The performances in phonemic awareness and word reading tasks improved more after this "experimental" training than after the "control" training which only made use of semantic activities. However, although this type of intervention really has a positive effect on reading preparation, reading acquisition generally remains slow and difficult and several months of formal instruction are necessary before young children grasp the logic of the alphabetic principle and apply it (Colé, Magnan & Grainger, 1999; O.N.L, 1998; Sprenger-Charolles, Siegel & Bonnet, 1998; Sprenger-Charolles, Siegel, Béchennec & Serniclaes, 2003).

In the light of Bryant and Bradley's work (1985), we might well imagine that one of the difficulties involved in learning to read relates in part to the task of establishing connections between the orthographic representations and the corresponding phonological representations. More precisely, it lies in a difficulty in establishing a connection between the visual image of a word and its auditory image. In an attempt to overcome this difficulty, these authors recommended the use of a "multisensory" learning method calling not only on the visual and auditory modes as is traditionally the case, but also on the manual haptic mode. Indeed, our hands do not simply possess the motor function of moving or transforming the objects in our environment, but also a highly efficient perceptual function (e.g. Gisbon, 1962; for recent reviews, see Hatwell, Streri, & Gentaz, 2000, 2003; Heller, 2000; Millar, 1994).

This multisensory approach was first proposed by Montessori (1915, 1958) and is still used today in a number of schools. This method had been successfully used to help children with reading difficulties and a number of older studies point out the benefits of using the haptic mode in addition to the visual and auditory modes.

Thus, Fernald (1943) employed a "multisensory" technique (largely based on Montessori's principles) with children exhibiting reading difficulties. This technique, known as the "multisensory trace" involves the children in tracing a written word with their index finger while pronouncing it and looking at it. In line with this, Ofman and Shaevitz (1963) compared the effectiveness of the "multisensory trace" with that of the "visual trace" and "reading only" in a task involving the learning of new words. The "visual trace" task consists of asking the children to track with their eyes a word which is gradually written in front of them. The results revealed that poor readers (aged 13 years) were significantly better able to learn new words using the "multisensory trace" and the "visual trace" techniques (which are identical) than with the "reading only" technique. The introduction of an exploratory movement (visuo-haptic or visual) in the apprehension of a written word seems to facilitate the learning in this type of readers.

In a similar vein, Hulme (1979) examined in younger children (8-9 years) the effect of the haptic exploration of abstract graphical figures on their memorization. The figures were explored either by looking at each of them ("Visual" condition), or by looking while simultaneously tracing them with the finger ("Visuo-Haptic" condition). The results indicated that the children in the "Visuo-Haptic" condition achieved significantly better performances in a subsequent recognition task than those in the "Visual" condition. Similar results were obtained with alphabet letters, in children with reading difficulties and normal-reading children (aged 9 years) (Hulme, 1981).

Recently, Gentaz, Colé and Bara (2003) investigated, in kindergarten children, the effects of adding a visuo-haptic and haptic exploration of letters in a reading training program, designed to develop phonemic awareness and knowledge of letters and letter/sound correspondences. Two interventions, which differed in the perceptual mode they address, were

compared. The HVAM training (Haptic-Visual-Auditory-Metaphonological) involved the haptic, visual and auditory mode whereas the VAM training (Visual-Auditory-Metaphonological) only exploited the visual and auditory modes. Both interventions made use of the same phonological exercises. However, whereas the work on letter identity was based on a visuo-haptic and haptic exploration (the shape of the letters was traced with the finger) in the HVAM training, only the visual exploration was exploited in the VAM training. Performances were assessed before and after interventions by means of pseudo-word reading, letter recognition and phonological tasks (rhyme and phoneme identification). The results revealed that the improvement in the pseudo-word reading was greater after HVAM training than after VAM training. Similar improvements between HVAM and VAM were observed in letter recognition and in the phonological tests. These results showed that incorporating the visuo-haptic and haptic exploration of letters increases the positive effects of the interventions on the understanding and use of the alphabetic principle in young children and thus on their reading level.

This positive effect of the haptic mode was explained in terms of the functional specificities of the various sensory modes in question (Gentaz & Rossetti, 1999; Hatwell, Streri & Gentaz, 2000, 2003; Lederman & Klatzky, 1987). Indeed, vision is characterized by its quasi-simultaneity and is therefore more suitable for processing and representing spatial stimuli such as letters. On the other hand**,** listening is sequential in nature and is more suitable for processing temporal stimuli such as the sounds of speech. This functional difference could explain why young children have some difficulties to establish the association between letters, which are processed visually, and sounds, which are processed auditorily. In contrast, the haptic mode shares characteristics with both the auditory and the visual modes. Even though its functioning is highly sequential in nature, the haptic mode is also a spatial mode since the exploration in this mode is not linear and subject to a fixed order.

Within this perspective, research into the development of the visual and haptic apprehension of objects has made it possible to better identify the characteristics of haptic exploration. Since objects are multidimensional, they possess values along a number of different dimensions such as texture, location, size, shape, etc. In the case of sight, all the dimensions are perceived practically simultaneously (separated by only a few milliseconds). The same is not true in the haptic mode because, in this case, the exploration involved makes the perception very sequential. This is the reason why the haptic perception appears to be less "global" and more "analytical" than the visual perception. Thus, as far as our study is concerned, the incorporation of the haptic mode should require children to process letters in a more sequential and therefore a more analytical way, something which they do not do naturally when letters are presented in the visual mode only.

The first goal of the present research was to confirm that incorporating the visuo-haptic and haptic exploration of letters in phonological and letter knowledge exercises, increases their positive effects on the understanding and use of the alphabetic principle in young children and thus on their reading skills. The second goal was to investigate whether these positive effects observed after HVAM training could be explained by the sequential exploration of letter induced by the haptic perception or by the haptic perception of letter *per se,* in evaluating a third training.

To study these issues, we examined in kindergarten children the effect of three interventions that were different by the sensory mode requested (visual, auditory and haptic) and by the way of exploring the letters (simultaneous or sequential). Thus, we presented children with the two interventions proposed by Gentaz *et al.* (2003) named HVAM and VAM respectively and with a third training. In the third training, labelled “VAM-sequential”, the letters were explored visually and sequentially (they take shape gradually on a computer

screen). The three interventions made use of exercises involving phonemic awareness and exercises bearing on letter recognition and learning of letter/sound correspondences.

Regarding the first goal (the investigation of the haptic exploration effects), we should observe an improvement in performances on both the tasks designed to evaluate the understanding and use of the alphabetic principle (pseudo-word reading and letter recognition tests) following HVAM and VAM training, but the amplitude of this improvement should be greater after HVAM training than VAM training. Regarding the second goal (the investigation of the role of the sequentiality of exploration), if the sequential exploration of letters explained the improvements in reading observed after the HVAM training, we should observe: 1) similar improvements (in pseudo-word reading and letter recognition tests) in the HVAM and VAM-sequential training and 2) lower improvements in the VAM training. By contrast, if haptic exploration *per se* was totally responsible for these improvements, we should observe greater performances after the HVAM training than after both the VAM-sequential and the VAM training. Finally, we also measured children's metaphonological abilities and we expected to observe similar improvements after the three interventions.

II. Method

II.1. Participants

Sixty monolingual French children (25 girls and 35 boys) with a mean age of five years seven months (5 years 2 months to 6 years 1 month) took part in this study. These children were attending three different kindergarten classes at schools in Grenoble (France). They all belonged to average socio-economic status. The children were pre-readers and had never been trained to phonological tasks. Only the children who were not at all the training sessions were removed from the group and not taken into account in the results analyses. In each classroom,

children in the three training groups were matched on the following criteria: age, vocabulary level (EVIP), non-verbal performance level (Kohs block from WIPSI) and metaphonological ability, knowledge of the alphabet letters and pseudo-word reading (see Tables 1, 3 and 5; all $p>.25$). Globally, there were 20 children in each training group.

(insert Table 1)

II. 2. Material and procedure

The selection of the phonemes and the order in which they were studied were based on their frequency of appearance in the French oral language (Rondal, 1997). Thus the sessions started with the study of the sounds /a/, /i/, (amongst the most frequent), continued with sounds /r/, /l/ and ended with the sounds /t/, /p/ and /b/ (less frequent). The typography of each letter resembled lowercase handwriting (Figure 1) and was used in all the exercises which required the use of the letters.

(insert Figure 1)

II. 2.1. Pre- and post-tests

Each child's understanding and use of the alphabetic principle and her or his metaphonological abilities were individually evaluated between one and two weeks before and after the interventions. These evaluations were carried out by the same experimenter who remained blind to training assignments of each child.

The understanding and use of the alphabetic principle were measured using a pseudo-word reading test and a test requiring the recognition of the alphabet letters. In the pseudo-word reading test, the experimenter told the children that words were made-up and meant nothing in their language. Three of these pseudo-words consisted of two letters, six of three

letters and three of four letters (score out of 12). These pseudo-words consisted only of the letters studied during the training sessions.

In 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 letters) the letter he had heard. Each correct response was scored 1. Before the interventions, all the 26 letters were tested (score out of 26) whereas in the post-test, only the letters involved in the training sessions were tested (score out of 7).

The children's metaphonological abilities were measured using three tests: a rhyme identification test, and two phoneme identification tests (in initial or final position in the words). In these three tests, pictures corresponding to familiar, easily depicted words were presented and the children were asked to perform a specific task. In our tests, the children were asked to look for the seven phonemes which had been included in the training sessions.

Each test consisted of three training trials, during which we made sure that the children had correctly understood the task, and six or seven trials on the basis of which a score out of six (for the rhyme test) or seven (for the two phoneme identification tests pb voir apres) 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" (for example: *b**ulle*** [bubble], ***pull*** [pull over], *four* [furnace]). In the test requiring the identification of the phonemes in initial position, four pictures were presented to the child 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 other three pictures, the one corresponding to the word "that starts with the same sound" (for example: ***b**ague* [ring] was the first word and the child had to choose between ***b**ouée* [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" (for example: ***lit,*** /li/ [bed]) was the first word and the child had to choose between *toup**ie*** [spinning top, /tupi/], *pomme* [apple], *clé* [key]; in the French oral language, the letter /t/ of /lit/ and the letter /e/ of /toupie/ are silent). In each test, the order of presentation of the pictures was controlled. Thus, in each trial, we changed the position of the target word with reference to the word that acted as the starting point for the child in order to prevent the establishment of retrieval strategies based on the order of picture presentation.

II.2.2. Training sessions

Three equivalent groups of 20 children each were formed from eight criteria: age, vocabulary level (EVIP), Khos blocks, three metaphonological tests, recognition of letters and pseudo-word reading (Tables 1, 3 and 5). A specific training (namely: HVAM, VAM or VAM-sequential) was administered to each of the groups of selected children by the same experimenter. Each intervention consisted of seven sessions, conducted in the same way (the same exercises were performed in the same order) and one revision session. A different sound (and the corresponding letter) was learned in each session. By the end of the interventions, the children were familiar with the sounds/letters -a-, -i-, -r-, -l- , -t-, -p- and -b-. One session was conducted each week. As a consequence, each intervention took 8 weeks (7 training sessions and 1 revision session). The interventions were conducted from February to May. The context in which the different groups were asked to work was identical. Each training session lasted for approximately 25 minutes and took place in an acoustically insulated room in order to optimise the children's attention. The children sat in groups of 5 or 6 around a table in order to encourage their interactions. The experimenter involved each of them during the different exercises.

The three interventions used the same metaphonological exercises which included the nursery rhyme, the posters and the card games. The basic difference between the three lies in

the sensory modes that were requested and in the manner of exploring the letters (simultaneous or sequential).

II.2.2.1.The HVAM training sessions

a) The identification exercise

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

b) The nursery rhyme

After the first identification exercise, the experimenter recited a nursery rhyme. The rhyme contained many examples of the sound on which the children were required to concentrate during the session. Its aim was to sensitise the children to the sound by means of short, playful stories which they found easy to remember and fun to repeat. During this rhyme, the children attempted to detect the sound that corresponded to the target letter. The children then repeated the rhyme sentence by sentence. Repeating the rhyme enabled them to pronounce the target sound a large number of times and to familiarize themselves with it. We expected this familiarization to encourage the learning of the letter/sound correspondences.

c) The two poster exercises

The children then started working on two posters (40 cm high by 60 cm wide). The first of these 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 the sound learned during the session and 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. The experimenter then moved on to the poster containing pictures corresponding to words which ended with the learned sound and repeated the above exercise accordingly.

d) The visuo-haptic and haptic exercises

The large letters (fixed to a 20 cm x 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-, -p- and –b- were 10 cm high. The children were told to explore the relief letter with their fingers and run their index finger along its outline in a fixed exploratory order corresponding to its writing (Figure 1). The experimenter observed and checked the way each child explored the letter. Once this exercise was finished, the 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, which were fixed to a 10 x 13 cm board (a-, -i- and -r- were 2.5 cm high and the letters -t-, -l-, -p- and –b- were 4.8 cm). It should be noted that we used two letter sizes in order to facilitate the learning and exploration of the letters. Indeed, we know that medium amplitude movements are easier to control with precision than low amplitude movements (Hatwell, Streri & Gentaz, 2003). Thus the large letters, which induced medium amplitude movements, helped the children succeed in this visuo-haptic tracking task and give them the way of exploring the letters. This therefore facilitated the exploration of the small letters which induce low amplitude movements.

Once the haptic exploration was finished, the children performed a recognition task using the small fixed letters. They 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- and the TL -t- with the DL -b-, the TL –p- with the DL –q- and the TL –b- with the DL –l-. The two foam letters were arranged under the cover where the children again had to slide their hands in order to handle them. Their task was to explore both letters and to identify the target. If the 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 letters again.

e) The two card game exercises

The final stage of the session took the form of two card games. Pictures representing the target and distractor words were spread out on the table. In the first game, the 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.

II.2.2.2 The VAM training sessions

a) The identification exercise

The visual exploration boards were distributed to each child. Each letter, printed on a sheet of paper, was glued to a small board. The experimenter showed the correct orientation of the letter and asked them to guess its identity. The size of each letter was the same as the size of the foam letters used in the identification exercise in the HVAM training. These boards displayed the handwritten letter to be learned and remained visible throughout the two following activities (the nursery rhyme and the posters).

b) The nursery rhyme

The nursery rhyme was the same as in the HVAM training sessions.

c) The two poster exercises

The two poster exercises were the same as in the HVAM training sessions.

d) The visual exercises

The letter was then explored visually. The experimenter asked the 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 the children to subdivide the letter into organized elements and track its contour visually in a fixed exploratory order (Figure 1). When the children had explored the letter for long enough, the experimenter distributed the sheets containing a visual recognition test. The children were asked to cross out the target letter presented together with a number of distractors (letters sharing physical characteristics with the target). This test was presented on a sheet of paper (A4 format) containing four lines of twelve 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 the children from using a strategy based on the number of items to be crossed out. It should be noted that 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 easy and to fast). 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- and the TL -l- with the DL -t- and -h-, the TL –p- with the DL –q- and -g- and the TL –b- with the DL –l- and –k-.

In order to attempt to equalise the global duration and the number of exercises between the interventions, we proposed an additional card game. In this game, the cards were spread on the table and each child had to take one of it. Each game consisted of 12 cards amongst

which there were four cards corresponding to the target letter, and four cards of each of the two distractors letters. The distractor letters used for each target letter were the same as those used in the crossing-out task. The children had to judge whether the letter they had taken corresponded to the target letter or to a distractor, in placing it in one of the two boxes placed in front of them (one for the target letter and one for the distractor letters as specified by the experimenter).

e) The two card game exercises

The two card game exercises were the same as in the HVAM training sessions.

II.2.2.3 The VAM-sequential training sessions

The progress of VAM-sequential training sessions was exactly the same as the VAM training sessions, except for the presentation of the letters (visually but sequentially). Indeed, the letter presented visually took shape gradually on the screen of a computer. The letter was traced sequentially on the screen by a black spot which moved while following its outlines. Once the letter was entirely drawn, it remained motionless and visible on the screen during 2 seconds, then disappeared during 10 milliseconds and started again to take shape. The experimenter asked the 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 sequential drawing allowed the children to subdivide the letter into organized elements and track its contours visually in a fixed exploratory order. Then, the children performed an observation work of the letter which takes shape on the screen. They had to follow with their eyes the layout of the letter and try to memorize it.

I.2.2.3. The revision session

A revision session was planned for each group at the end of the seven training sessions. First of all, we summarized the work done during the sessions and reminded the children of the seven letters they had studied together with the corresponding sounds. In the HVAM training, the children were told to explore each relief letter with their index finger. In the VAM training, the children were asked to explore visually each letter. In the VAM-sequential training children explored the letters seeing them gradually take shape on the computer screen. The purpose of this session was to reactivate the knowledge acquired by the children during the training sessions. Then they worked with the dominos, which formed part of the metaphonological training. The dominos consisted of two pictures placed side by side. All these pictures represented words which started (or ended) with one of the seven sounds learned during the training sessions. The children's task consisted of matching the dominos in such a way that the different pictures, when placed 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 one of the sounds learned during the training sessions, while the second contained pictures corresponding to words which finished with one of these sounds. The dominos also made it possible to check the children's knowledge of the different sounds they had learned.

III. Results

III.1 Pseudo-word reading

The mean number (and standard deviations) of correctly read pseudo-words (maximum 12) before and after each of the three interventions are presented in Table 3.

(insert Table 3)

A 3 (training) x 3 (period) ANCOVA, with the pretest scores in vocabulary, Khos blocks, phonological tests and letters recognition as covariates, was performed on the number of correctly read pseudo-words. It revealed that the effect of period was significant [$F(1,57)=62.88$, $p<.001$]: the performances were better after the interventions (M=3.86) than before (M=0.5). The training effect was not significant [$F(2,50)=1.53$]. The period x training interaction approached significance [$F(2,57)=2.97$, $p=.059$]. The pre-planed comparisons showed a significant difference between HVAM and VAM training [$F(1,50)=9.98$, $p<.01$]: the number of read pseudo-words was better after HVAM training (M=5.2) than after VAM training (M=2.75). The Newmans-Keuls comparisons showed that there were no differences between the three interventions in pre-test whereas, in post-test, the number of read pseudo-word was significantly higher after HVAM training than after VAM-sequential training (M=3.65). No difference was found between VAM and VAM-sequential.

III.2 Recognition of the seven target letters

The mean number (and standard deviations) of correctly recognized target letters (maximum 7) before and after each of the three interventions are presented in Table 4.

(insert Table 4)

A 3 (training) x 3 (period) ANCOVA, with the pretest scores in vocabulary, Khos blocks and phonological tests as covariates, was performed on the number of correctly recognized target letters. It revealed a significant effect of period [$F(1,57)=54.41$, $p<.001$]: the performances were better after the interventions (M=4.98) than before (M=3.78). The training effect and the interaction were not significant.

II.3. Metaphonological abilities

The mean scores (and standard deviations) obtained in the three metaphonological tests before and after each of the three interventions are presented in Table 5.

(insert Table 5)

a. The rhyme test (score out of 6)

A 3 (training) x 3 (period) ANCOVA, with the pre-test scores in vocabulary, khos blocks and letters recognition as covariates, was performed on the scores in the rhyme test. It showed a significant effect of period [$F(1,57)=18.21$, $p<.001$]: the performances were better after the interventions (M=5.65) than before (M=5.08). The training effect and the interaction were not significant.

b. The initial phoneme test (score out of 7)

A 3 (training) x 3 (period) ANCOVA, with the pre-test scores in vocabulary, khos blocks and letters recognition as covariates, was performed on the scores in the initial phoneme identification test. It showed a significant effect of period [$F(1,57)=51.67$, $p<.001$]: the performances were better after the interventions (M=5.25) than before (M=3.56). The training effect and the interaction were not significant.

c. The final phoneme test (score out of 7)

A 3 (training) x 3 (period) ANCOVA, with the pre-test scores in vocabulary, khos blocks and letters recognition as covariates, was performed on the scores in the final phoneme identification test. It revealed a significant effect of period [$F(1,57)=73.66$, $p<.001$]: the performances were better after the interventions (M=5.36) than before (M=3.7). The training effect and the interaction were not significant.

IV. Discussion

This study attempted to show that the addition of the haptic mode in a preparatory reading training program with kindergarten children can assist their understanding of the alphabetic principle and induce a major improvement in their reading skills. Moreover, the role of the sequential exploration of letters induced by the haptic perception in these positive effects was investigated. We measured the children's abilities before and after the HVAM, VAM and VAM-sequential interventions using two tests evaluating the understanding and use of the alphabetic principle (pseudo-word reading and letter recognition tests) and three tests involving phonological awareness (rhyme, initial and final identification tests).

First we observed an improvement of performances after each measures. These results were in line with the idea that any work in the field of phonemic awareness, associated with a work which develops both letters and letter/sound correspondences knowledge, assist children to understand the alphabetic principle and use it to decode written words (cf. Bus & van Ijzendoorn, 1999).

It is clear that the pseudo-word reading test is a good indicator of children's understanding of the alphabetic principle. Indeed, success in this test requires the application of the letter/sound correspondences with which the children were familiarized during the training sessions. This can only be effective if the children have understood the principle by which the sounds are represented by the letters. The results observed were consistent with those reported previously by Gentaz *et al.* (2003). The mean number of correctly read pseudo-words (close to 0 before the interventions) increased significantly after each of the intervention.

The results confirmed our hypothesis since the improvement in observed performances was greater after HVAM training than after VAM training (see also Appendix), given that the

addition of the haptic mode in the type of training inspired by Byrne and Fielding-Barnsley (1991) almost makes it possible to improve the beneficial effects in pseudo-word reading. The performances observed after the HVAM training were also greater than those observed after the VAM-sequential training (which did not differ from those after the VAM training). The sequential exploration of the letters seems not to be sufficient alone. A visual sequential perception of letters did not permit to benefit more of the training than a simultaneous way of perceiving letters. The sequentiality induced by the haptic exploration of letters seems not to be the most important component of haptic perception, which permit to make easier the connection between the letter and the sound. The fact that the haptic perception is necessarily sequential did not explain, on his own the beneficial effects on reading. These results about the beneficial role of a sequential exploration were not exactly in line with those observed by Ofman and Shaevitz's (1963) in poor readers (aged 13 years). Indeed, these authors found that a word was easily learned when it was explored sequentially (by sight or by touch). However, in this study, the children were older, and haptic perception is maybe less attractive than for young children.

The results in the test of recognizing the learned letters partially confirmed our hypothesis. The three interventions improved (in a similar way) the mean number of correctly identified target letters. However, as in the previous study (Gentaz & al, 2003), the improvement of the number of recognised letters was not greater after the haptic exploration than after the visual exploration.

The rhyme, initial and final phoneme identification tests make it possible to evaluate the effectiveness of the metaphonological exercises presented in the three training programs. The results were compatible with our hypotheses since the three interventions improved performances in each of the three tests in a similar way. This result could be easily explained

by the fact that the metaphonological exercises were the same in the three interventions.

Taken together, the results showed that incorporating the haptic mode in exercises involving letter and letter/sound correspondences knowledge, combined with exercises involving phonemic awareness, increase the positive effects of this type of training on the understanding and use of the alphabetic principle in young children and thus on their reading skills. Since this specific improvement was only observed after the HVAM training on pseudo-word reading (whereas the performances were similar after the three interventions on letters recognition), we can supposed that the haptic mode facilitates not exactly the knowledge of the letters and the sounds, but the connections between the two. The haptic exploration help to establish the links between the orthographic representation of the letters and the phonological representation of the corresponding sounds. This beneficial effect of incorporating the haptic mode could be due to various functional specificities of the sensory modes. Incorporating the haptic mode would force children to process the letters in a more analytical way, something which they do not do implicitly when the letters are presented in a visual form only (simultaneously or sequentially). This would favour the association with the sound of the letter, which is processed auditorily. This hypothesis could also partially explain the beneficial effects of writing activities on the understanding of the alphabetic principle observed in some studies (cf. Zesiger, 1995).

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

	EVIP	Kohs Block	Alphabet letters	Mean age
	M (σ)	M (σ)	M(σ)	M
HVAM	68.35 (16.06)	25.75 (4.63)	15.2 (6.3)	5 years and 6 months
VAM-sequential	66.9 (15.03)	23.7 (4.45)	16.5 (6.9)	5 years and 7 months
VAM	71.8 (16.77)	26.25 (5.32)	13.2 (5.45)	5 years and 7 months

Figure 1: The typography of each letter

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

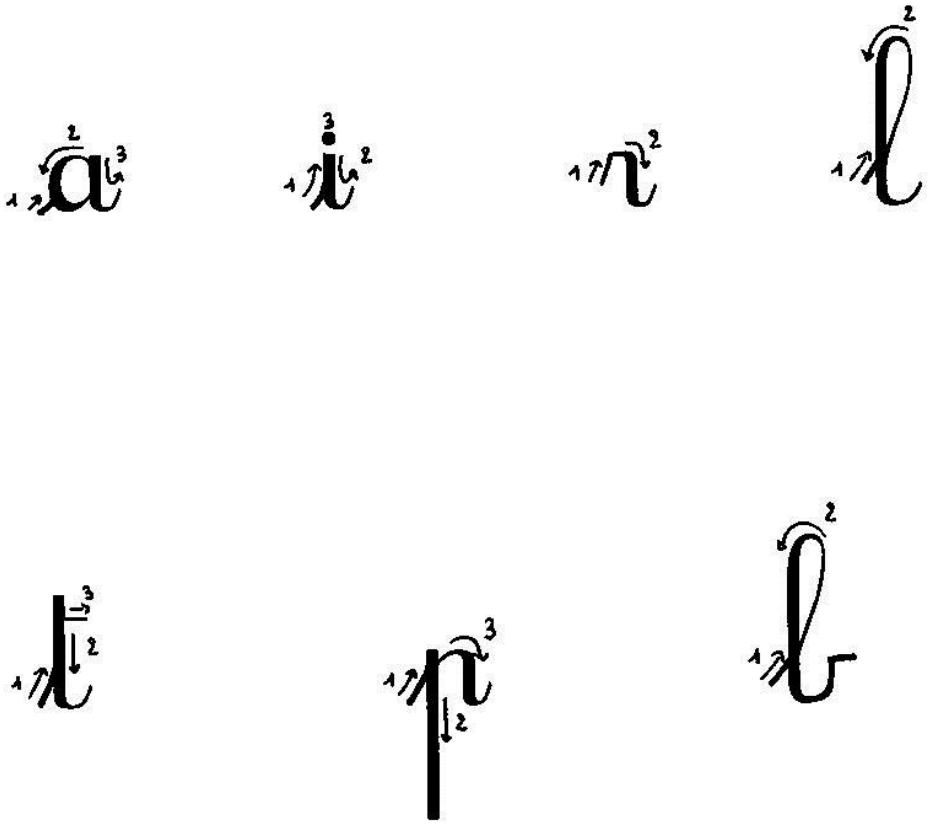

Table 3: Mean number (and standard deviations) of read pseudo-words (maximum 12) before and after each of the three interventions.

	Period	
	Pre-test	Post-test
Training	M (SD)	M (SD)
HVAM	0.55 (1.6)	5.2 (3.97)
VAM-sequential	0.45 (1.23)	3.65 (4.37)
VAM	0.6 (1.87)	2.75 (3.54)

Table 4: Mean number (and standard deviations) of recognized letters (maximum 7) before and after each of the three interventions.

	Period	
	Pre-test	Post-test
Training	M (SD)	M (SD)
HVAM	3.75 (1.8)	5 (1.33)
VAM-sequential	4.25 (2.02)	5.15 (1.9)
VAM	3.35 (1.66)	4.8 (1.7)

Table 5: Mean scores (and standard deviations) obtained in the three metaphonological tests before and after each intervention.

	Period	
	Pre-test	Post-test
Test x Training	M (SD)	M (SD)
Rhyme (max. 6)		
HVAM	5.15 (0.98)	5.55 (1.14)
VAM-sequential	4.8 (1.32)	5.75 (0.64)
VAM	5.3 (1.17)	5.65 (0.74)
Initial phoneme (max. 7)		
HVAM	3.7 (1.89)	5.5 (1.5)
VAM-sequential	3.35 (1.78)	5.25 (1.44)
VAM	3.65 (1.79)	5 (1.86)
Final phoneme (max. 7)		
HVAM	3.4 (1.4)	5.5 (1.6)
VAM-sequential	3.8 (1.19)	5.6 (1.18)
VAM	3.9 (1.74)	5 (1.77)

APPENDIX: CONTROL STUDY

The main purpose of this control study was to reproduce the results observed both in the main experiment and in Gentaz *et al*'s (2003) experiment. The HVAM and VAM interventions were evaluated in forty-two monolingual French children with a mean age of five years seven months (5 years 3 months to 6 years 1 month). Two equivalent groups of 21 children were formed (see Table A).

(insert Table A)

The method (pre- and post-test, the HVAM and VAM interventions) was the same as in the main experiment, except for the proposed phonemes (/a/, /i/, /r/, /l/ /t/). The results in the pseudo-word reading test confirmed the findings observed in the main experiment and by Gentaz, Colé and Bara (2003), since the improvement in observed performance was greater after HVAM training than after VAM training (see Table B; ANOVA revealed a main effect of training type [$F(1,40) = 16.09$, $p<.01$]). This means that the addition of the haptic mode in this type of training almost makes it possible to improve the beneficial effects in pseudo-word reading.

(insert Table B about here)

Table A: Characteristics of children in each group before the interventions.

	Training	
	HVAM	VAM
Mean age: M	5 years and 5 months	5 years and 6 months
TVAP-F : M (σ)	41.01 (4.3)	41.4 (6.8)
Khos Block: M (σ)	9.6 (0.6)	9.5 (0.9)
Alphabet letters: M (σ)	14.04 (5.5)	14.85 (4.86)

Table B: Mean number (and standard deviations) of read pseudo-words (maximum 9) before and after each of the two interventions in the control study.

	Period	
	Pre-test	Post-test
Training	M (SD)	M (SD)
HVAM	0.14 (0.36)	4.9 (2.3)
VAM	0.43 (0.92)	2.52 (2.61)