

Telemaque, a new visuo-haptic interface for remediation of dysgraphic children

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Abstract

The aim of this paper is to present a new visuo-haptic interface for remediation of dysgraphic children. This interface allows teaching the children to reproduce a letter according to a standard not only static (i.e. its correct shape) but also dynamic (i.e. the rules of motor production). A new specific handwriting static and dynamic font was built. Using this font, four exercises were carried out for each letter. First, the sculpturing of a letter was designed to familiarize the child with the haptic pen and the static and the global shape of a letter. Second, the circuit game was focused on the correct order of production of a letter. Third, the dynamical tracing exercise was dedicated to dynamical aspect of production of a letter. Fourth, the blindfolded recognition exercise of letters was focused on the static and dynamical aspects of a letter. This exercise required retrieving the letter in memory from dynamical haptic cues. The effects of these exercises on a dysgraphic child were currently assessed.

1. Introduction

Handwriting is usual activity in our developed society which seems us so easy. We forgot that handwriting is a very complex activity that involves attentional, memory, language and cognitive skills and obviously, motor skills [1, 2]. Indeed, writing a letter requires retrieving and holding the letter in memory, accessing the corresponding motor program, setting the parameters for the program (establishing the size of the letter and speed of writing) and executing it.

The studies on handwriting in adults have shown that there is an unambiguous relationship between the letter and the movement for tracing it: A specific motor program corresponds to each letter. These motor programs are characterised by at least three laws [3, 4]: (1) There is a proportional and direct relationship between the linear extent of trajectories and movement velocity (labelled "isochrony law"). The time for tracing a letter remains constant whatever its size; (2) Handwriting keeps its spatial characteristics whatever its size (labelled "homothety law"); (3) The shape of the letter determines the movement dynamic (labelled "the two-thirds power law"). The tangential velocity and the curvature of the trajectory are inversely related in a precise manner specified by this law.

Handwriting acquisition globally consists in acquiring visual representation of the letters, which guides their production, and motor representation (motor program) which is specific to each letter. We also forgot that its acquisition generally remains slow and very difficult because several years of formal instruction are necessary before young children grasp this skill. Globally, formal training in handwriting begins in first grade. However, many kindergarten teachers informally train children in producing single letters and single words and their own names [5]. Even if handwriting acquisition begins at the school entry, the child had to wait until the end of the primary school for a satisfactory skill. From off-line evaluation of handwriting, three stages of development in children from 6 to 11 year-olds were described [6-9]. From 6 to 7 years: The trembling gradually disappears. However, the curvature, the line straightness and the letter forms are not well acquired. From 8 to 10 years, the children produce the letters carefully and the line straightness improves. From 10 years, the first requirement is handwriting speed. The handwriting tends to be more automatic and the letter form simplified.

The off-line evaluation did not provide information about the underlying dynamics producing the movement. The advances of computerized analyses enable to assess with precision the development of the kinematic (average velocity, maximal velocity, time of production, fluency of the movement and acceleration) and the spatial characteristics of writing (size and curvature). A global a-posteriori variable has particularly been observed: The dysfluency variable. It is the number of time that the module of the pen speed vector changes its sense of variation, or the number of the zeros of the time derivative of this pen speed module. When the children are at the beginning of their handwriting acquisition, they copy the letters from some models using their eyes to check and visually compare the rightness of their stroke to the same stroke of the model. This task is rather slow and needs successive phases. During these phases, the pen brakes down or speeds up a lot of times: The dysfluency is very high. When the children have reached the end of their hand-writing acquisition, they used their eyes only for global control along one line, and all the motor orders have become unconscious. The task is much fast and the pen speeds up and brakes only once per rising or falling: The dysfluency is drastically reduced. This regularity is observed simultaneously on the x and y signals, on the pressure signal and on the pen speed signal. That is why the dysfluency is a very good measure of the level of the handwriting acquisition.

The studies in educational psychology revealed a strong link between handwriting and writing. The quality of handwriting affects academic performance such transcription and text generation. For example, a basic measure of handwriting (ex: the alphabet writing from memory) correlates with and predicts compositional fluency [10-12] but also compositional quality [12], for both primary and intermediate elementary students [13]. Consequently, it seems of a crucial importance to identify handwriting difficulties as early as possible.

The children who do not succeed in developing proficient handwriting are defined as "poor handwriter" or "dysgraphic". Dysgraphia characterises children who are not able to product an acceptable script even though they have had the proper amount of instruction and practice in writing [14]. It is a writing disorder which is observed in children of average intelligence and has no distinct neurological cause [6]. Dysgraphia has been described as a learning disorder that concerns the mechanical writing skills and is not concerned by a perceptual-motor handicap [15]. Even if dysgraphia is

often associated with learning troubles, it exists without associated language deficit in **50%** of the cases. The handwriting troubles vary from letter substitution to incapacity of writing. Four distinct troubles in dysgraphia can be distinguished: Distortions (trembling, bad letter forms, lack of link, lack of loops, letter touched up ...), spatial troubles (bad straightness of letters words and sentences, too small spacing between words), syntactic troubles (spelling), and distaste of handwriting [16]. The prevalence of handwriting difficulty among school-aged children varies between 10 and **34%** [17, 18]. These troubles mainly concern the boys and their ratio is approximately of one dysgraphic girl for three boys [10, 14, 19]. Children with motor coordination and/or learning disabilities are particularly likely to experience difficulties in learning to write. More precisely, about 90% of children with learning disabilities experience fine motor difficulties or handwriting problems [20] and many children with Developmental Coordination Disorder have been reported to have problems in acquiring handwriting [21-23]. The proportion of dysgraphic children is the same in left-handed and right handed. Bad writers show difficulty with the size of letters, the oblique lines, the space between the letters within the words and the alignment [14]. They also show more variability in writing a same letter several time [24].

As regards the handwriting process of children, the computerized studies permit to show that the difference between children with and without handwriting difficulties lies not only on their written product but also in the dynamics of their handwriting [24]. In a study, the production of children from 7 years to 12 years divided in two groups in function of their handwriting quality was compared [25]. Children were asked to write small loops linked, arcade and pseudo-words (for example: "eenn" or "mnee"). The first conclusion of the authors is that poor handwriters lack precision in time and space in handwriting process and have faster and larger movements. The most important characteristic of poor handwriting concerns the difficulty in controlling spatial accuracy and this problem that persists over time [25, 26]. In an other study, children from grade 2 to 4 were asked to write letter strings of various complexities [27]. They observed that poor writers have less stroke curvature, more overshoots (lines extending beyond available space) and undershoots (lines not reaching the limits of the available space) and more neuromotor noise. Children with handwriting difficulties took intermissions at greater frequency and for longer periods of time [28]. Moreover, their writing speed was

inconstant, too fast or too slow. They mainly use visual feedback to guide their production, which in consequence provokes some problems of dysfluency in handwriting [28]. It was assumed that poor handwriting is part of a wider neuromotor condition characterized by faster and cruder movements, lack of inhibition of co-movements and poor coordination of fine motor skills [17].

In summary, poor handwriting is characterized by less mature movements pattern with neuromotor noise [25, 26], variability in writing time, pauses at greater frequency and for longer periods of time, lack of continuity and fluency [24, 28], failure to obey spatial constraints and lack of consistency [27]. Because handwriting problems do not disappear without intervention [14, 27], it is necessary to develop and evaluate programs for handwriting remediation.

The aim of this paper is to present a new visuo-haptic interface for remediation of dysgraphic children. This interface allows teaching the children to reproduce a letter according to a standard not only static (i.e. its correct shape) but also dynamic (i.e. the rules of motor production). We already showed that incorporating the visuo-haptic and haptic exploration of letters in a training designed to develop children's understanding of the alphabetic principle makes easier the connections between the orthographic representation of letters and the phonological representation of the corresponding sounds, thus improving the decoding skills of young children [29-35]. Thus, we assumed that a multisensory training using Telemaque should be suitable for dysgraphic children and should have positive effects on their handwriting.

2. An original ergonomic visuo-haptic interface

The basic device is a force-feedback programmable pen. To preserve the exact distance between the child chest, his elbows duly setting comfortably on the desk plane, at a repetitive distance from the horizontal screen displaying the letters, we built a specific working station (Figure 1). It contains a notch for the flat screen gliding between two planes and a notch for the force feedback device. We pass from right-handed to left-handed pupils merely by pushing both the screen and the force-feedback device respectively to the extreme right or to the extreme left of these notches. The chest of the pupils goes inside a third specific roughly circle notch. An ergonomic constant X-axis distance between the middle of this last notch and the position of the screen and pen is kept, as well as a

constant Y-axis distance between the middle of the child chest and the middle of the screen.

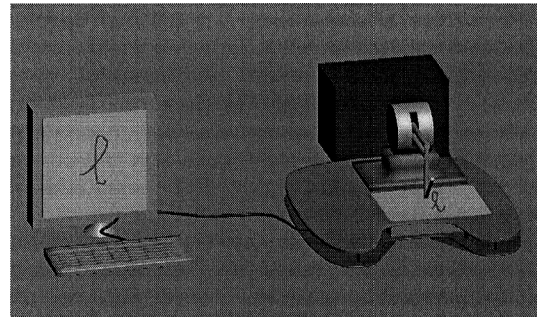
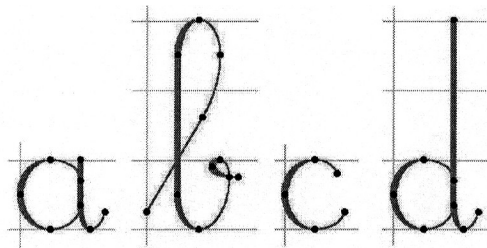


Figure 1. Global and schematic view of the Telemaque working station.

3. A new specific hand-writing static and dynamic font

3-1 Static aspect of the font

We build a new hand-writing font based on control points, elliptic arcs and straight lines (Figure 2). The control points are the beginning of the strokes, the end of the strokes, the vertical tangent points, the horizontal tangent points, the inflexion points and the turn back points. Pen raisings are also fully described in the font. Each control point has its tangent angle. Elliptic arcs are computed at the mathematical limits, between every couple of successive control point with different tangent angles. This leads to esthetic minimal curvature variation lines for the letters.



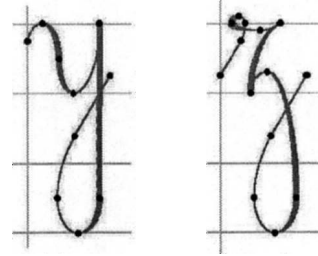
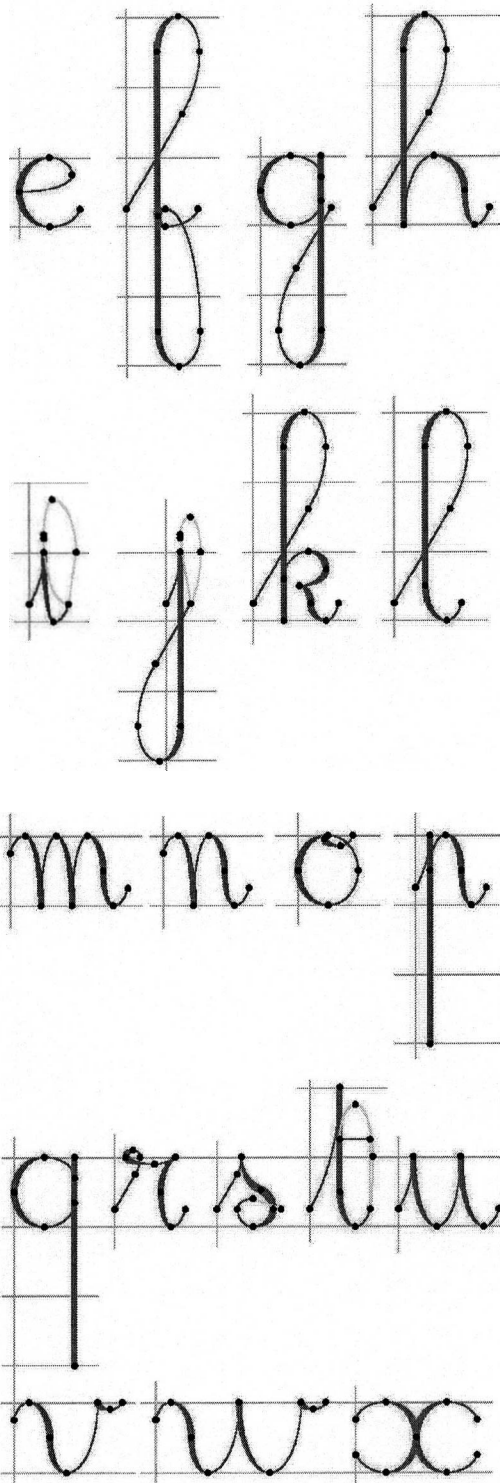


Figure 2. The 26 letters.

3-2 Dynamical aspect of the font

Between two successive control points the curvature has a monotonous variation. Elliptic arcs are the only conic curves that possess this feature between two control points with perpendicular tangents. More, the choice of elliptic arcs between two successive control points with different tangent angles allows the computation of the dynamical aspect of the font according to the two-thirds power law for pen velocity (see Introduction). This is done using a parametric generation of the elliptic arcs according to the formulas:

$$X = X_{\text{centre}} + A * \cos(\Omega * t + \Phi) \quad (1)$$

$$Y = Y_{\text{centre}} + B * \sin(\Omega * t + \Phi) \quad (2)$$

Ω is the angular speed which according to the isochrony law (see Introduction) does not depend on the letter size. The only hypothesis made here on the ellipse is that their main and second axes are horizontal and vertical.

X_{centre} , Y_{centre} , A , B and Φ are automatically computed from the relative position of the two controlling points of the elliptic arc and their two tangent angles (See 3-3 for mathematical details). Should the arc does not exist according to spatial constraints, a straight line is drawn (Between two points it exists one and only one elliptic arc if and only if the angle between the two tangents is large enough). This mathematical limitation is used in the sculpturing mode (see 4-3) and it allows us to comfortably build and check the font. It appears that the more “beautiful” letters are those who tackle with the mathematical limit. This is not only due to hazard, though beauty is a rather non scientific notion. Actually, this construction leads in fact to minimal arcs, which like some minimal surfaces, look pretty.

3-3 Some computational details

Due to the parametric construction of the elliptic dynamic arc, we can compute the speed of the pen at each instant t :

$$dX/dt = -A * \Omega * \sin(\Omega * t + \Phi) \quad (3)$$

$$dY/dt = B * \Omega * \cos(\Omega * t + \Phi) \quad (4)$$

At the first control point $M1(X1, Y1, \alpha1)$, we have:

$$X1 = X_centre + A * \cos(\Omega * t1 + \Phi) \quad (5)$$

$$Y1 = Y_centre + B * \sin(\Omega * t1 + \Phi) \quad (6)$$

$$A * \sin(\Omega * t1 + \Phi) * \sin(\alpha1) + B * \cos(\Omega * t1 + \Phi) * \cos(\alpha1) = 0 \quad (7)$$

In the same manner, at the second control point $M2(X2, Y2, \alpha2)$, we have:

$$X2 = X_centre + A * \cos(\Omega * t2 + \Phi) \quad (8)$$

$$Y2 = Y_centre + B * \sin(\Omega * t2 + \Phi) \quad (9)$$

$$A * \sin(\Omega * t2 + \Phi) * \sin(\alpha2) + B * \cos(\Omega * t2 + \Phi) * \cos(\alpha2) = 0 \quad (10)$$

This leads to a system of 6 equations in the 7 following unknowns:

X_centre , Y_centre , A , B , $t1$, $t2$, and Φ .

Actually, absolute time is of no importance to solve that system, and we may reduce it to 6 unknowns, making the assumption for instance that $t1 = 0$. More, due to the definition of controlling points, in every letters the elliptic arcs either begins or ends to a horizontal or a vertical tangent point. In the following §, we assume that $M2$ is a vertical tangent point, that is:

$$\alpha2 = \pi/2.$$

The other cases, $M1$ horizontal, $M1$ vertical, $M2$ horizontal are computed in the same manner.

Eq (10) leads to: $\Omega * t2 + \Phi = \pi/2$

Eq (5),(8) lead to:

$$X_centre = X1 - A * \cos(\Phi) = X2$$

or:

$$A = (X1 - X2) / \cos(\Phi) \quad (11)$$

$$X_centre = X2 \quad (12)$$

In the same way, Eq (6),(9) lead to:

$$Y_centre = Y1 - B * \sin(\Phi) = Y2 - B$$

or:

$$B = (Y2 - Y1) / (1 - \sin(\Phi)) \quad (13)$$

$$Y_centre = Y2 - B \quad (14)$$

Finally replacing A , B in Equation (7) leads to:

$$(X1 - X2) * \sin(\Phi) * \sin(\alpha1) * (1 - \sin(\Phi)) + (Y2 - Y1) * \cos2(\Phi) * \cos(\alpha1) = 0$$

that is by replacing $\cos2(\Phi)$ by $1 - \sin2(\Phi)$ and divide both terms by $1 - \sin(\Phi)$, we obtain:

$$(X1 - X2) * \sin(\Phi) * \sin(\alpha1) + (Y2 - Y1) * (1 + \sin(\Phi)) * \cos(\alpha1) = 0$$

and

$$\Phi = \text{Arcsin}((Y1 - Y2) * \cos(\alpha1) / ((X1 - X2) * \sin(\alpha1) + (Y2 - Y1) * \cos(\alpha1))) \quad (15)$$

Assuming $\cos(\alpha1)$ and $Y2 - Y1$ different of 0, the 2 optimal necessary conditions for the existence of a solution angle Φ becomes:

$$-1 \leq 1 / ((X2 - X1) / (Y2 - Y1) * \tan(\alpha1) - 1) \leq 1$$

that is:

$$(X2 - X1) / (Y2 - Y1) * \tan(\alpha1) \geq 2 \quad \text{and:} \\ (X2 - X1) / (Y2 - Y1) * \tan(\alpha1) \leq 0$$

or:

$$\alpha1 \geq 0 \quad \text{and:} \\ \alpha1 \geq \arctan(2 * (Y2 - Y1) / (X2 - X1)) = \alpha_{opt} \quad (16)$$

α_{opt} is the maximal value for $\alpha1$. Above this value, no elliptic arc exist between $M1(\alpha1)$, $M2(\alpha2)$ and the software draw a straight line. The α_{opt} elliptic arc is the shortest one between $M1$ and $M2(\alpha2)$.

Assuming $\alpha1 \geq \alpha_{opt}$, then we compute Φ from (15), and, knowing Φ , A from (11), B from (13), X_centre from (12) and Y_centre from (14). This ends the

computation by giving us our 5 unknowns in the 2 parametric elliptic pen displacement equations (1), (2)

3-4 The link with the psychophysical dynamic law

A well known result from the ellipse equations (1), (2) is the local curvature radius:

$$R = ((A/B) \sin^2(\Theta) + (B/A) \cos^2(\Theta))^{3/2}$$

and the speed of the pen: (where $\Omega = d\Theta/dt$)

$$V = \Omega \cdot (A \sin^2(\Theta) + B \cos^2(\Theta))^{1/2}$$

Choosing:

$$\Omega = k \cdot (A \sin^2(\Theta) + B \cos^2(\Theta))^{1/2} / AB$$

leads to the well-known psychophysical two-thirds power law:

$$V = k \cdot R^{2/3}$$

The 2/3 power law describes a behaviour. Indeed, some psychophysical experiments have shown that imposed movements following circular trajectory with a velocity profile that corresponds to an ellipse are perceived as an ellipse and reproduces as such [36].

3-5 Straight lines consideration

For many letters as b, l, f, g, h, y there exists a straight line between two elliptic arcs. In some other letters, as in j, k, p, q, t, d, straight lines are beginning or ending to a turn back controlling point. Here again we consider psychophysical laws to compute the pen speed.

In the straight part: We assume the same Ω value, and we consider the straight line as a degenerated ellipse with $A = 0$. Continuity consideration of the speed at M1, $V1$, gives the lacking equation to solve in Y_{centre} , B , Φ , the pen parametrical dynamic equations:

$$Y = Y_{\text{centre}} + B \cdot \sin(\Omega \cdot t + \Phi) \quad (17)$$

$$dY/dt = B \cdot \Omega \cdot \cos(\Omega \cdot t + \Phi) \quad (18)$$

For instance for the k letter, the 4 limit conditions lead to the following equations:

$$Y1 = Y_{\text{centre}} + B \cdot \sin(\Phi) \quad (19)$$

$$V1 = B \cdot \Omega \cdot \cos(\Phi) \quad (20)$$

$$Y2 = Y_{\text{centre}} - B \quad (21)$$

$$V2 = 0 \quad (\text{turn back controlling point condition})$$

Eliminating f between (19) and (20) leads to:

$$B^2 = (Y1 - Y2 - B)^2 + (V1/\Omega)^2 \quad (22)$$

That ends the computation by giving us our 3 unknowns in the parametric straight pen displacement equation (17):

$$B = 0.5 \cdot ((Y1 - Y2) + (V1/\Omega)^2 / (Y1 - Y2)) \quad (23)$$

$$Y_{\text{centre}} = Y2 - B \quad (24)$$

$$\Phi = \arcsin((Y1 - Y_{\text{centre}}) / B) \quad (25)$$

3-6 Global parameters of the font

The font presents global parameters which lead to a certain homogeneity and coherence between the different letters such as:

- The height of the beginning and the ending controlling points (1/4 or 2/3 of line spacing);
- The tangent angle at these points (for instance 75°, the same for the beginning and for the ending, because when letters are attached, the pen speed vector must be continuous and no deviation angle is allowed between 2 successive letters;
- The width of the large ascenders;
- The height of large letters (3 line spacings, except for the f, which is 5 line spacings);
- The height of the t, which is 2 line spacings;
- The width of small letters (those of 1 line spacing high).

Once given the line spacing, then the static and dynamic font is totally computable. Italic font is achievable by simply pushing a keyboard touch. Automatically affinity is applied on all letters. Thick and thin strokes are available according to ups (thin) or downs (thick) of the pen displacements.

3-7 "Bi-letter" considerations

If you want to go from single letters to words and sentences, some couples of letters generate a second variant shape for the second letter. For instance, after the letters b, o, v, w, which end horizontally at the 2/3 height of the line spacing, the following letters present a variant beginning controlling point: f, h, j, k, l, m, n, p, r, s, t, u, v, w, y, z. The letters e, a, o, when they are preceded by any of the letters a, c, d, e, f, g, h, i, g, k, l, m, n, p, q, r, s, t, u, x, y, z need a specific link which

can be either a straight oblique line or an elliptic specific line at the tangent begin or end.

If one makes the assumption that, when writing a l letter, for instance, a straight line is inserted between the uppermost and the lowest elliptic arc, then a curvature discontinuity appears at the junctions of elliptic and straight part of the letter due to the infinite curvature of the straight line. Actually, when we write without thinking too much the l letter, a low eccentricity semi-elliptic arc is observed for the falling down part. This strongly suggests to build a dynamic police with no exception of discontinuity at all.

Extending the psychophysical law to these links enables Telemaque to compute exactly these elliptic links. This is due to the fact that at each extremity of the link, a second order continuity condition is required. Pen trajectory must be continuous, pen speed vector must be continuous (same tangent) and curvature must be continuous, a second order condition directly derived from the 2/3 law. The three continuity conditions at both ends, leads to one and only one elliptic trajectory. This trajectory then leads to a specific spacing between these coupled letters.

Telemaque computes automatically these specific elliptic links for bi-letters such as: l-l, l-a, l-e, l-i, l-o, l-y, a-l, c-l, e-l, i-l, o-l, y-l, a-m, etc (Figure 3)

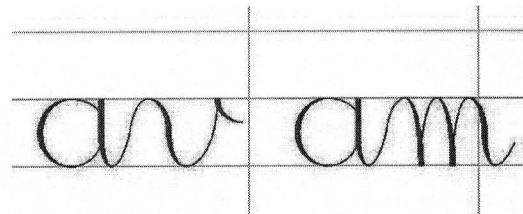
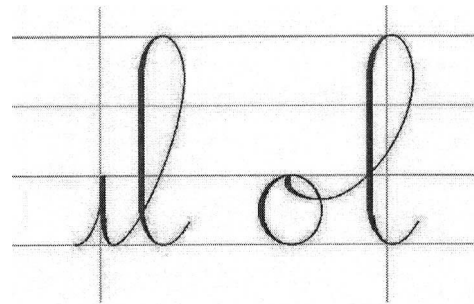


Figure 3. Bi-letters elliptic links.

4. The four exercises

After having developed this font, we designed four different exercises to struggle against handwriting difficulties of dysgraphic children.

4-1 The sculpturing of letters

In this exercise, the child hands the force feed-back device whose pen is drawn towards the nearest point of the letters, and each time the pen passes over a controlling point, s/he feels a haptic notch (Figure 4). Then, he may press the switch button of the force feedback device, and this controlling point will follow his orders of displacement. During this displacement, the elliptic arcs are recomputed in real time, so that the child is able to see the effect of their deformations. A yellow dot is kept visible at the original controlling point initial place. When the child displaces a point, a specific sound is generated. After having unshaped the letter, the child may recreate the good shape by recovering every displaced controlling point in its initial place. A victory happy sound is generated when the displaced point is near enough from its initial place (in the yellow circular dot). This game is used to familiarize the child with the haptic pen and the static



shapes of the letters. No dynamical considerations are introduced here, and there is no time constraint.

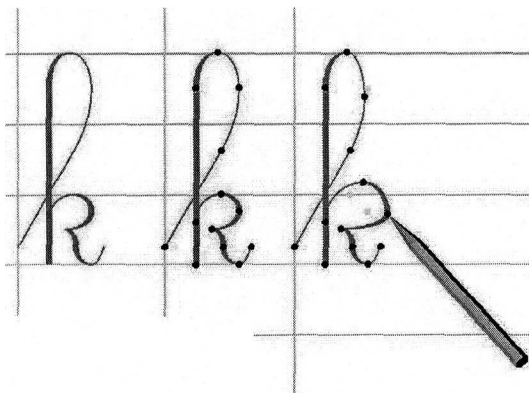


Figure 4. The sculpturing exercise of a letter

4-2 The dynamical tracing of letters

The dynamical font is used here to drive the pen at the right place in the right time in a psychophysical and natural way. This exercise is more precisely dedicated to the dynamical aspect of handwriting learning. At the beginning of their learning, children close the feedback visually and their curve present high dysfluency, that is high number of changing signs of the module of their pen speed. When acquisition is achieved, they no longer use visual feedback to drive their fingers, and all the motor orders have become unconscious. But this learning is very hard, and some children may be failing. They are called dysgraphic. Our Telemaque software is able to take their pen and guide their fingers both in spatial and dynamical movements. That is why this exercise will be systematically used in our experiments on dysgraphic children.

4-3 The circuit game

In this game, every letter appears with two borders representing a road (Figure 5). Each time the pen goes off this road, the child loses life points materialized by a decreasing coloured rule. If he reaches the end of the letter before this rule disappeared, a victory happy sound is generated. In the opposite case, a defeat unhappy sound is generated. The pen is attracted towards the nearest point of the letters, perpendicularly to the curve. No tangential force is applied in this exercise. The child cannot go backward, but has no time constraint for its pen displacements. The width of

the road may be progressively reduced. The strength with which the pen is attracted towards the nearest point of the letter may also be progressively reduced. At the end of successive exercises, the pen runs freely on the haptic plane of the virtual paper sheet. This exercise is focused on the correct order of production of a letter.

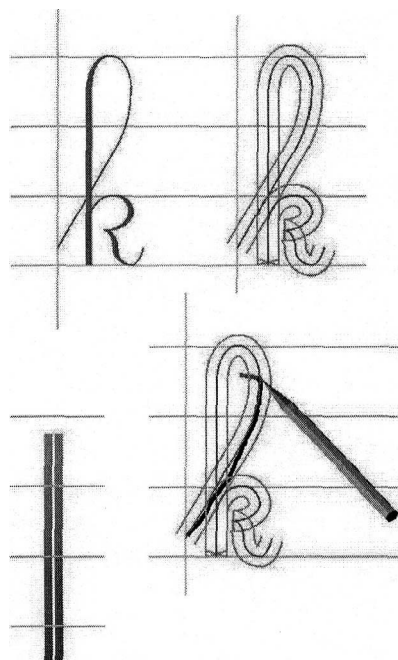


Figure 5. A letter used in the circuit game exercise.

4-4 The blindfolded recognition of letters

Blindfolded children were asked to recognize a letter, two-letters, small words, and simple sentences generated by the interface. This recognition exercise, without visual control, requires retrieving the letter from dynamical haptic cues (cf. Gentaz, Bara, & Colé, 2003; Bara, Gentaz & Colé, 2004). It has been observed frequently a spontaneous slower but more accurate recognition of the letters, words, etc than by sighted children, suggesting systematic quantification further studies for that specific point.

5. Discussion and perspectives

The aim of the Telemaque visuo-haptic interface is to provide a new tool for the remediation of handwriting troubles in dysgraphic children. The handwriting of dysgraphic children can be distinguished from "normal handwriting" by differences both in the product and in the process of handwriting. Their writing speed is inconstant, they show more variability in writing the same letter several times, their letters are irregular (size and form), intermissions are more frequent and their duration is longer and the traces show trembling and dysfluency. Globally, these problems lie not only in the spatial characteristics of handwriting but also in the dynamic of handwriting. That suggests either a trouble in the elaboration of the motor program or a trouble in the execution of this program.

The program of remediation proposed by means of the interface is more able to act on the problems of handwriting distortion. These troubles are characterised by bad letter forms, lack of link, trembling, lack of loops, letters touched up, irregularity in letter form and incorrect size proportion between letters. The dysgraphic children who will take part in this program will be selected in function of their performances in the BHK (concise evaluation scale for Children's handwriting, a test developed by [37]). The test consists in a copy, in cursive handwriting, of a text presented in script. This test is standardized and permits to compare the performances of one child to the mean of a large population of children of same age. This scale has been found to clearly discriminate between children with and without dysgraphia and is commonly used in the early identification of children with handwriting difficulties. This scale permits to point out difficulties in the spatial characteristics of letters (size, line straightness, and distortions in letter form) and also in some dynamic characteristics like trembling and speed of writing.

Our program of remediation will be administered to the children selected as dysgraphic. It will be made up of several sessions. In each session the four exercises will be proposed to the child and will allow the study of some letters and words.

The haptic dynamical tracing of letter leads the child to respect and learn the natural and ideal motor execution of the trace. It acts more particularly on the problems of trembling, dysfluency and speed inconsistency. The haptic sculpturing of letter acts on the perception of the letter form because the child must retrieve in memory

the right form and reproduce it. The circuit game concerns both the visual perception of the letter form and the realisation of the trace. The aim of this game is to improve the child motor control for the production of the trace. In the blindfolded recognition of letters, the child has to retrieve from the motor execution the visual trace of the letter in memory. One of the problems of dysgraphic children concerns the fact that they use more often a visual feedback instead of a motor feedback. In forcing them to work without vision, it should help them to improve their motor act.

This remediation program aims at improving both the visual perception of the letter and the motor act which have to be produced for tracing a letter or a word. This program of remediation using Telemaque interface is currently tested with one dysgraphic child.

References

1. Levine, M.B., *Developmental variation and learning disorders*. 1987, Cambridge: MA: Educators Publishing Service.
2. Zesiger, P., *Ecrire: Approche cognitive, neuropsychologique et développementale*. 1995, Paris: P.U.F.
3. Viviani, P., *Les habiletés motrices*, in *Traité de Psychologie Expérimentale*, M. Richelle, J. Requin, and M. Robert, Editors. 1994, PUF: Paris. p. 777-844.
4. Viviani, P., *Motor competence in the perception of dynamic events*, in *Common mechanisms in perception and action: attention and performance*, W. Prinz and B. Hommel, Editors. 2002, Oxford University Press: Oxford. p. 406-442.
5. Marr, D., M. Windsor, and S. Cermak, *Handwriting readiness: locative and visuomotor skill in the kindergarten years*. *Early Childhood Research and Practice*, 2001.34: p. 1-28.
6. Ajuriaguerra, J., M. Auzias, and A. Denner, *L'écriture de l'enfant, I: L'évolution de l'écriture et ses difficultés*. 1971, Neuchâtel: Delachaux & Niestlé.
7. Ajuriaguerra, J., M. Auzias, and A. Denner, *L'écriture de l'enfant II: La rééducation de l'écriture*. 1971, Neuchâtel: Delachaux & Niestlé.
8. Blöte, A.W. and L. Hamstra-Bletz, *A longitudinal study on the structure of handwriting*. *Perceptual and Motor Skills*, 1991.72: p. 983-994.
9. Hamstra-Bletz, L. and A.W. Blöte, *Development of handwriting in primary school: A longitudinal study*. *Perceptual and Motor Skills*, 1990.70: p. 759-770.
10. Berninger, V.W. and F. Fuller, *Gender differences in orthographic, verbal and compositional fluency: Implications for diagnosis of writing disabilities in primary grade children*. *Journal of School Psychology*, 1992.30: p. 363-382.

11. Beminger, V.W., *Reading and writing acquisition: A developmental neuropsychological perspective*. 1996, Boulder: CO: Westview Press.
12. Berninger, V.W. and H.L. Swanson, *Modifying Hayes and Flower's model of skilled writing to explain beginning and developing writing*, in *Children's writing: Toward a process theory of development of skilled writing*, E. Butterfield, Editor. 1994, CT: JAI Press: Greenwich.
13. Graham, S., et al., *Role of mechanics in composing of elementary school students: A new methodological approach*. *Journal of Educational Psychology*, 1997, 89: p. 170-182.
14. Hamstra-Bletz, L. and A.W. Bletz, *A longitudinal study on dysgraphic handwriting in primary school*. *Journal of Learning Disabilities*, 1993, 26: p. 689-699.
15. Sovik, N., O. Amtzen, and R. Thygesen, *Relation of spelling and writing in learning disabilities*. *Perceptual and Motor Skills*, 1987, 64: p. 219-236.
16. Gaddes, W. and D. Edgell, *Learning disabilities and brain function: A neuropsychological approach*. 1994, New-York: U.S.: Springer-Verlag Publishing.
17. Smits-Engelsman, B.C., A.S. Niemeijer, and G.P. van Galen, *Fine motor deficiencies in children diagnosed as DCD based on poor grapho-motor ability*. *Human Movement Science*, 2001, 20: p. 161-182.
18. Rubins, N. and S.E. Henderson, *Two sides of the same coin: Variation in teaching methods and failure to learn to write*. *Special Education Forward Trends*, 1982, 9: p. 17-24.
19. Ziviani, J., *Some elaborations on handwriting speed in 7 to 14 year-olds*. *Perceptual and Motor Skills*, 1984, 58: p. 535-539.
20. McHale, K. and S.A. Cermak, *Fine motor activities in elementary school: preliminary findings and provisional implications for children with fine motor problems*. *American Journal of Occupational Therapy*, 1992, 46: p. 898-903.
21. Miller, L.T., et al., *Clinical description of children with developmental coordination disorder*. *Canadian Journal of Occupational Therapy*, 2001, 68: p. 5-15.
22. Miller, L.T., et al., *A pilot trial of a cognitive treatment for children with developmental coordination disorder*. *Human Movement Science*, 2001, 20: p. 183-210.
23. Missiuna, C. and H. Polatajko, *Developmental dyspraxia by any other name: are they all just clumsy children?* *American Journal of Occupational Therapy*, 1995, 49: p. 619-627.
24. Wann, J.P. and M. Kadiramanathan, *Variability in children's handwriting computer diagnosis of writing difficulties*, in *Development of Graphic Skills*, J. Wann, A.M. Wing, and N. Sovik, Editors. 1991, Academic Press: London. p. 223-236.
25. Van Galen, G.P., et al., *Neuromotor noise and poor handwriting in children*. *Acta Psychologica*, 1993, 82(1-3): p. 161-78.
26. Smits-Engelsman, B.C., G.P. Van Galen, and S.J. Portier, *Psychomotor development of handwriting proficiency: A cross sectional and longitudinal study on developmental features of handwriting*, in *Advances in Handwriting and Drawing. A multidisciplinary approach*, C. Faure, et al., Editors. 1994, Europa Press: Paris. p. 187-205.
27. Smits-Engelsman, B.C. and G.P. Van Galen, *Dysgraphia in children: lasting psychomotor deficiency or transient developmental delay?* *Journal of Experimental Child Psychology*, 1997, 67: p. 164-184.
28. Wann, J. and J. Jones, *Space-time invariance in handwriting: contrasts between primary school children displaying advanced or retarded handwriting acquisition*. *Human Movement Science*, 1986, 5: p. 275-296.
29. Bara, F., E. Gentaz, and P. Cole, *The visuo-haptic and haptic exploration of letters increases the kindergarten-children's reading acquisition*. *Cognitive Development*, 2004, 19: p. 433-449.
30. Bara, F., E. Gentaz, and P. Colé, *Effet de l'exploration visuo-haptique et haptique de lettres dans les entraînements de préparation à la lecture*. *ANAE*, 2004, 78.
31. Bara, F., E. Gentaz, and P. Colé, *Quels entraînements de préparation à la lecture proposer aux jeunes enfants de maternelle?*, in *Comprendre les apprentissages. Sciences cognitives et l'éducation*, E. Gentaz and P. Dessus, Editors. 2004, Dunod: Paris. p. 11-25.
32. Bara, F., E. Gentaz, and P. Colé, *Les effets des entraînements phonologiques et multisensoriels destinés à favoriser l'apprentissage de la lecture chez les jeunes enfants*. *Enfance*, in press.
33. Bara, F., E. Gentaz, and P. Colé, *The visuo-haptic and haptic exploration increases the decoding level of children coming from low-socioeconomic status families*, submitted.
34. Gentaz, E. and P. Dessus, *Comprendre les apprentissages. Sciences cognitives et l'éducation*. 2004, Paris: Dunod.
35. Gentaz, E., P. Cole, and F. Bara, *Evaluation d'entraînements multisensoriels de préparation à la lecture chez les jeunes enfants de grande section maternelle*. *L'Année Psychologique*, 2003, 104: p. 561-584.
36. Viviani P, Baud-Bovy G, Redolfi M. *Perceiving and tracking kinesthetic stimuli: further evidence of motor-perceptual interactions*. *Journal of Experimental Psychology: Human Perception and Performance*, 1997, 23: p. 1232-52.
37. Hamstra-Bletz, L., J. DeBie, and B. Den Brinker, *Concise Evaluation Scale for children's handwriting*, Lisse, Swets, and Zeitlinger, Editors. 1987: Germany.