EVALUATION OF DIFFERENT HANDWRITING TEACHING METHODS BY MEANS OF KINEMATIC ANALYSIS

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Abstract— **Development of fine motor skills, especially drawing and handwriting, plays a crucial role in school performance and, more generally, in autonomy of everyday life.**

In recent years, the analysis of writing movements that allows to characterize the handwriting process itself, has been directly performed through digital tablets, by measuring parameters extracted from the basic elements of writing, such as components and strokes.

In order to evaluate the handwriting performance in two groups of twenty children each, in which two different teaching methods were used, we examined drawing and handwriting responses by a digital tablet. The dynamic aspects of written traces were studied in five different drawing and writing tasks: a doodle, three graphomotor sequences and a cursive sentence.

Results show differences both in each class across the development and between the two methods.

Keywords— **Handwriting, learning, teaching methods, digital tablets.**

I. INTRODUCTION

Children spend from 31 to 60% of their school day performing fine motor tasks, in particular handwriting. The combination of digital tablet and of appropriate algorithms permits today to examine both static and dynamic characteristics of writing [1], providing information for the study of fine motor movements also useful for the detection and quantification of both dysgraphia [2] and neurological movement disorders [3-4].

In this work we studied the handwriting process for the evaluation of scholastic teaching methods, using parameters that measure precise kinematic features extracted from digitally recorded writing by means of a commercial tablet [5]. In particular the factors concerning the basic elements of writing, such as components and strokes [6] have shown to be very promising for hand motor performance quantification. A component represents the writing segment between two successive pen lifts, while a stroke is the basic element of writing movements, delimited by the points of minimal curvilinear velocity. The typical kinematic parameters of hand movements, such as duration, length, mean velocity of strokes (and sometime of the components), have been frequently used for handwriting characterization, providing information on the level of automation and fluency achieved by a student.

This paper represents a preliminary study to evaluate in two samples of Primary school Italian students, how different teaching methods could influence these parameters.

II. MATERIALS AND METHODS

A. Study population and teaching methods

Each of the two considered samples consisted of about 20 students, Italian mother-tongue, right-handed and without handwriting problems and organic pathologies. In a sample the experimental Terzi's method was used (S1) while in the other one the traditional teaching method was applied (S2). In the latter teaching approach the child has to solve, without a lot of support, the main instrumental problems of handwriting (space and direction of movements). With no intervention or external help, the risk is that the student automates more and more possibly painful postural habits and ineffective pen handgrips, as well as bad graphic gestures that may foreshadow cases of dysgraphia.

The Terzi's method is a cognitive-motor technique, developed in the first half of the '900 by an Italian teacher, Ida Terzi, to allow blind students to move freely in the great outdoors, thanks to a series of exercises. These exercises act on the organization of the brain, using body movement to arrive at a correct time-space representation in the motor cortex of what the body has made. Over the years, this method has also found several other fields of application in rehabilitation or in schools for the study of mathematics and writing. The exercises improve the perception of space and the time between one movement and another. This method represents a valid method of rehabilitation in cases of children with handwriting and/or learning difficulties.

Acquisitions were performed in two specific phases of learning: the end of first grade of Primary (T1), when the children had learned the grapheme and the end of the second grade of Primary (T2), when they learned the cursive.

B. Tasks

In order to study possible parameter dependence on different teaching method as well as on motor development, all children undertook a series of five exercises: the first fourth tests, acquired both at the first and second grade, were totally independent from linguistic aspects differently to the last one that was acquired only at the end of the second grade, after the cursive learning.

The first test (D test) required pupils to draw in fast way, for 7s, a continuous doodle in the oblique direction.

In the second test (M task), the student had to continue as quickly as possible a zigzag sequence (Fig. 1) without pen lifts to the end of the line.

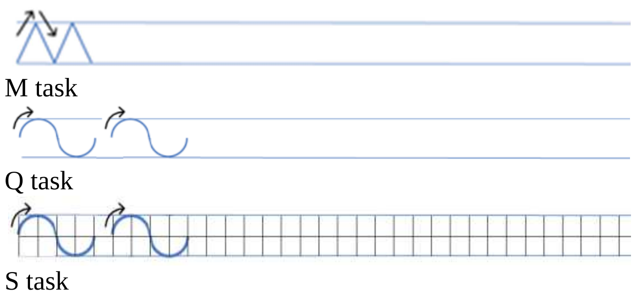

Fig 1: Representation of the M, Q and S tasks.

The third (Q task) and the fourth (S task) tests required the student to continue as quickly as possible the illustrated symbol sequence (Fig. 1) to the end of the line, at first in a white line (Q task) and then (S task) in a squared line (requiring more accuracy).

In the last test (V task), in which adequate linguistic competences were required, pupils were asked to copy in cursive, as fast as possible, the Italian sentence: *In pochi giorni il bruco diventò una bellissima farfalla che svolazzava sui prati in cerca di margherite e qualche quadrifoglio* (meaning “In few days the caterpillar became a beautiful butterfly that fluttered on the grass in search of daisies and some cloverleaf”). This sentence was constructed in order to contain all the letters of the Italian alphabet.

No indication was given to the students about the posture and the prehension to keep. Data was acquired by means of a commercial digitizing tablet (Wacom, Inc., Vancouver, WA, Model Intuos3), using an ink pen. Pen displacement across the tablet was horizontally and vertically sampled at 200Hz with a spatial resolution of 5 μm.

C. Analysis

Analysis was carried out with a proprietary program written in MATLAB [7]. At first, for each test, the components were identified as the written tracts between two consecutive pen lifts. Then, the horizontal and vertical pen positions were filtered by means of a second order low-pass Butterworth filter (10Hz cut-off frequency) and the curvilinear motion characteristics, i.e. position and velocity curves, were derived. To identify the strokes, an automatic segmentation procedure detected points of minimal curvilinear velocity, hypothesizing that each velocity minimum corresponds to a different motor stroke, as claimed by the bell-shaped velocity profile theory [8]. A series of kinematic and static parameters were calculated and analyzed for each task: the total length and duration of the task; the mean length and duration of each component and stroke; the mean curvilinear (Vc), horizontal (Vx) and vertical (Vy) velocities (the last two in absolute value) of each stroke. In order to study possible changes of these characteristic parameters with schooling as well as between the teaching methods, at first the mean value of each parameter was calculated in each subject and averaged across students of the same sample (S1 or S2) and acquisition time (T1 or T2).

For each task and parameter, the significance of the difference between the two acquisitions (T1 and T2) in each sample (S1 and S2) was evaluated by means of the *Wilcoxon* paired-sample test. To evaluate instead the two teaching methods, we compare the two samples, in each acquisition, by means of the *Wilcoxon* rank sum test.

III. Results

A. Trends with age in the two samples

Tab.1 shows that in the D task, the only fixed time test, child trace a longer length across the age in both samples due to a higher velocity. As regard the motor planning, in both samples the mean duration of stroke decreases with schooling and also the fragmentation degree (number of stroke normalized on the total numbers of written tracts) is reduced. In the M test, the whole duration decreases only in the S2 although the velocities increase in both samples. This trend can be explained by a greater increment of written path in the S1 rather than in the S2. Despite the child makes a written path longer in the second acquisition for both samples, the velocity growth is so strong that even the total duration is reduced. Also in this task the fragmentation decreases with schooling but the mean stroke duration increases probably because of an increment of their length. In the Q and S tests we can observe similar behavior that in the M test as regard the velocities, the fragmentation, the total duration and the stroke duration. The reduction of the total duration is due to the decrease of both mean pen lift duration and mean component (pen down) duration. Unlike of the Q test, in the S test children reach lower speeds due to the increased accuracy required performing the task.

Table 1 Mean±1SD of parameters calculated in all test (except V task, because it was acquired only in T2) in the two acquisitions (T1 and T2) for each sample (S1 and S2). The p-values indicate significance of the difference between the T1 and T2 in each sample (*Wilcoxon* paired-sample test).

Tests	S1-Terzi's Method			S2-Traditional Method		
	T1	T2		T1	T2	
Test: D	mean±1SD	mean±1SD	p-value	mean±1SD	mean±1SD	p-value
Whole length (mm)	279±127	487±148	0.0003	304±140	701±142	<0.0001
Mean Stroke Duration (ms)	210±40.8	184±55.6	0.03	192±43.3	149±29.2	0.007
Mean Curvilinear Velocity (mm/s)	38.8±17.5	69.6±23.9	0.0003	43.5±20.2	98.2±20.1	<0.0001
Mean Horizontal Velocity (mm/s)	24.8±12.2	44.9±18	0.0005	28.6±14.2	65.2±14.2	<0.0001
Mean Vertical Velocity (mm/s)	29.6±14.3	53.5±17.2	0.0006	32.6±15.2	73.4±15.1	<0.0001
#Strokes/#Tracts	1.36±0.941	1.07±0.199	0.02	1.38±0.733	1.02±0.075	0.01
Test: M	mean±1SD	mean±1SD	p-value	mean±1SD	mean±1SD	p-value
Whole duration (s)	19.20±2.20	18.63±7.88	n.s.	19.99±0.02	14.26±3.93	0.0006
Whole length (mm)	199±54.5	352±44.5	<0.0001	188±39.2	299±43.4	0.0003
Mean Stroke Duration (ms)	183±25.3	233±28	0.0005	170±10.6	219±29.3	<0.0001
Mean Curvilinear Velocity (mm/s)	9.7±2.76	17.1±4.34	0.0001	9.12±1.74	18.8±3.01	<0.0001
Mean Horizontal Velocity (mm/s)	4.39±1.49	6.95±1.87	0.0009	3.83±0.911	9.11±2.46	<0.0001
Mean Vertical Velocity (mm/s)	7.85±2.41	15±4.03	0.0001	7.55±1.57	15.6±2.29	<0.0001
#Strokes/#Tracts	4.28±1.68	1.62±0.583	<0.0001	3.73±1.94	1.8±0.348	0.0004
Test: Q	mean±1SD	mean±1SD	p-value	mean±1SD	mean±1SD	p-value
Whole duration (s)	18.91±2.36	13.63±5.58	0.008	19.11±1.51	11.10±4.69	0.0001
Whole length (mm)	110±28	166±22.2	0.0003	141±20.4	165±31.4	0.008
Mean pen lift duration (s)	1.51±0.64	0.85±0.23	0.0003	1.23±0.25	0.66±0.21	0.0001
Mean Component Duration (s)	2.01±0.60	1.12±0.40	0.0002	1.80±0.35	0.94±0.32	<0.0001
Mean Stroke Duration (ms)	154±10.2	170±20.1	0.004	154±8.5	160±16.4	n.s.
Mean Curvilinear Velocity (mm/s)	8.86±2.36	20.7±9.14	<0.0001	10.8±1.83	24.6±8.57	<0.0001
Mean Horizontal Velocity (mm/s)	4.82±1.61	11.9±5.82	<0.0001	5.85±0.974	15.8±5.95	<0.0001
Mean Vertical Velocity (mm/s)	5.85±1.5	14.1±5.9	0.0001	7.3±1.75	15.8±5.52	<0.0001
#Strokes/#Tracts	3.03±1.16	1.65±0.568	0.0002	2.83±0.68	1.58±0.348	<0.0001
Test: S	mean±1SD	mean±1SD	p-value	mean±1SD	mean±1SD	p-value
Whole duration (s)	18.90±1.85	14.51±5.12	0.004	19.27±1.34	10.76±4.14	<0.0001
Whole length (mm)	99.8±25.9	142±26.7	0.0006	120±21.6	133±14.5	0.03
Mean pen lift duration (s)	1.54±0.48	1.02±0.23	0.001	1.47±0.60	0.82±0.26	0.001
Mean Component Duration (s)	3.44±1.76	1.62±0.62	0.0001	2.30±1.12	1.39±0.69	0.02
Mean Stroke Duration (ms)	158±10.4	162±12	n.s.	156±10.2	163±11.1	n.s.
Mean Curvilinear Velocity (mm/s)	7.06±2.48	15.3±5.6	0.0001	9.1±2.17	19.2±6.45	0.0003
Mean Horizontal Velocity (mm/s)	4.1±1.47	9.12±3.02	0.0001	5.17±1.6	12.5±4.18	<0.0001
Mean Vertical Velocity (mm/s)	4.24±1.86	9.89±4.66	0.0001	5.72±1.66	11.4±4.23	0.001
#Strokes/#Tracts	3.26±1.01	2.32±1.04	0.003	2.35±0.84	1.57±0.55	0.05

B. Comparison between the two samples

In the first acquisition (T1) the parameters analyzed in the two samples do not show significant differences in D and M tests (Table 2). In T2, in D test, the S1 (Terzi's method) has a path length shorter than the S2 (Traditional method) probably because of a lower velocity. In the M test lower velocity and longer written path in S1 produce higher duration of execution. For these two tests, the fragmentation is similar in both S1 and S2 while the stroke duration is higher in the S1. In the Q and S tests some differences are found already in the first learning phase, T1: sample 2 reaches higher speeds than S1 thus it is able to draw a greater number of graphemes (greater total path). In T2, the children of the school which adopted the traditional method (S2) are faster than the others and, since at this time both groups write about the same lengths, they also gain in execution time (total duration, mean pen lift duration and mean component duration). For the S1, the mean stroke duration and the fragmentation degree (Nr Stroke/Nr tracts) are higher in the test S, where accuracy is required.

The V test, acquired only at the end of second grade, shows that the level of fragmentation does not differ significantly between the two samples. The subjects of the sample

2 have similar velocity values than the others, even if with differences in time and length values. In fact the students of the sample 1 write larger letters (higher values of whole length) but using more time than children of the sample 2.

Table 2 p-values of the difference between the two samples S1 and S2 in T1 and T2 acquisitions (Wilcoxon rank sum test) in the five Tests.

	Test D		Test M		Test Q		Test S		Test V
	T1	T2	T1	T2	T1	T2	T1	T2	T2
Whole duration (s)			n.s.	0.01	n.s.	n.s.	n.s.	0.02	n.s.
Whole length (mm)	n.s.	0.0003	n.s.	0.004	<0.0001	n.s.	0.008	n.s.	0.004
Mean Stroke Duration (ms)	n.s.	0.02	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.0001
Mean Curvilinear Velocity (mm/s)	n.s.	0.001	n.s.	n.s.	0.004	n.s.	0.005	n.s.	n.s.
Mean Horizontal Velocity (mm/s)	n.s.	0.001	n.s.	0.009	0.007	0.02	0.008	0.008	n.s.
Mean Vertical Velocity (mm/s)	n.s.	0.002	n.s.	n.s.	0.02	n.s.	0.003	n.s.	n.s.
#Strokes/#Tracts	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.007	0.01	n.s.
Mean pen lift duration (ms)					n.s.	0.03	n.s.	0.02	<0.0001
Mean Component Duration (ms)					n.s.	n.s.	0.005	n.s.	<0.0001

IV. DISCUSSION

From the comparison between the two acquisitions in each student group it is possible to state that both samples made progresses between the first and the second learning phase in terms of duration, speed and reduction of the degree of fragmentation.

Furthermore where greater accuracy is required, kinematic performances are more contained.

From the second statistical analysis it appears that the sample 2, in which the traditional method was used, is almost always faster than the other one. However, performance in terms of time and length vary greatly depending on the test, even if it is often observed that students in S1, in which the Terzi's method was adopted, reproduce a longer written path than the others belonging to S2 even if both groups had to write the same number of letters.

Since early years of school, Terzi's method makes a more readable and accurate writing and this result could surely support prevention from dysgraphia, but at the expense of movement fluency.

It can be also concluded that the tools deployed for the kinematic analysis of handwriting are a way to quantitatively evaluate graphomotor performance and can be also used in the evaluation of teaching methods.

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