Characterization of drawing movement as schooling advances in primary school

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Abstract

This study was to investigate the development characteristics of several parameters as schooling advances in primary school using computerized movement analyses.Sixty children without handwriting deficits were selected from a Chinese primary school, and they were asked to perform drawing tasks on a digital tablet for kinematic data collecting. In this study four drawing tasks were used: horizontal strokes, vertical strokes, squares and circles. We investigated a series of kinematic parameters such as velocity, acceleration and drawing force, to exam how these parameters change as schooling proceeds. The mean velocity and mean acceleration increase across the grade in all drawing tasks. The mean force of x-axis decreases only in vertical strokes and circles, while the mean force of z-axis decreases across the grade in horizontal strokes and squares. However, there was no significant correlation between grade and the force of y-axis in all tests.The digital tablet is an effective tool to determine the development of hand movement skills of children. This dynamical analysis technique can be used to study the underlying pathology of fine motor disorders.

*Keywords: d*rawing movements, kinematic analysis, digital tablet, children.

1 Introduction

Handwriting is an important fine motor activity, and the complex task involves bilateral and sensory awareness of the fingers, motor planning, visual perception, visual motor integration and continuous partial attention and so on. At a time when even small children spend hours on their PCs, handwriting seems on its way out. However, Elementary school children still spend 30% to 60% of their time at elementary school on handwriting tasks [1-3]. Learning to write legibly and efficiently allows children to achieve high-level academic studies and to build healthy self-esteem [4]. But studies have found that more than 10% of primary school children have handwriting problems or other fine motor disorders. Handwriting difficulty children may be related to their actual handwriting capabilities or related to biomechanical and environmental components [5].

In the past two decades, movement analysis researches have made important contributions to the understanding of movement disorders, fine motor control and motor development. In particular, handwriting and drawing tasks have been used to highlight neurological deficits affecting hand movements. Analyses of static stroke on chirography characteristics are limited to investigations of accuracy and legibility. With the development of electronic technology, digital graphic tablet has opened a new way for the evaluation of handwriting and drawing. The kinematic parameters of handwriting and drawing movement can be analyzed more precisely [6, 7]. The data of the pen location and pressure that acquired by the digital tablet are saved on a computer and post-processed using computer algorithm to determine all kinds of kinematic parameters that reflect the differences of hand movement.

Digitizer-based technology is widely used to study the motor control mechanisms of normal handwriting and drawing. General effects of age on all elementary movement patterns can be observed in childhood. Blank et al. studied the effects of age on basic fine motor functions of simple repetitive drawing movements in 7- to 15-year-old children and found the most marked effects of age were observed in drawing movements generated by fingers [8]. Lange-Kuttner also investigated pressure, velocity and time in drawing tasks by comparing several kinematic parameters in 4- and 6-year-old children, and found that the analysis of psychophysical measures of drawing gives important clues about the specific problems produced by relatively basic graphic patterns [9]. Rueckriegel et al. studied the influence of age on kinematic hand movement parameters in childhood, and showed that age of completed maturation depended on the task complexity and kinematic parameters, and the complex fine motor function reaching maturity later than basic movement patterns [10]. Accardo, et al. studied the writing of school children of Italian mother tongue from 2nd to 8th grade, and found many changes of parameters across the classes [1].

The drawing tasks were commonly used in the analysis and evaluation of human motor function. Many investtigations focus on English-speaking countries, but very little research in China. There are many differences among different countries because of cultural and linguistic and teaching differences. Compared with the researches of foreign counterparts, studies on Chinese handwriting analysis are still in the exploratory stage and assessment

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methods still need to be improved. Aiwu Xie, et al. explored the basic features of motor control on middle school students, and they found their ability of motor control develops and maturates with their growth. The motor control ability is in progress at the age of junior middle school [11]. Xiangzhi Meng and Shuang Yang et al. reported two cases about handwriting difficulty children, but they just used pencil and paper tests to assess the extent of dysgraphia [12, 13]. These methods were very subjective, and the test results generated may be inaccurate.

This paper represents a preliminary study to evaluate in a sample of Primary Chinese students. In China, children are taught to writing Chinese within the first year of primary school. So we investigated the drawing of school children of Chinese mother tongue from 1st to 6th grade, using four different drawing tasks: horizontal strokes, vertical strokes, squares and circles. Drawing was acquired by means of a digital tablet which was designed by our lab and it can acquire three perpendicular forces and position of the pen-tip simultaneously [14].

The aim of this study was to investigate the development characteristics of several parameters as schooling advances in primary school using computerized movement analyses. With the development of children's fine motor skill, we hypothesized that the velocity and acceleration would increase with grade in all tasks, while the drawing force would decrease.

2 Materials and methods

2.1 PARTICIPANTS

In order to study the influence of schooling on drawing kinematics, a total of 60 students with typical development recruited from a primary school, of Chinese mother-tone, right-handed and without handwriting problems or the other movement disorders.The distribution of subjects along the six considered grades and ages was: 10 in 1st grade (Mean= 6.2 years ± 0.4), 8 in 2nd grade (Mean= 7.1 years ± 0.5), 10 in 3rd grade (Mean=8.0 years ± 0.5), 11 in 4th grade (Mean= 9.2 years ± 0.4), 11 in 5th grade (Mean= 10.1 years ± 0.5), and 10 in 6th grade (Mean=11.3 years ± 0.3).

Before the experiment, written informed consent was obtained from the children, parents and teachers. The experimental procedures were approved by the local ethics committee, and the experiments were performed in accordance with the Declaration of Helsinki.We did not use any specific neuropsychological and neurological assessments in this study, but we used teachers' judgments of children academic achievement to evaluate their health status.

2.2 MEASURING DEVICE

The information of writing includes contacting force direction, amplitude and pen-tip trajectory [15]. In our lab, we designed a force sensitive tablet named F-Tablet (Force-sensitive Tablet), which can capture the three perpendicular forces of the pen-tip to the contacting plane and torques in two directions directly with a multi-dimension force/torque sensor, see Figure 1. The sensor's accuracy is 0.4%*FS* (Full Scale), and its nonlinearity is within 0.05%. The force range is -10*N*~+10*N*, the speed of response is smaller than 0.01sec. In addition, the static trajectory of the pen-tip on the writing plane and the other dynamic information such as the accelerations and velocities can be calculated. The device is connected to computer via USB interface with a sample rate of 100Hz with a spatial resolution of 0.01mm. The data were recorded online using dedicated C++ software; data analysis was performed off-line. The system is shown in Figure 2.

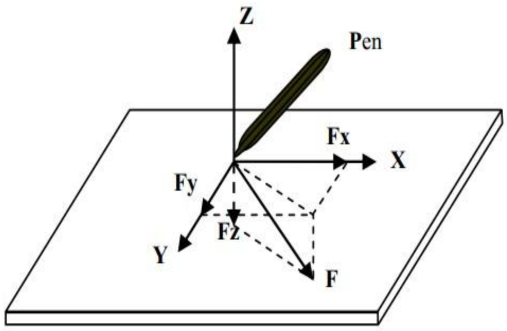

FIGURE 1 Schematic diagram of force action.

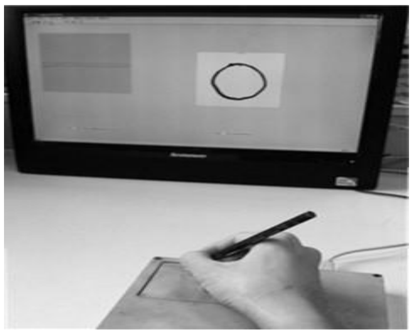

FIGURE 2 The data collection system of force sensitive tablet (F-Tablet).

When a stylus writes on the input tablet at point P (Figure 1), the writing force F can be decomposed into forces in three perpendicular directions, the writing force of x-axis $Fx(t_i)$, the writing force of y-axis $Fy(t_i)$, the writing force of z-axis $Fz(t_i)$. At the same time, the torque of the x-axis $Mx(t_i)$ and , the torque of the y-axis $My(t_i)$ are also measured directly by the multi-dimension force/torque sensor. These five elements are all functions of time ti. The coordinates ($x_p(t_i)$,$y_p(t_i)$) of the point P can be calculated from the equilibrium of moments. They can be expressed as (1-2):

$$x_p(t_i) = (M_y(t_i) - \frac{F_x(t_i) \bullet h}{F_z(t_i)}, \quad (1)$$

$$y_p(t_i) = (-M_x(t_i) - \frac{F_y(t_i) \bullet h}{F_z(t_i)}, \quad (2)$$

Where h is the distance between the input tablet and the origin of the coordinate, it is constant.

2.3 PROCEDURE

In our study, we used four basic geometric shapes: horizontal strokes, vertical strokes, squares and circles. The four drawing tasks were performed in this order: (1) horizontal strokes: the left-right horizontal movements that primarily require the wrist joint movements; (2) vertical strokes: the up-down vertical movements that require the finger joint movements; and they are two basic strokes of Chinese characters; (3) the squares, and (4) the circles movements that require the coordination of both finger and wrist movements [15].

The participant sat on a seat in front of the F-Tablet digitizer that was placed on a desktop, held a stylus pen in a writing fashion with the dominant hand, and performed drawing on the surface of the digital tablet. The forearm of the participant was approximately 45 degree relative to the digitizer. The bottom side of the digitizer was parallel with the table edge. The participants performed the tasks under similar ambient conditions of daily experience in a classroom and were instructed to draw the four tasks with the speed of their usual drawing. Before the data trials, the participant exercised these four tasks on the digitizer to familiarize with the equipment and understand the task requirements. Then each participant performed ten times on each of the four drawing tasks, a total of 40 data trials.

2.4 DATA ANALYSIS

Analysis was carried out with a program implemented in MATLAB. The following kinematic variables were analyzed:

Velocity: this parameter was used in many literatures, and very useful to measure quality of important parts of the drawing [16], mean velocity (MeanV) of the pen-down movements was measured in *mm/s*.

Acceleration: this parameter was used to measure the variation of velocity, mean acceleration (MeanA) of the pen-down movements was measured in mm/s^2.

Force: this parameter was used in many studies, but they only used the pressure of the pen-tip, and our F-Tablet is capable of capturing three perpendicular forces of the pen-tip to the contacting plane. In this study, mean forces in three perpendicular directions were measured in Newtons, the mean force of x-axis (MeanFx), the mean force of y-axis (MeanFy), the mean force of z-axis (MeanFz).

In order to investigate possible changes in these characteristic parameters as schooling advances, the mean value of each parameter was calculated in each student and averaged across subjects of the same grade. Pearson correlations were calculated to investigate associations between the kinematic parameters for each of the four tasks and the grade of subjects. If correlation was significant, regression analysis of linear, square, logarithmic and cubic curve fitting was applied. And we chosen the best fitting curve (highest r^2) corresponded to the grade of maturation.

3 Results and discussion

The relationship between the schooling and each parameter is reported in Figure 3–Figure 5. We used four different models (linear, logarithmic, square and cubic) in regression analysis for every parameter in these four tasks, the results showed that cubic models provided the highest r^2 in all tasks.

3.1 VELOCITY

Figure 3 contains an overview of the relationships between grade and drawing velocity. Correlation parameters were calculated for each of the kinematic parameters of four tasks. The four tasks have significant positive (Pearson's) correlation between grade and mean velocity (MeanV) with respect to hand movement execution (horizontal strokes: r^2=0.41; p<0.001; vertical strokes: r^2=0.35, p<0.05; squares: r^2=0.39, p<0.001; circles: r^2=0.32, p<0.01).

From the curve of regression analysis for mean velocity (MeanV), we found that the mean velocity increased across grade with a similar behavior in the four tasks (Figure 3). But the curve showed a stable tendency between grade 1 and grade 2 in vertical strokes and circles task, and between grade 5 and grade 6 in circles task.

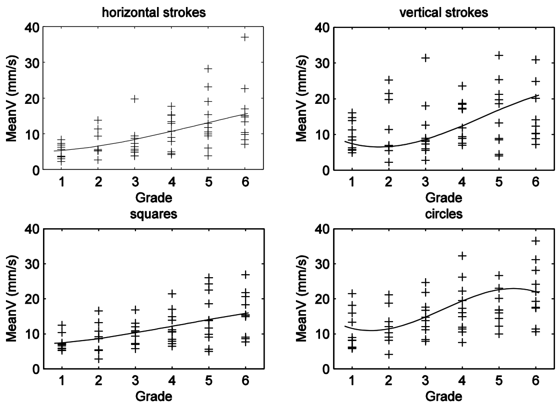

FIGURE 3 Non-linear regression analysis of grade for all tasks. Non-linear regression curves show changes of mean velocity (MeanV).

3.2 ACCELERATION

Figure 4 shows an overview of the relationships between grade and drawing acceleration. And the correlation between grade and acceleration was investigated. The four tasks have significant positive (Pearson's) correlation between grade and mean acceleration (MeanA) (horizontal strokes: r2=0.36; p<0.01; vertical strokes: r^2=0.27, p<0.05; squares: r^2=0.37, p<0.01; circles: r^2=0.25, p<0.05).

From the curve of regression analysis for mean acceleration (MeanA), and the mean acceleration increases across the grade with a similar trend in all tasks between grade 2 to grade 6 (Figure 4). And the curve showed a stable tendency between grade 1 and grade 2 in all tasks.

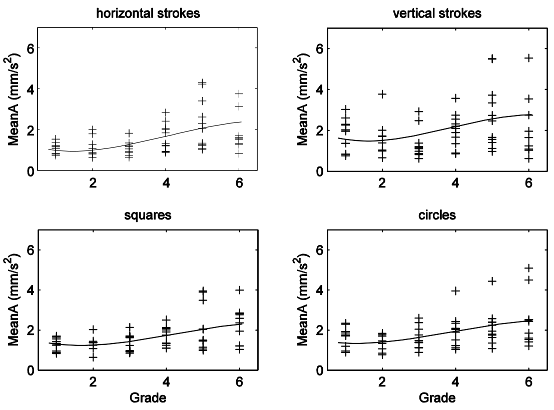

FIGURE 4 Non-linear regression analysis of grade for all tasks. Non-linear regression curves show changes of mean acceleration (MeanA)

3.3 FORCE

Figure 5 shows the relationships between grade and drawing force. The correlation of grade for the interprettation of drawing force parameters was studied. There are many different characteristics between grade and force parameters in each task: a. in the horizontal strokes tests, significant (p-values <0.01) between grade and mean force of z-axis (MeanFz); b. in the vertical strokes tests, significant (p-values <0.05) between grade and mean force of x-axis (MeanFx); c. in the squares tests, significant (p-values <0.01) between grade and mean force of z-axis (MeanFz); d. in the circles tests, significant (p-values <0.05) between grade and mean force of x-axis (MeanFx).

From the curves of regression analysis for mean force of z-axis (MeanFz) horizontal strokes task and squares task showed a similar declining trend from grade 2 to grad5, but there was a stable tendency between grade 1 and grade 2 in both of them. The mean force of x-axis (MeanFx) decreases across the grade with a similar trend in vertical strokes and circles task from grade 2 to grade 5, and a stable tendency between grade 1 and grade 2, and also steady between grade 5 and grade 6. (Figure 5).

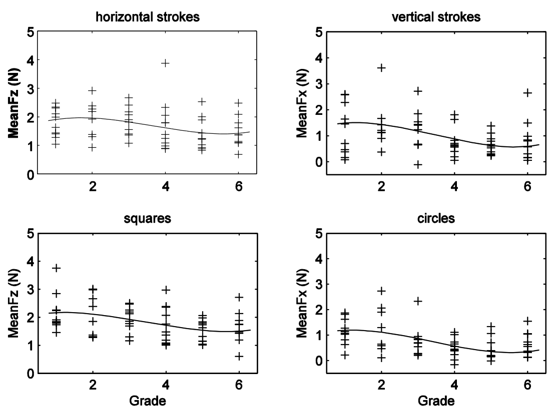

FIGURE 5 Non-linear regression analysis of grade for all tasks. Non-linear regression curves show changes of MeanFz in horizontal strokes and squares and MeanFx in vertical strokes and circles.

3.4 DISCUSSION

In recent years, digital tablets have been used as a research tool for the quantitative measurement of the kinematics and kinetics of handwriting and drawing [1]. But the characteristics of handwriting and drawing can be affected by different language, and little reports about Chinese children. So this work is very useful for a deeper research on the characteristics of Chinese handwriting.

In our research, the quality of drawing measured by the three kinematic domains: velocity, acceleration, drawing force. This study investigated the characteristics in typically developing children during drawing tasks. Just as we expected, in the four tasks children developed their drawing product with grade. But they also have many different characters in different tasks.

We found significant positive correlation between grade and mean velocity (MeanV) in all tasks. This finding agrees with the results of previous studies that investigated the changes of age on drawing tasks in children, in which a positive correlation between age and velocity also emerged[17]. There was also significant positive correlation between grade and mean acceleration (MeanA) in these four tasks from grade 2 to grade 6, there was no significant changes between grade 1 and grade 2. One prior study by Mergl et al. found handwriting acceleration decrease with increasing age [18], and Dixon et al. also found younger adults performed reliably faster than older adults on all tasks [19]. But their subjects were all adults and they were comparatively mature in motor and cognition ability on handwriting skills.

In this study we wanted to find the correlation between grade and the drawing force of x-axis (Fx), the drawing force of y-axis (Fy) and the drawing force of z-axis (Fz). In horizontal strokes and squares we found the mean force of z-axis (MeanFz) decreases across the grade. However, one prior study by Rueckriegel et al. found pressure increased and significantly with age [10]. In these two studies, the participants were from different countries with different cultural and linguistic and teaching may lead to such results. We found no significant correlation between the mean force of z-axis (MeanFz) and grade in vertical strokes and circles , the difference of drawing tasks may lead to this different results. In another study by Bland et al. also found no age-related effect on drawing pressure in children [8].

We found the mean force of x-axis (MeanFx) decreases in vertical strokes and circles. The result was similar to Lange-Kuttner's finding. They compared children at an age of 4 and 6 years and found drawing pressure decreased [5, 18]. But the change was not found in horizontal strokes and squares. There was no obvious development between grade 1 and grade 2, and these changes did not plateau until grade 5. So the change of mean force of x-axis (MeanFx) could be affected by different tasks, and from grade 2 to grade 5 is a key stage for children to develop the skill of force control.

However, there was no significant correlation between grade and the force of y-axis (Fy) in all tests. This may be partly because the different hand-holding postures of different children.

4 Conclusion

To the authors' knowledge, this is the first study that researched drawing characteristics kinematic parameters in Chinese children using a three-axis force-sensitive tablet. We found an association between grade and the variability of velocity, acceleration and drawing force, and some parameters also depended on the drawing tasks. The mean velocity and mean acceleration increase across the grade in all drawing tasks and the mean force of z-axis decreases across the grade in horizontal strokes and squares, while the mean force of x-axis decreases in vertical strokes and circles. Because of different pen-holding gestures, everyone has different forces parameters of y-axis.

In conclusion, this research quantified many parameters that measure the drawing features and pointed out how their changes among the grade. The research presented a new technical means for children fine movement disorder's clinical diagnosis and quantitative assessment. Meanwhile an effective rehabilitation training tool could be provided for school-age children with handwriting difficulties.

Acknowledgementssection of your paper

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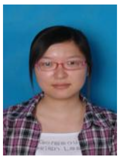

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