Gender and Age Influence in Handwriting Performance in Children and Adolescents

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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. Moreover, a variety of neurological and psychiatric conditions in childhood and adolescence could stunt the normal motor and cognitive development [1].

In recent years, the analysis of handwriting movements, that allows objective quantitative kinematic analyses of writing quality, has been directly performed through digitizing tablets. This technology has been used to acquire and successively characterize the handwriting process [2] by measuring parameters extracted from the basic elements of writing, such as components and strokes.

In order to study the normal development of some kinematic parameters of handwriting movements (such as length, duration, mean and peak velocity of components and strokes) and determine the influence of gender we examined the writing responses of two hundred and eighteen children and adolescents.

Cursive writing was acquired by a digital tablet and its dynamic aspects were studied in five different experimental conditions: two repetitive sequences of le and uno, a series of numbers (in letters) in ascending order and a sentence written in two different ways.

Some results show that in the first grades of Primary school, females have better performances than males.

Keywords—Gender, handwriting, kinematic analysis, motor skill, age school.

1. INTRODUCTION

Many studies have addressed the question of whether or not motor performance abilities, in terms of either speed, accuracy or both, differ between genders at some stages of development [3-4].

Although there is compelling evidence that in physical strength and in many athletic domains adult males may perform better than age-matched females [5] it is not clear whether “peripheral” factors such as aerobic capacity, bone length or muscle mass [6] are at work or whether central nervous system factors also contribute to the males advantage, i.e., males have a real advantage in gaining skill (procedural knowledge) from training. It is also not clear whether differences between genders, in motor task performance, exist in childhood, and if/when these differences are established during development [7].

The nature of the task requirements may play a role in determining gender differences in performance, with, presumably, a male advantage in tasks requiring spatial manipulations and a female advantage when language skills are important [8].

Handwriting analysis, performed using characteristic parameters that measure precise kinematic features extracted from digitally recorded writing samples, provides information for the study of fine motor movements [9]. In particular the factors concerning the basic elements of writing, such as components and strokes [10] have shown to be very promising for hand motor performance quantification. A component represents the segment between two successive penlifts, 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 the duration and length, the mean and peak 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. Moreover, although many studies indicate some changes in the relations among these kinematic parameters depending on individual variables (age, gender, handedness, health status, etc.), to date, their connections have not been systematically examined.

In this paper we investigated possible differences between genders concerning stroke and component patterns in seven different school grades; in particular we examined the writing of school children from 2nd grade of Primary school to the 3rd grade of Secondary school. Each participant had to produce two repetitive cursive sequences, about independent from linguistic aspects, then a task, partly dependent on the mathematical knowledge acquired by the child, and finally had to copy a short meaningful sentence, for which adequate linguistic competences were required.

II. MATERIALS AND METHODS

A. Study Population

A sample of 218 students of Italian mother-tongue, right-handed and without handwriting problems and organic pathologies was considered. Participants attended from Primary (P) to Secondary (S) schools and their distribution...
along the seven considered classes was: 34 in 2nd P (12 males and 22 females; \(\text{Mean}=7.9\) years), 23 in 3rd P (10 males and 13 females; \(\text{Mean}=9.0\) years), 32 in 4th P (13 males and 19 females; \(\text{Mean}=10.0\) years), 42 in 5th P (22 males and 20 females; \(\text{Mean}=10.9\) years), 32 in 1st S (14 males and 18 females; \(\text{Mean}=11.9\) years), 34 in 2nd S (14 males and 20 females; \(\text{Mean}=13.1\) years) and 21 in 3rd S (6 males and 15 females; \(\text{Mean}=14.0\) years).

Before starting the acquisition, written informed consent was obtained from the parents.

### B. Tasks

In order to study possible parameter dependence on motor development and linguistic competences acquired by both genders, all children undertook a series of five exercises: the first two tests (LE and UNO tasks) were partially independent from linguistic aspects and required pupils to write in fast way, for a minute, a cursive sequence of ‘le’ or ‘uno’, respectively. The third test (NUM task), requiring the student to write as quickly as possible numbers (in cursive) in ascending order for a minute, was partly dependent on the mathematical knowledge acquired by the child. In the last two tests (A and F tasks), in which adequate linguistic competences were required, pupils were asked to copy in cursive the Italian sentence: *L’elefante vide benissimo quel topo che rubava qualche pezzo di formaggio* (meaning “The elephant clearly saw that mouse stealing some pieces of cheese”). This sentence was constructed in order to contain all the letters of the Italian alphabet. In the A task child had to write as accurately as possible, while in the F task, he had to write as Fast as possible. As regard the posture and the prehension to keep, no indication was given to the students.

Data was acquired by means of a commercial digitizing tablet (Wacom, Inc., Vancouver, WA, Model Intuos3), using an ink pen and a sheet of a lined paper, appropriate to the grade attended, in order to reproduce a normal ‘pen and paper’ context. Pen displacement across the tablet was sampled at 200Hz, both horizontally and vertically, and acquired with a spatial resolution of 5 \(\mu m\).

### C. Analysis

Analysis was carried out with a proprietary program written in MATLAB [11]. 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 separately filtered by means of a second order low-pass Butterworth filter (10Hz cut-off frequency) with phase compensation 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 [12].

A series of kinematic and static parameters were calculated and analyzed for each task: the total length (mm) and duration (ms) of the task; the mean length (mm) and duration (ms) of each component and stroke; the mean curvilinear (\(V_c\)), horizontal (\(V_x\)) and vertical (\(V_y\)) velocities (the last two in absolute value) of each component and stroke (mm/s). Taking into account the number of written letters, the number of strokes per letter was also derived.

To study possible changes of these characteristic parameters with schooling advances as well as between genders, at first the mean value of each parameter was calculated in each subject and averaged across students of the same gender and grade. For each task and parameter, the significance of the difference between genders in each class was evaluated by means of the Wilcoxon rank sum test (or Mann-Whitney U test).

### III. RESULTS

Significant differences between genders were observed only in the first grades in the LE task and in the two phrases. Moreover, in all tests, the velocities calculated in the components showed the same behavior as those observed in strokes, consequently we analyzed only the significance of differences in strokes.

In the LE task, the peak velocities were similar for both sexes. In this test the two parameters in which significant differences are present were the number of letters (Fig. 1) that is greater in females in 2nd P, 3rd P, 4th P and 3rd S (\(p<0.05\)) as well as the total track and the curvilinear and vertical velocities of the stroke (Table 1) in the 2nd P (\(p=0.04\)).

![Fig. 1 Number of letters in the LE task](image)