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Development, maturation and learning influence on handwriting kinematics

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ABSTRACT

Handwriting is the result of a process in which linguistic, psychomotor and biomechanical factors interact with physical maturation, cognitive development and learning. Digital tablets, which record the writing in real time, allow a kinematic analysis of written trace: the implemented algorithms analyze parameters as length, duration and speed of the components (trace between two pen-lifts) and strokes (trace between two minima of curvilinear velocity). The purpose of this work is to fill, at least for Italy, the lack of normative data on typical handwriting processes. This cross-sectional study will present data on 218 right-handed and Italian mother-tongue students, attending classes from 2nd to 8th grade. They performed specific tasks (tests of writing speed; transcription of a sentence accurately vs. speedily) by a digital tablet. The analysis showed many changes of the considered parameters across the classes, as in the horizontal, curvilinear mean and peak velocities of components and strokes, with higher values in the last years of schooling and a parallel decrease in the number of strokes/letter (improvement of automation). In conclusion, some of these parameters are useful for studying development and learning of writing and their values can be used as references to evaluate samples with different characteristics.

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1. Introduction

Despite the widespread use of computers, legible handwriting remains an important life skill that deserves greater attention from educators and health practitioners (Feder & Majnemer, 2007). In

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particular in childhood and adolescence, writing plays a crucial role in school performance, with important implications for motor and cognitive development.

During the past 20 years, graphonomic research provided important contributions to the understanding of fine motor control, motor development, and movement disorders (van Gemmert & Teulings, 2006). In particular, the analysis of performance in handwriting and drawing tasks has been used to highlight neurological deficits affecting hand movements (Dounskaia, van Gemmert, Leis, & Stelmach, 2009; Elble, Brilliant, Leffler, & Higgins, 1996; Popovic, Dzoljic, & Kostic, 2008; van Gemmert, Teulings, Contreras-Vidal, & Stelmach, 1999), alcohol and substance effects (Lange et al., 2006; Phillips, Ogeil, & Müller, 2009), psychiatric diseases like schizophrenia and depression (Mergl, Mavrogiorgou, Juckel, Zaudig, & Hegerl, 2005; Mergl et al., 2004; Tigges et al., 2000) as well as motor learning disabilities (e.g., DCD and dysgraphia; Engel-Yeger, Nagauker-Yanuv, & Rosenblum, 2009; Hamstra-Bletz & Blöte, 1993; Rosenblum, Parush, & Weiss, 2003; Smits-Engelsman, Niemeijer, & van Galen, 2001; Smits-Engelsman & van Galen, 1997). Researchers identified both static and dynamic indices of handwriting efficiency: in particular, product legibility analysis, which considers specific static handwriting features as spacing between letters and words, letter formation, degree of line slant, etc. proved to be limited because only the study of dynamic characteristics of the handwriting process provides information on the motor control mechanisms (Rosenblum, Weiss, & Parush, 2003).

For this reason most recent studies were carried out through writing acquisitions performed by means of digitizing tablets that allow objective quantitative kinematic analyses of the writing quality. Moreover, this analysis characterizes the handwriting process (Rosenblum, Chevion, & Weiss, 2006; van Galen & Weber, 1998), studying the basic elements of words, such as single letters, components (the segment between two successive pen-lifts) and strokes (the segment delimited by successive points of minimal curvilinear velocity). These analyses indicate that some kinematic parameters are particularly promising to discriminate poor from good hand motor performance (Mavrogiorgou et al., 2001). Duration, length, velocity (Mergl et al., 2004) and numbers of strokes or components, extracted from these basic elements, are the typical kinematic parameters of hand movements that provide information on the level of development achieved by hand movements.

Mergl, Tigges, Schroter, Moller, and Hegerl (1999) highlighted that bradykinesia can be quantified through mean stroke duration, and micrographia by means of mean stroke length, while the variation coefficients of kinematic parameters, like peak velocity, can be used as an index of regularity; moreover, their analysis showed that depressed patients wrote slower than healthy controls. Rosenblum, Dvorkin, and Weiss (2006) found significant differences between the proficient and dysgraphic groups in the number of segments used to trace individual letters or letter components, as well as the number of occurrences of direction reversals. These variables provide information about the child writing fluency (as revealed by the number of segments used when writing a passage of text) and about the child's ability to plan and execute the task in an efficient and accurate manner (as revealed by the number of direction reversals). Data show that a high number of segments per letter, as well as multiple direction reversals, are both inefficient writing techniques, often associated with fatigue and less readable writing.

Reviewing the literature on typical developing children, a difficulty is noticeable in generalizing results across different countries because of linguistic, cultural and teaching differences. There are also few analyses regarding the handwriting changes due to development, maturation and learning (Berninger, Graham, Weintraub, & Shafer, 1998; Blöte & Hamstra-Bletz, 1991; Contreras-Vidal, Teulings, & Stelmach, 1998). The lack of normative data on typical handwriting processes prevents a deeper comprehension of handwriting disorders, for selected clinical evaluations and intervention planning during developmental stages.

This study fills this gap at least for Italy, where sufficiently reliable and informative studies have not yet been conducted. To this aim, we examined the writing of school children of Italian mother tongue from 2nd to 8th grade (i.e., 2nd grade of Primary school to the 3rd grade of Secondary school), performing four different cursive tasks: a sentence transcription under two different conditions and two speed exercises. Writing was acquired by means of a commercial digital tablet, and its characteristics were analyzed.

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