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Abstract. Handwriting difficulties represent a common cause of underachievement in children education and low self-esteem in daily life. The analysis of handwriting could be an important tool for the evaluation of a teaching method in order to assess its efficacy in preventing dysgraphia. We performed a comparative analysis of the traditional handwriting method and the alternative Terzi's approach in pupils at the end of primary school, when cursive skills should have been achieved.

Qualitative and kinematic parameters were considered: the first ones were calculated as a visual analysis of written texts (by using check-lists and scales regarding qualitative, postural and pen grasp aspects), while the latter ones were automatically extracted through digitizing tablet acquisitions. Results showed significant differences concerning handwriting quality and dynamic movement in pupils handwriting depending on the teaching method applied.

1. Introduction

A large number of school-aged children have difficulties with handwriting. Dysgraphia is one of these: it consists in a learning disability that often involves a written illegible product. Problems like this can affect not only their self-esteem, but also their school performance and everyday life in the future. (Losse & al., 1991; Skinner & al., 2001; Cummins & al., 2005).

The increase in worldwide percentage of children with writing difficulties may be caused by: increasing use of modern technologies (Sülzenbrück & al., 2011); lacking cursive instruction for elementary school students (Hanover Research, 2012); inappropriate teaching methods and failure to detect child's difficulties (Martins & al., 2013). In order to evaluate teaching methods and identify handwriting problems like dysgraphia, the approach usually performed includes two different analysis. The first one is related to digitally recorded writing samples, using characteristic parameters that measure the specific kinematic features (Accardo & al., 2014); the second one is a visual analysis of the written product for a qualitative evaluation of handwriting goodness (Genna et al., 2015).

In this paper, involved teaching handwriting methods are the traditional ones and the Terzi's approach (Terzi, 1995). Ida Terzi was a primary school teacher at the institute of blind people in Reggio Emilia, Italy, in the first half of the 1900s. She proposed a space-time method which aim was to develop students' perception of the body moving in space. Information from personal (body perception), peri-personal (objects manipulation) and extra-personal (environment) spaces are mixed up in order to facilitate perceptual consistency and transition from unconscious to conscious use of the body in motion. In Terzi's approach blindfolded pupils experience on the wall the graphic symbol with large movements of the arm and hand by their teacher aid; then they independently reproduce the motor representation on the wall and at a later stage on large sheets with brush and colour, shifting from a vertical plane to a horizontal one. At last, letters are reproduced, with decreasing size, in elliptical patterns, in squares of 0.5 cm and finally in ruled paper of their specific classes. Instead, in the traditional handwriting programs, instructions about letters formation take place as a group activity rather than as an individualized one. Teacher requires children to observe from blackboard or books the shape of letters, to remember them, and to transfer on their copybook what their visual memory stored.

The aim of this work is to compare the traditional way to teach writing with the experimental space-time method of Ida Terzi during the last year of primary school, when cursive skills should have been achieved.

2. Materials and methods

Participants. The present study provides the enrollment of 20 pupils (7 male and 13 female) for each classroom and therefore for each teaching handwriting method: the "Don Milani" primary school of Cernusco sul Naviglio, that follows the Ida Terzi's method (experimental group labelled with CE) and the primary school of Pioltello, that instead uses the traditional teaching method (control group, labeled with PI). The analysed acquisitions were made at the end of the 5th grade, the last year of cursive handwriting classes. All subjects were Italian mother-tongue, right-handed, with no handwriting problems or organic pathologies, and belonging to the same area with medium socioeconomic status.

Tests. Kinematic and qualitative handwriting evaluations were mainly based on two tests that require adequate linguistic competences and cursive writing skill. These tests consist in writing in accurate (A test) and in fast (F test) mode the following Italian sentence: *In pochi giorni il bruco diventò una bellissima farfalla che svolazzava sui prati in cerca di margherite e qualche quadrifoglio* (meaning "In a few days the caterpillar became a beautiful butterfly fluttering on the lawns in search of some daisies and clover"). This sentence was constructed with the aim of containing all the letters of the Italian alphabet and several phonological rules.

Processing and statistical analysis. In order to evaluate differences between the two teaching methods, qualitative and kinematic parameters were separately processed for each test.

Hand-motor performance quantification was undertaken with special regard to the basic writing elements: strokes and components assessment (Van Galen, 1998). A proprietary MATLAB program (Genna & al., 2011) was used to perform this analysis. Strokes were identified as segments between points of minimal curvilinear velocity, as suggested by the bell-shaped velocity profile theory (Djioua, 2009). Components were identified as the written tracts between two consecutive pen lifts.

In order to provide information on the level of automation and fluency achieved by a child, a series of kinematic and static parameters were calculated and analysed for each test (Rosenblum, 2006): duration, length, mean and peak of curvilinear, horizontal and vertical velocity evaluated for the whole written track, components and strokes; pen lift duration; number of components, strokes and letters per second and per unit space.

About qualitative analysis, a manual approach was used (Genna & al., 2015): an evaluation scale based on a new neuromotor model of handwriting production. In order to define the TQSs (total quality scores), the ratio between the number of errors made and the maximum number of the possible ones for each parameter was evaluated. In addition, this normalized scores was weighed through the AHP method to guarantee an objective evaluation of handwriting goodness.

For both qualitative and kinematic parameters, the significance of difference between PI and CE group score was evaluated by means of the Wilcoxon test for independent samples. In order to identify the most significant parameters, in terms of difference between groups, stepwise regression with forward selection was used in both A and F tests.

3. Results and discussion

Results were obtained from kinematic and qualitative analysis: the writing process is "stressed out" to evaluate the speed of handwriting and the quality of the graphics performance.

Kinematic analysis. Starting from the digitally recorded writing samples of each student, kinematic and static parameters, relative to the whole written track and its components and strokes, were estimated. The first step has been the evaluation of the statistically significant differences (p-values<0.05) between results of two groups arising from the application of the Wilcoxon test for independent samples.

Table 1. Mean±1SD of most significant full track parameters calculated in both A and F test for CE and PI groups.

	A test			F test		
Track Parameters	CE	PI	p-value	CE	PI	p-value
Whole duration (s)	97±16	128±28.3	< 0,0001	74.4±11.5	76±9.4	n.s.
Whole length (mm)	1262.8±223.2	1451.8±205.4	< 0,02	1365.3±269.3	1505.9±239.6	n.s.
Curvilinear vel (mm/s)	18.6±4.7	21±6.7	n.s.	25±5.2	32.9±6.2	< 0,0002
Horizontal vel (mm/s)	8.9±2.3	10.9±3.8	n.s.	12.4±2.5	17.8±4.1	< 0,0001
Vertical vel (mm/s)	13.9±3.9	14.8±4.7	n.s.	18.1±4.3	22.3±4.4	< 0,004
Whole pen lift durn. (s)	28±9.1	55±17	< 0,0001	19.2±6	30±8.5	< 0,0002
#Components	57.4±17.3	103.8±21.7	< 0,0001	55.7±17.6	97.1±20	< 0,0001
#Strokes	431.2±41.7	485.7±85.8	n.s.	381.4±43.1	365.8±40	n.s.
#Components/#Letters	0.5±0.2	1±0.2	< 0.0001	0.5±0.2	0.9±0.2	< 0.0001
#Strokes/#letters	4±0.3	4.5±0.8	n.s.	3.6±0.4	3.4±0.3	n.s.
#Letters/cm	0.89±0.15	0.76±0.1	< 0,01	0.81±0.15	0.73±0.12	n.s.
#Letters	108.8±3.4	107.8±0.5	n.s.	107.1±4.2	106.7±3.2	n.s.

In fast modality, the two groups use the same time to write the sentence. The control group (PI) is significantly faster with the pen on the paper than CE group but spend more time during pen lift.

In accurate modality, the experimental group (CE) ends the test in less time than PI. The control group finds greater difficulty in accurate writing indeed they spend significantly more time during pen lift respect CE group and respect itself in the fast modality.

A greater pen lift duration is related to a bigger number of components and, as the number of letters is the same between groups, it entails a higher level of fragmentation in letters execution (#Component/#Letters) for the control class. Components are the written tracts between two consecutive pen lifts, therefore the minimum number expected is equal to the number of words plus the number of *"i"*, *"t"*, *"z"*, *"ò"*, that is, those characters which need a pen lift for their completion (in our sentence the minimum #Components is 40).

Kinematic analysis shows that PI students need more time to organize the graphomotor task (greater pen lift) and struggling more to tie together the letters smoothly (using one component per letter). CE students spend less time during pen lift because they have successfully automated the graphomotor process and the ligation process between letters (on average, one component every two letters).

By means stepwise regression was possible to detect the most significant parameters for both tests: *number of components* and *strokes* for A test and *mean length, mean vertical velocity* and *mean horizontal ascendant velocity of components* for F test.

Qualitative analysis. A similar analysis was performed on the 16 qualitative parameters in terms of TQS (Genna & al., 2015). Table 2 represents the most statistically significant parameters in which the two schools was compared. The p-values indicate significance of the difference between samples in terms of error rate.

Table 2. Mean±1SD of most significant qualitative parameters (TQSs) calculated in both A and F tests for each sample. a: posture area; b: handgrip area; c: sheet graphic space area; d: row graphic space area; e: graphomotor patterns area

	A test			F test		
	CE	PI	p-value	CE	PI	p-value
Total error score	0.076±0.016	0.116±0.023	< 0.0001	0.082±0.02	0.354±0.086	< 0.0001
a.1. Inefficient posture	0.004±0.006	0.009±0.005	< 0.003	0.004±0.006	0.009±0.005	< 0.003
b.2. Inefficient handgrip	0.015±0.011	0.027±0.013	< 0.005	0.015±0.011	0.027±0.013	< 0.005
c.1. Variability of the left alignment	0.001±0.003	0.001±0.004	n.s.	0.001±0.004	0.013±0.007	< 0.0001
d.1. Irregular word spacing	0.008±0.009	0.015±0.011	< 0.03	0.007±0.008	0±0	< 0.0001
d.2. Letter collisions	0.001±0.002	0.001±0.001	n.s.	0.002±0.002	0.021±0.015	< 0.0001
d.3. Max variation of letter size	0.022±0.007	0.028±0.008	< 0.02	0.023±0.009	0.001±0.001	< 0.0001
d.4. Wrong letter size	0.005±0.002	0.006±0.003	n.s.	0.004±0.002	0.11±0.043	< 0.0001
e.1. Wrong graphomotor pattern	0.008±0.006	0.013±0.007	< 0.02	0.01±0.008	0±0	< 0.0001
e.2. Dysmetria in letters execution	0.003±0.003	0.007±0.005	< 0.007	0.004±0.004	0.014±0.008	< 0.0001
e.3. Self-corrections of grapheme written	0±0.001	0±0	< 0.003	0±0.001	0.121±0.041	< 0.0001

Total error score of PI group is higher (then worst) than CE group for both accurate and fast modalities of execution in the handwriting context. Comparing the two tests, the experimental group obtained almost the same total quality score; unlike the control group has a slightly greater number of errors switching from accurate modality to the fast one. It is useful to observe the single sub-areas, and then their relative sub-criteria, to better understand the specific differences between the two groups.

About peripersonal space, CE group keeps a better posture and handgrip than PI group.

In accurate modality, other significant differences between CE and PI group are present in the *row graphic space* and *graphomotor patterns* areas. Indeed, CE group keeps a more regular word spacing, a better letter size uniformity, more correct graphomotor patterns and less dysmetria in letters execution. Besides that, switching to F test, more significant differences are detected. Increasing handwriting speed, PI group makes more errors unlike CE group.

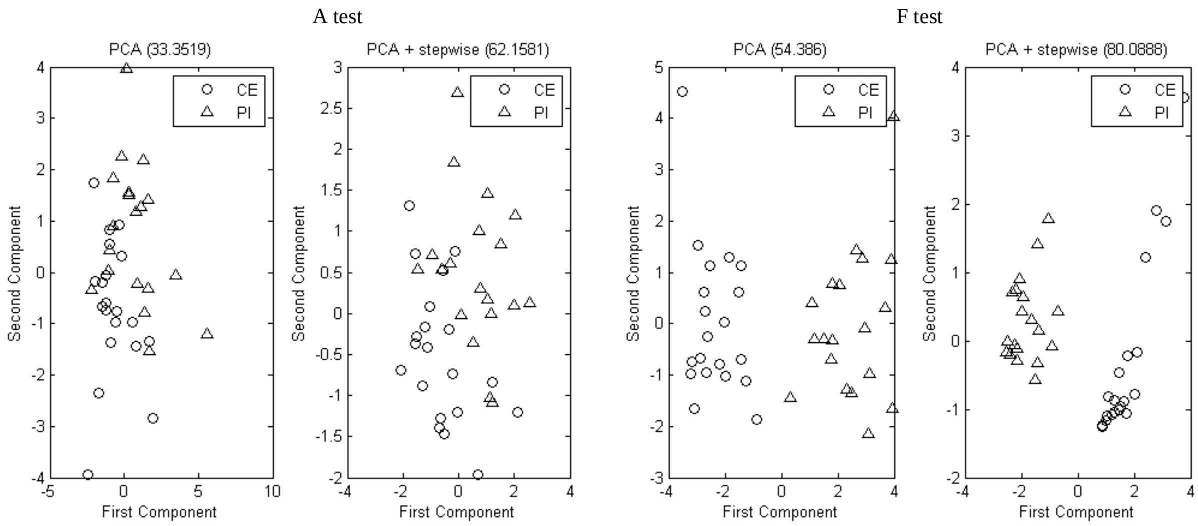

Figure 1. Loading PCA plot obtained in A and F tests using first all qualitative parameters and then those selected by the stepwise regression. Circle: Terzi's Method subjects (CE); Triangle: Control Group (PI).

After comparing the two schools for each qualitative parameter, principal component analysis (PCA) has been carried out, considering first all qualitative parameters and then only a part of them, selected by stepwise regression. Loading PCA plot (Figure 1) shows the weights for variables calculated for both groups and in relation to the first two PCA components.

Principal Component Analysis (PCA) in A test, conducted using first all parameters for each qualitative criterion and then only those selected by stepwise regression (*inefficient posture* and *handgrip, irregular word spacing, wrong graphomotor pattern*), shows that the first two components have an associated explained variance of 33.3% in the first case and 62.2% in the second case. PCA for F test, computed on all parameters and on selected parameters through stepwise regression (*letter collisions, fluctuations on the line, maximum variation of letter size, wrong letter size, wrong graphomotor pattern, self-corrections),* shows an explained variance of the first two PCA components of 54.4% and 80%. For both A and F test, using PCA on selected parameters, groups are more distinguishable.

4. Conclusion

Results confirm the hypothesis of a better qualitative performance from pupils who use the Terzi's method. Comparing the two tests, the experimental group maintains almost the same quality; unlike the control group has a slightly greater number of errors switching from accurate modality to the fast one. In the evolutional development of the calligraphy, CE students have achieved a balance between accuracy and speed performances. PI students, from a kinematic point of view, spend more time with pen off the paper to organize the correct graphomotor pattern. In addition, PI students have a less fluent handwriting. PI student make a pen lift every letter, registering a greater number of components.

Since early years of school, Terzi's method makes a more readable and accurate writing and this result could surely support prevention from dysgraphia, although at the expense of movement fluency. The automation of accurate movements is facilitated paying special attention to improve handgrip of the writing tools used.

In the other hand, the tools deployed for the kinematic and qualitative analysis of handwriting are a good way to quantitatively evaluate graphomotor performance and can be also used in teaching methods evaluation.

References

Losse, A., Henderson, S.E., Elliman, D., Hall, D., Knight, E. & Jongmans, M. (1991). Clumsiness in children: Do they grow out of it? A 10 year follow-up study. *DMCN, 33*, 55-68.

Skinner, R. & Piek, J. (2001). Psychosocial implications of poor motor control coordination in children and adolescents. *Human Movement Science, 20*, 73-94.

Cummins, A., Piek, J. & Dyck, M. (2005). Motor coordination, empathy and social behaviour in school aged children. *Developmental Medicine & Child Neurology, 47*, 437-442.

Sülzenbrück, S., Hegele, M., Rinkenauer, G., & Heuer, H. (2011). The death of handwriting: Secondary effects of frequent computer use on basic motor skills. *Journal of motor behavior, 43(3)*, 247-251.

Hanover Research. (2012). *The Importance of Teaching Handwriting in the 21st Century*. Retrieved from https://www.hw21summit.com

Martins, M.R., Bastos, J.A., Cecato, A.T., Araujo, Mde L., Magro, R.R., & Alaminos, V. (2013). Screening for motor dysgraphia in public schools. *Jornal de Pediatria (Versao en Portugues), 89(1)*, 70-74.

Accardo, A., Genna, M., Perrone, I., Ceschia, P., Mandarino, C. (2014). Evaluation of different handwriting teaching methods by kinematic analysis. *XIII MEDICON 2013. IFMBE Proceedings, 41*, 579-582.

Genna, M., D'Antrassi, P., Ajčević, M., Accardo, A. (2015). A New Approach for Objective Evaluation of Writing Quality. *16th Nordic-Baltic Conference on Biomedical Engineering. Springer International Publishing*, pp.32-35.

Terzi, I. (1995). *ll Metodo spazio-temporale, basi teoriche e guida agli esercizi*. Ghedini (Eds.), Milano.

Van Galen, G.P., Weber, J.F. (1998). On-line size control in handwriting demonstrates the continuous nature of motor programs. *Acta Psychol (Amst), 100*, 195-216

Genna, M., Accardo, A., Borean, M. (2011). Kinematic Analysis of Handwriting in Pupils of Primary and Secondary School, *15th IGS 2011 Conference Proc., Cancún, México*. Elena Grassi & Jose L. Contreras-Vidal (Eds.), pp.193-196.

Djioua, M., Plamondon, R. (2009). A new algorithm and system for the characterization of handwriting strokes with delta-lognormal parameters, *IEEE Trans Pattern Anal Mach Intell, 31(11)*, 2060-2072.

Rosenblum, S., Chevion, D., Weiss, P.L. (2006). Using data visualization and signal processing to characterize the handwriting process. *Pediatric Rehabilitation, 4*, 404-17