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Acta Psychologica 119 (2005) 67–79
acta psychologica
www.elsevier.com/locate/actpsy

The influence of writing practice on letter recognition in preschool children: A comparison between handwriting and typing

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Received 4 August 2004; received in revised form 27 October 2004; accepted 29 October 2004
Available online 4 January 2005

Abstract

A large body of data supports the view that movement plays a crucial role in letter representation and suggests that handwriting contributes to the visual recognition of letters. If so, changing the motor conditions while children are learning to write by using a method based on typing instead of handwriting should affect their subsequent letter recognition performances. In order to test this hypothesis, we trained two groups of 38 children (aged 3–5 years) to copy letters of the alphabet either by hand or by typing them. After three weeks of learning, we ran two recognition tests, one week apart, to compare the letter recognition performances of the two groups. The results showed that in the older children, the handwriting training gave rise to a better letter recognition than the typing training.

PsycINFO classification: 2330; 2343
Keywords: Children; Handwriting; Typing; Learning; Letter recognition; Motor–perceptual interactions

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0001-6918/$ - see front matter
doi:10.1016/j.actpsy.2004.10.019

1. Introduction

Nowadays, most adults probably write using a computer. Intensive use of word processing programs and the handy tools they contain (copy/paste, automatic spelling checks, etc.) is likely to modify high-level cognitive functions such as text composition (see Cochran-Smith, 1991). The present study deals with a more basic aspect of computer writing: the effects of dramatic motor changes resulting from the use of a keyboard instead of a pen. Computers are now being increasingly used at school, even at the preschool level, by very young children. If children happen to learn to write with a keyboard before they master handwriting, will this affect the way they perceive written language?

The idea that our movements organize our perceptions and contribute to setting up our spatial representations is not new and has by now become widely recognized (see Viviani, 2002). Some of the properties of objects (such as their shape, color and size) are perceived via the visual channel and others (such as their texture and temperature) by touch; all the diverse sensory inputs involved are combined together in time and space via active manipulatory movements, which also add their own information (weight, size, etc.). During childhood, we learn to associate actions with their correlated perceptions in order to build up unified, coherent representations of objects. Once the neural network underlying a given representation has been structured, any one of the inputs which was initially present suffices to reactivate the whole network (Martin, Ungerleider, & Haxby, 2000; Pulvermüller, 1999). The existence of these motor-perceptual links has been observed with neuroimaging techniques in humans; in particular, the visual presentation of pictures of objects, to which can be attributed a specific action, activated a premotor cortical area, even when no actual motor response was required (Chao & Martin, 2000). Furthermore, a growing body of lesion study data (e.g. Sirigu, Duhamel, & Poncet, 1991) suggests that sensorimotor knowledge about the functional properties of manipulatable objects is part of their representation, and can be used to recognize or name them (Martin et al., 2000). These motor-perceptual interactions involve associations of objects with potential actions: this is clearly what occurs in the case of tools.

Although alphabetic characters are not graspable objects, motor-perceptual links presumably contribute to their representation, since they are associated with highly specific writing movements. The fact that inability to write letters can be associated with reading deficits, due to an impaired ability to identify letters visually, is consistent with the existence of a tight coupling between the visual and sensorimotor perception of letter shapes (Anderson, Damasio, & Damasio, 1990). In addition, it has been established that writing movements can help subjects whose reading abilities are impaired: for instance, patients with pure alexia, who were no longer able to recognize letters visually, sometimes succeeded in doing so when they were asked to trace the outline of the letters with their fingers (Bartolomeo, Bachoud-Lévi, Chokron, & Degos, 2002; Seki, Yajima, & Sugishita, 1995). Handwriting movements may therefore somehow activate the visual representation of letters. The writing order of the numerous strokes composing ideograms is used as a cue to retrieve them from memory (Flores d'Arcais, 1994), which suggests that the motor scheme specific to each ideogram may be an essential component of its representation. This idea has been supported by neuroimaging studies on Japanese subjects who showed motor activation while looking at ideograms (Matsuo et al., 2001). Similarly, Longcamp, Anton, Roth, and Velay (2003) reported that, the simple visual presentation of Roman characters activated a premotor zone in the left hemisphere in right-handed subjects, even though no motor response was required. The activation of the corresponding area in the opposite hemisphere of left-handed subjects confirmed that this visually induced activation depends on the writing hand (Longcamp, Anton, Roth, & Velay, submitted for publication).

These various data converge to indicate that the cerebral representation of letters might not be strictly visual, but might be based on a complex neural network including a sensorimotor component acquired while learning concomitantly to read and write. Close functional relationships between the reading and writing processes might occur at a basic level, in addition to the interactions that have been described at a more cognitive level (Fitzgerald & Shanahan, 2000).

However, the existence of a sensorimotor component of this kind does not necessarily mean that it is involved in identifying letters. Nevertheless, there is some evidence which strongly suggests that writing movements are involved in letter memorization. For instance, repeated writing is an aid that is commonly used to help Japanese children memorize ideograms. In the same vein, Japanese adults often report that they write with their finger in the air to identify complex characters. In fact, it has been reported that learning by writing facilitated subjects' memorization of graphic forms but not that of ideograms, words or syllables (Naka & Naoi, 1995). This effect was stronger when the forms were freely recalled in writing, but visual recognition of graphic designs was also enhanced by writing. The results of a subsequent study by Naka (1998) confirmed the positive effect of writing training on free recall of graphic designs, but no such effect was observed on visual recognition. Visual recognition was also studied by Hulme (1979), who compared children's learning of a series of abstract graphic forms, depending on whether they simply looked at the forms or looked at them as well as tracing the forms with their index finger. The tracing movements seemed to improve the children's memorization of the graphic items; Thus, it was suggested that the visual and motor information might undergo a common representation process.

There do exist some discrepancies between the results of the studies devoted to the effects of motor activity on letter memorization. Some authors have examined whether the graphic movements involved in tracing or writing may enhance the high-level cognitive processes involved in the acquisition of reading skills (see Graham & Weintraub, 1996 for a review). This was the case in the few studies in which the respective advantages of learning by handwriting versus typewriting were compared. In one study (Cunningham & Stanovich, 1990), children spelled words which were learned by writing them by hand better than those learned by typing them on a computer. However, subsequent studies did not confirm the advantage of the handwriting method (Vaughn, Schumm, & Gordon, 1992, 1993). The results obtained in these studies showed that children's word writing and recognition performances were not affected when they had used a typing method, and since the act of typing is simpler than handwriting, typewriting was thought to constitute an efficient method of teaching moderately mentally retarded students how to read and write (Calhoun, 1985).

We assume that the main process, if any, influenced by motor activity is likely to be a spatial process, in the initial step in the recognition of written characters. In other terms, writing movements may contribute to memorizing the shape and/or orientation of characters. If this is so, changing the motor conditions present during learning by using a typing method instead of a handwriting one will probably affect the subjects' representation of letters and hence their subsequent letter recognition performances. We therefore studied the early letter learning process in very young children (3–5 years) who had not yet begun to learn to read and write at school. The two modes of learning, i.e. handwriting and typing, were compared between two groups of children by testing their letter recognition performances. Since the children who participated were very young and their age range was large (2 years), and since they had obviously not all reached the same stage of cognitive and motor development, we assumed that all the children would not benefit identically from the learning. We therefore compared the learning modes as a function of the children's age. Finally, it should be pointed out that most studies dealing with the effects of writing movements on reading ability have focused on quite short retention intervals (Cunningham & Stanovich, 1990; Vaughn et al., 1992 but see Vaughn, Schumm, & Gordon, 1993). Yet as mentioned by Hulme (1979), in teaching children to read and write, one is dealing with long term memory, since the information learned is retained for periods of time. Two recognition tests were therefore carried out in the present study: the first immediately following the learning phase (T1) and the second, one week later (T2).

2. Methods

2.1. Participants

Seventy-six children, 41 boys and 35 girls, with a mean age of 3:10 years (46 months) and an age range of 2:9 (33 months) to 4:9 years old (57 months) participated in the experiment. They were tested in three classrooms at three different preschools.

2.2. Procedure

2.2.1. Learning groups

All the children were first subjected to a battery of pre-tests. An adapted version of the Bender–Gestalt test for children younger than 6 years old was used to assess their perceptual-motor development. Manual dexterity was assessed using a 9-hole pegboard in which the children had to insert nine cylindrical pieces as fast as they could. The experimenter noted the time spent and the hand used. Manual laterality was assessed using a simplified version of the Edinburgh Handedness Inventory (Oldfield, 1971). In order to evaluate their initial level of letter knowledge before learning, the children were submitted to a letter recognition pre-test. This test was exactly the same as the test used after learning. The twelve uppercase letters, which were to be learned after the pre-test, were used (B, C, D, E, F, G, J, L, N, P, R, Z). The children were seated in front of a computer screen on which four character-like patterns, including three distractors, were presented (Fig. 1). Three distractors were used with each letter: the mirror image of the letter, a transformed letter (with a stroke added or missing from the letter), and the mirror image of the transformed letter. The instructions were: "Look carefully at the four letters on the screen: only one of them is the 'proper' letter, which is the letter you have learned with us. The other three are not correct. Show me this 'proper' letter with your index finger!". No speed instructions were given. The children's responses were recorded by the experimenter on the keyboard of the computer used for the test. Each of the four possible responses (upper left, upper right, lower left and lower right) was associated to a given key of the keyboard. Each letter and its distractors were presented twice in a random order (24 trials per session). The position of the four different letters and distractors on the screen varied randomly across trials.

After the letter recognition pre-test, we computed a score for each child for the number of correct responses (CR). In order to minimize the risk of getting a correct response by chance, we considered that a letter was known only when two CR were given in the two trials for this letter. This procedure reduced the number of CR but allowed us to distinguish the children who really knew the letters from those who gave random responses. The maximum score that could be scored in the test was thus 12, corresponding to 24 CR. The results of the pre-test are given in Fig. 2.

On the basis of all the pre-tests, we divided the child sample into two learning groups of 38 children which were matched in terms of age, sex, handedness, manual dexterity, educational level and letter recognition level. In addition, the children constituting both groups were equally distributed in each classroom in order to prevent any 'teacher effect' from occurring. In each learning group, the age range was 24 months. The 38 children of each group were sorted by age and divided into three equivalent sub-groups of 8-month ranges (see Table 1). Six groups were thus obtained, depending on the method used during learning, and age: Handwriting-older,

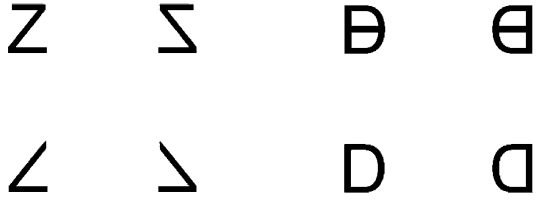

Fig. 1. Two example of visual configurations displayed on the computer screen during the letter recognition test.

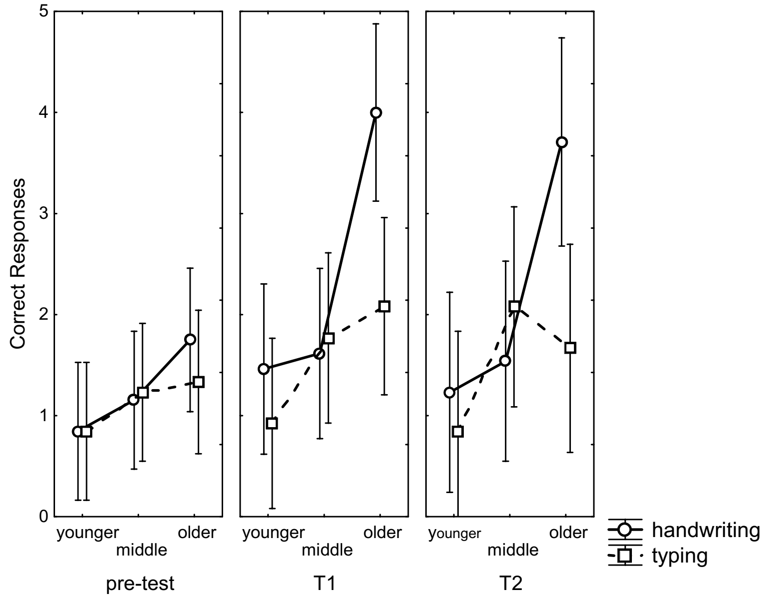

Fig. 2. Correct responses produced by younger, middle-age and older children, in the three recognition tests in the case of both learning methods. Solid line: handwriting group. Dashed line: typing group. T1: recognition test run immediately at the end of the learning session. T2: recognition test run one week later. Error bars denote 95% confidence intervals.

Table 1
Mean ages and mean scores in the pre-tests for each of the six groups

Group		Children number	Age (months)	Laterality quotient (%)	Bender test score	Time spent for peg-board (s)	CR number
Handwriting	Younger	13	38.5	76.2	4.41	30.6	0.8
	Middle	12	45.4	66.5	5.92	27.7	1.3
	Older	13	53.2	58.4	10.77	24.7	1.6
Typing	Younger	13	38.1	66.7	4.33	29.6	0.8
	Middle	13	45.0	77.1	6.84	25.2	1.2
	Older	12	53.5	61.6	10.75	24.2	1.3

Handwriting-middle, Handwriting-younger, Typing-older, Typing-middle and Typing-younger. In order to ensure that the two learning groups were not different with regard to initial letter knowledge before the beginning of learning, the CR were analyzed by means of a two (Learning mode: Handwriting vs. Typing) by three (Age: Older, Middle and. Younger) ANOVA. The results of the ANOVA showed that neither the main factors (Learning mode and Age) nor their interaction reached the significance level. In particular, the slight difference between handwriting and typing in the older children was far from significant ($F(1,70) < 1$).

2.2.2. Learning

The aim of the experiment was for the children to implicitly learn the form of 12 uppercase letters by writing them. We used uppercase letters for several reasons: first, they are the simplest letters to write and they were the first letters that were taught at these schools, and second, the uppercase letters are what one sees on computer keyboards. Furthermore, we chose these 12 letters because they are not symmetrical, so we could use their mirror image as a distractor in the recognition tests. We did not want children to be trained with too many letters because we had just a few weeks to carry out the training and the tests. In order to make the learning more attractive, instead of teaching the 12 letters separately, they were included in four words. To form words, we added three vowels (A, O, I), which were not included in the recognition tests. The words were included in turn in a story that was told to the children by the teachers for a few weeks prior to the learning period. The four words were: LAPIN (rabbit), JOB (the rabbit's name in the story), CERF (stag) and ZADIG (the stag's name in the story). Each letter to be learned was present only once in the four words (L-P-N, J-B, CERF, Z-D-G). The learning period lasted for 3 weeks, and consisted of one half-hour session per week. The children were trained in groups of four, in presence of two experimenters, in a quiet classroom. The parents were informed about the aim of the experiment and they were asked not to have the children practice at home during the duration of the experiment.

2.2.2.1. Typing training. Each word was displayed separately on the upper left side of the computer screen, with 3 cm tall characters. The children were asked to look at the letters constituting the word, find the appropriate letters on the keyboard, and type each of them. No constraints were imposed regarding the order of the letters. When the child typed a wrong letter, the experimenter informed him/her, cancelled the wrong letter, and asked the child to find and type the correct letter. When all the letters composing the target word had been typed, the experimenter displayed the next word. The keyboard had been adapted for the purpose of the study: all the keys other than the 15 keys required to type the words (plus the backspace key and the carriage return bar for the experimenter) were removed from the keyboard. The 15 remaining keys were arranged in the central part of the keyboard. The four words were copied twice at each session, so the children typed each letter twice per session.

2.2.2.2. Handwriting training. Each word was presented on the upper left side of a piece of paper with 3 cm tall characters. The children were asked to copy the letters of the word underneath the model with a felt-tip pen. The letters could be copied anywhere on the paper and in any order. No constraints were imposed regarding the size of the letters. Since we wanted both types of training to be as similar as possible, we gave the same kind of feedback in handwriting and typing. In the typing training, the only errors that could occur were lack of a letter and confusion between two letters. In handwriting, confusion was not possible but the children could miscopy the letter. We did not correct the children when the form of the written letter was not perfect. However, if a letter was not written, the experimenter informed the child that a letter was lacking and asked him/her to find the lacking letter on the model and write it. When all the letters composing the target word had been written, the experimenter replaced the worksheet with the following one on which the next model word was presented. Each letter was copied twice at each session.

2.2.3. Letter recognition tests

The letter recognition tests were exactly the same as the aforementioned test performed before learning. A first test was run immediately at the end of the last learning session (T1) and repeated one week later (T2).

3. Results

The number of CR was computed for T1 and T2 as previously described for the pre-test. The overall CR results are presented in Fig. 2. In order to analyze the impact of learning on the letter recognition, the CR in the pre-test and in T1 were submitted to a two (Learning mode: handwriting vs. typing) by three (Age: older, middle and younger) by two (Time of testing: pre vs. T1) ANOVA, with repeated measures on the third factor. This first analysis showed that the number of CR was significantly greater after learning (T1) than before (pre-test) ($F(1,70) = 11.1$, $p < 0.002$). The 'Time of testing' by 'Age' interaction was not significant ($F(2,70) = 2.29$, ns), but the increase of CR was only significant in the older ($F(1,23) = 14.7$, $p < 0.001$) and not in the middle ($F(1,23) = 1.95$, ns) and younger children ($F(1,24) < 1$). Finally, in the older children, the increase in CR was significant in the handwriting group ($F(1,12) = 17.5$, $p < 0.005$) but not in the typing group ($F(1,11) = 1.76$, ns).

In order to compare the performances of children immediately after learning (T1) and one week later (T2), the CR were submitted to a two (Learning mode: handwriting vs. typing) by three (Age: older, middle and. younger) by two (Time of testing: T1 vs. T2) ANOVA, with repeated measures on the third factor. The analysis showed that the number of CR was not the same at all ages ($F(2,70) = 9.71$, $p < 0.001$): the older children gave more CR than the middle ($F(1,46) = 6.51$, $p < 0.005$) and younger children ($F(1,47) = 18.3$, $p < 0.001$). The performance of middle and younger children did not differ significantly ($F(1,47) = 2.92$, ns).

As a whole, the children who wrote the letters gave more CR than those who typed them, but the difference only marginally reached the significance level ($F(1,70) = 3.86$, $p < 0.06$). However, the 'Learning mode' by 'Age' interaction was significant ($F(1,70) = 4.50$, $p < 0.02$). As can be seen in Fig. 2, the older children who used the handwriting method produced a larger number of CR than the same age children who used the typing method ($F(1,23) = 7.35$, $p < 0.02$). Conversely, the performances showed no change with the learning method in the middle and younger children. Finally, neither the time of testing nor the interactions implying this factor reached the significance level.

4. Discussion

The aim of this experiment was to determine whether two different types of writing training could induce different letter memorization. As a whole, the level of learning was low, since only the older children showed an increase in CR between pre-test and T1 and more precisely, only the older children who learned by handwriting. Such a low effect of learning can be explained by several causes. First, we did not explicitly teach the form of the letter because we wanted to compare two quite different writing methods and it was impossible to give comparable feedback in both types of learning. In typing, the letter is displayed with its perfect shape and no feedback has to be given about the typing movement. Thus we did not give feedback in the handwriting training to be as close as possible to the typing situation. In addition, we never directed the children's attention towards the exact form of the letter they wrote. In consequence, the learning was implicit. Furthermore, the effective time for learning was short (1.5 h within 3 weeks) with respect to the time usually required for learning to write and read. A longer time would have been more efficient but it was not possible to extend the teaching sessions. Despite this, the older children who were trained by handwriting performed more successfully in the letter recognition tests than those who were trained by typing.

In this debate about the importance of motor conditions when learning to read and write, the results of the present study are in agreement with those showing that writing letters facilitates their memorization and their subsequent recognition (Hulme, 1979; Naka & Naoi, 1995). However, a negative result was obtained in a study in which learning methods differing in their motor involvement were compared in children (aged 3–6 years) (Courrieu & De Falco, 1989). In the motor situation, instead of writing, the children had to trace over a picture of the letters where the dynamics of the tracing movement were indicated graphically. After the training phase, no effects of the motor involvement which had occurred during the learning period were observed. Another negative result was obtained by Naka (1998), who observed that an advantage of handwriting showed up only when the memorization was tested by free writing recall, and not in simple visual recognition tests.

There are points that should be mentioned which may help to explain the advantage of handwriting we observed. First, the subjects were very young: they were preschool children who had not had any previous experience of learning to read and write before the experiment. We were hence able to examine the very first step in the learning process, when the letters are still perceived as graphic forms without any particular phonological meaning. During the learning phase, the children were not required to learn the words they saw, and not even to name the letters, but only to write or type them. Likewise, in the recognition test, we did not ask the children to identify or spell words, but only to detect the letters among the distractors and to point at them without any verbalization. The whole procedure was therefore focused on a low level spatial processing of letters where sensorimotor signals might play a crucial role.

Secondly, another difference in comparison with previous studies was that learning extended over a period of three weeks, whereas in other studies on this topic, the training period generally consisted of a single session lasting anything from a few minutes to an hour. However, motor performances are known to evolve slowly, requiring many repetitions during several training sessions (Karni, 1996). The acquisition of motor skills seems to involve two main stages: an early, fast learning stage in which performances improve considerably as the result of a single training session, and a later, slow learning stage in which further gains can occur during several sessions (and even weeks) of practice (Ungerleider, Doyon, & Karni, 2002). A 3-week learning period certainly seems to provide favorable conditions for the children to set up a motor program for writing each letter and create the perceptual-motor links with its visual form. Assuming that the motor program associated with a letter is automatically reactivated when looking at it (Longcamp et al., 2003), this mechanism might help to recognize letters among close graphic forms.

Handwriting training allowed the older children to improve their performance in character recognition whereas the same training was not efficient in the children younger than fifty months. Of course, several reasons might explain this age-related difference: in particular, the lesser cognitive development of the younger children. Another reason might be that the fine motor control involved in handwriting was not mature enough in the younger children for them to produce the writing movements exactly. The fact that the graphic performances of 4- to 6-year old children have been found to correlate better with a motor score than with chronological age (van Galen, 1980) confirms that motor development is a key factor in handwriting. It has been suggested that handwriting development may be characterized by increased efficiency in inhibiting noise in the neuromotor and muscular system (van Galen, Portier, Smits-Engelsman, & Schomaker, 1993). Therefore, failure to inhibit the neuromotor noise might be the most likely cause of poor handwriting (Smits-Engelsman & van Galen, 1997). For the same maturational reasons, the peripheral kinaesthetic signals accompanying movements might be particularly noisy in younger children. The authors of studies on changes in kinaesthetic sensitivity with age have claimed that more than 30% of all 5-year old children may be 'kinaesthetically inept' (Laszlo & Broderick, 1991). Finally, the interhemispheric relationships involved in visuo-motor coordination develop from 4 to 14 years of age, without acquiring all the characteristics present in adults (Hay & Velay, 2003). Thus, at the ages of the children who participated, a few months difference in age is undoubtedly crucial in terms of motor system maturation. In the younger children, the sensorimotor signals associated with movements might be too noisy to generate a correct sensorimotor representation of letters.

From the sensorimotor point of view, handwriting and typing are clearly two distinct ways of writing, and these writing methods may well involve distinct central processes. The children who participated in this experiment did not type with both hands as expert typists do, nor did they even use several digits. Actually, since they had just one key to press at a time, they used their index finger, as most beginners do. During the training period, in the case of both handwriting and typing, a hand movement was therefore associated with the visual image of a given letter, but the two movements performed were quite different. On the one hand, the handwriting learning method requires the writer to perform a movement that completely defines the shape of the letter in order to build an internal model of the character. Once the learning is completed, there exists a unique correspondence between a given printed letter and the movement that is used to write this letter. On the other hand, typing is also a complex form of spatial learning in which the beginner typist has to build a cognitive map of the keyboard (see for instance Gentner, 1983; Logan, 1999). Learning typewriting consists in precisely locating a key in the keyboard and pressing it, but since the trajectory depends on the location of the finger before it goes into action, no specific relationship between the visual form of a letter and a given movement is built. Moreover, there is nothing in this pointing movement which might inform about the shape of the letters. In short, handwriting provides on-line signals from several sources, including vision, motor commands, and kinaesthetic feedback, which are closely linked and simultaneously distributed in time. No such spatio-temporal pattern occurs in typewriting. In addition to the motor differences, there exist other differences between the two writing methods. In particular, attentional differences are apparent, since learning to write a letter may require a deeper level of processing than finding a letter on a keyboard. Typing, in contrast to handwriting, inherently requires visual discrimination among letters in the process of key selection. These different aspects probably play a role in the implicit learning during both writing methods.

Finally, we sought to determine whether the knowledge implicitly learned by writing practice was maintained after long delays; To this aim, we observed that, in the handwriting group, the recognition performance at the end of training and after one week were identical. This is in agreement with data showing that, once it has been thoroughly learned and stabilized, motor memory can last for very long periods of time without any further practice (Shadmehr & Brashers-Krug, 1997). It is clear that much longer delays should have been tested because the learning process in question here involves memory extending over much longer periods of time.

In conclusion, the present results indicate that, provided they are not too young, handwriting learning helps children to memorize the form of a letter. Clearly, we cannot tell whether this process plays a role in reading, where whole words are perceived instead of isolated letters. Yet, as it seems to be widely accepted that letter recognition is the first stage in reading (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), the way children perceive letters might indeed affect the way they read. Functional links have been found to exist between global motor skills performance and reading disabilities, in both children (Fawcett, Nicolson, & Dean, 1996) and adults (Nicolson et al., 1999; Velay, Daffaure, Giraud, & Habib, 2002), and further research is now required to be able to answer the question as to whether learning how to write really helps children to learn how to read.

Acknowledgments

The research was funded by the French Research Ministry (A.C.I. 'Cognitique' COG73). Marieke Longcamp was supported by a fellowship from the French Research Ministry (A.C.I. 'Cognitique'). We thank M. Besson and J.C. Gilhodes for critical comments on the manuscript and Reyna Leigh Gordon for revising the English. We are particularly grateful to the teachers of the three schools in Marseille (Château-Sec, Desautel and Valmante) who allowed us to work with their pupils during school time.

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