What is hidden behind handwriting of children with ADHD? - Kinematic analysis -

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What is hidden behind handwriting of children with ADHD?

- Kinematic analysis –

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***Abstract*—Handwriting analysis can be used to study function and organization of structures from the brain cortex all way down to the fingers. Graphic rules and kinematic parameters are suitable for assessing handwriting features in many disorders including attention deficit/hyperactivity disorder (ADHD).**

***Index Terms*—handwriting, graphic rules, kinematic parameters, ADHD**

I. Introduction

Movement investigations have had a long tradition in psychology and medicine providing many important clues for successful diagnosis in neurology and psychiatry. Movement disorders can be assessed with an efficient noninvasive procedure which registers handwriting characteristics by gathering two-dimensional hand movement data and surface pressure via the tip of the specialized stylus using digitizing graphic tablet [1].

Handwriting is skilled and coordinated motor activity involving smooth coordination of the arm, wrist and finger muscles [2]. In addition to motor and perceptual-motor skills, handwriting requires access to both memory engrams of learned letters and corresponding motor programs associated to its tracing, and finally engagement of effectors system to execute these programs. Writing maturates with age, in the beginning movements are slow, mainly guided by visual and kinaesthetic feedbacks, than writing becomes automated and mostly based on internal representation of motor acts [3]. Handwriting features are commonly analyzed throughout kinematic parameters: speed, stroke speed, velocity, acceleration, jerk, number of velocity/acceleration direction alteration, time during hand in-air/on-surface, horizontal/vertical/tangential velocity (acceleration/jerk) etc. [2].

Attention deficit/hyperactivity disorder (ADHD) is one of the most common neurobehavioral disorders among children and adolescents with a worldwide prevalence of 3.4% (CI 95% 2.6– 4.5) [4]. ADHD presents with symptoms of inattention, hyperactivity and impulsivity and combination of these. Children with ADHD also show difficulties in other aspects of functioning including social, emotional, cognitive, motor coordination and other difficulties [5]. About half of the children with ADHD have motor coordination’s difficulties, which can influence handwriting [5].

Common in children with ADHD, handwriting difficulties include too slow or too fast writing, illegible, inaccurate, inappropriate letter size and shape, applying larger surface pressure [6]. Limited handwriting skills can influence lower academic results and lead to poorer self-esteem and self-acceptance [6, 7].

When writing, copying or tracing, children reveal certain rules and strategies which tend to stabilize as they get older. These rules are called *the grammar of action* and they consist of starting rule, progression rule, and horizontal rule: all observed in a means of writing a single letter, copying a single letter or tracing/copying simple shapes. Several rules could be combined in many graphic principles depending on degree of difficulty and complexity of writing task [8, 9, 10]. Starting rule reflects subject’s preference to initiate writing by selecting certain location point. Progression rule reflects preference to write a segment in some direction. Horizontal rule reflects tendency to draw horizontal line after the vertical or oblique line and then proceed rightward [9, 11].

Graphic rules and graphic principles could reveal which cognitive strategies children use in writing tasks and possibly detect children with handwriting difficulties [11].

The aim of this study is to determine whether handwriting of children with ADHD differs from typically developed children (TDC) in graphic rules and kinematic features while tracing four semicircles rotated for 90 degrees in clockwise direction.

II. Subjects and Methods

This experiment included 24 right-handed children

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consisting of two groups (ADHD and TDC). For all children, informed consent from their parents was provided.

Experimental study group included 15 subjects (right-handed boys, mean age 9.7 ± 1.8 years) with ADHD diagnosed using the DSM-5 criteria [12]. Control group consisted of 9 typically developed boys attending 4th grade (right-handed, mean age 10.1 ± 0.2 years). Subjects from experimental group were tested individually in the Clinic of neurology and psychiatry for children and youth (Belgrade, Serbia), in conditions resembling school facility. Control group was tested in elementary school (Belgrade, Serbia) during class.

All subjects performed tracing task (3 repetitions) consisting of 4 semicircles rotated in clockwise direction by 90º (Figure 1). Writing task was done on the digitizing writing board (Wacom Intuos4 XL, sampling rate - 200 Hz, resolution - 0.005 mm) with stylus without ink trace on the writing surface.

Sampled data included: the starting point and the direction of progression for each of the semicircles for each repetition, kinematic parameters mean values for all 3 repetitions. Analyzed kinematic parameters were: velocity (V), pen tip pressure (P), acceleration (A), jerk (J), stroke duration (time) (ST), stroke speed (SS), number of changes in velocity (NCV) and number of changes in acceleration (NCA).

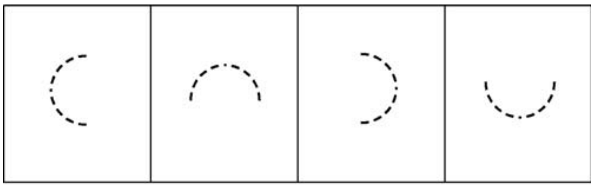

Fig.1. Tracing task: semicircles (1 to 4) with radius of 1.9 cm rotated in clockwise direction by 90º.

III. Results

Results relating to representations of predicted movements in semicircle tracing (according to starting and progression rule), expressed in percentage, are shown in Table I. Columns represent which percentage of subjects in both groups did tracing task using expected movement direction (for 1st semicircle from top to the bottom, 2nd from left to the right, 3rd from top to the bottom and 4th from left to the right).

TABLE I

PERCENTAGE OF PREDICTED MOVEMENTS IN SEMICIRCLE TRACING TASK.

Semicircle		1	2	3	4
predicted movement direction		**CCW**	**CW**	**CW**	**CCW**
Experimental group					
repetition	1	73,3	60	60	100
	2	86,7	80	73,3	100
	3	86,7	100	73.3	100
Control group					
repetition	1	66,7	77,8	44,4	100
	2	77,8	100	33,3	100
	3	88,9	100	66,7	100

CCW=CounterClockWise, CW= ClockWise

Table II shows summation of all movements used during one task constructing sequence (form 1st to 4th semicircle) and their distribution (in percentage) to predicted (or non-preferred movement based on motor rules). It also presents changes in the representation of predicted movement seen with repetition. Both groups show gradual increment of predicted movement percentage with task repetition with no significant difference between groups.

TABLE II

PERCENTAGE DISTRIBUTION OF TRACING MOVEMENT PREDICTED WITH GRAPHIC RULES

Group	Repetition	Predicted movement (%)
Experimental	**1**	73.3
	2	85
	3	90
Control	**1**	72.2
	2	77.8
	3	88.8

Regarding kinematic parameters values trough semicircle tracing task progression (see Figures 2A and 2B) experimental group showed that values for V, A, SS and J gradually increased with task progression, from 2nd to 4th semicircle. On the contrary, in the control group values of V, A, SS and J showed opposite trends with task progression (from 2nd to 4th semicircle). Values for ST, NCA and NCV gradually decreased with tracing progression in experimental group (from 1st to 4th semicircle), but in control group these values gradually increased from 2nd to 4th semicircle. Surface pressure was the only parameter that was stabilized early after 1st semicircle for both groups. The 2nd semicircle was turnover point after which experimental and control group showed opposite trends to the end of tracing task (for all kinematic parameters values except for pressure).

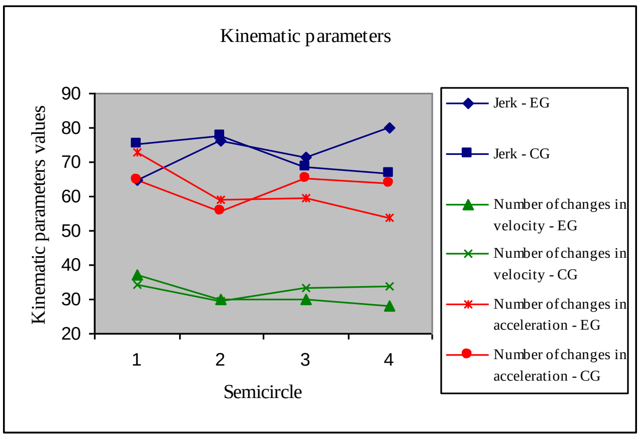

Fig.2A. Graphic representation of jerk, number of changes in velocity and acceleration through task progression (EG – experimental group, CG – control group). Mean values are presented.

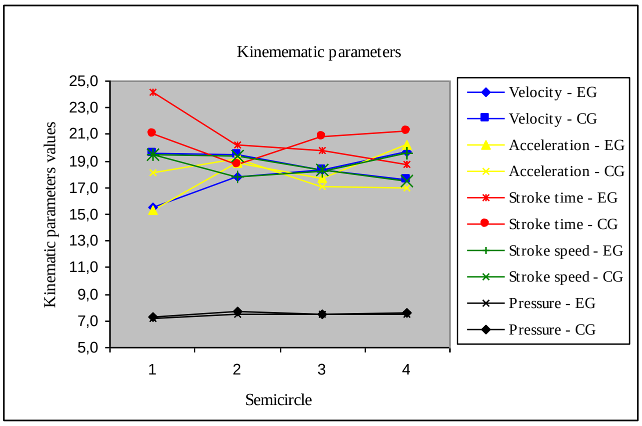

Fig.2B. Graphic representation of velocity, acceleration, stroke time, stroke speed and pressure through task progression (EG – experimental group, CG – control group). Mean values are presented.

IV. Discussion

According to the previous studies of handwriting, regarding handedness of subjects, graphic rules and type of task (semicircles resemble letters *c*, *n*, part of letter *b* or *p* and *u* respectively) it is predicted for the right-handed subjects to favor tracing semicircles by starting at the top and move downward and from left to right [9, 11]. Thus, the predicted movements for 1st and 4th semicircle would be in counterclockwise direction and for the 2nd and 3rd semicircle in clockwise direction [11].

In our study subjects fulfilled exceptions from predicted movements, especially during the first attempt, for the 1st, 2nd and 3rd semicircle in both groups, as reported previously [11]. However, percentage of non-preferred movement usage decreased with repetition of the task in both groups. This result can be explained that children favor more comfortable movements regarding energy saving during the process of learning and adaptation to the writing movements [8, 9, 13]. The largest percentage of non-preferred movement in the first attempt can also be explained with the lack of visual guidance during tracing task when stylus did not result in the trace on digitizing board surface. Visual feedback during writing is important, especially for young children who are learning to write, but in later age it becomes less important with automation of writing [13]. According to the literature, handwriting automation occurs between 8 and 11 years of age [14]. The majority of our subjects fall within this age group, so we can assume that their writing is almost fully automated.

None of the subjects in our study receded from graphic rules and predicted movement in the 4th semicircle in neither repetition (see Table I). This is in contrast with earlier research results [11]. This difference can be explained with the fact that 4th semicircle resembles small cursive script for the Cyrillic letter "*i*" (*u*). This letter is connected with other letters from left to right during writing (in Serbian language writing is from left to right). In addition, majority of our subjects prefer cursive script Cyrillic during writing.

Earlier research of handwriting in children with ADHD revealed that writing difficulties associated with attention problems are the consequence of both impaired graphemic buffer and kinematic motor production, and that they are not of linguistic nature [7]. In this regards the kinematic analysis of handwriting in ADHD could be considered as an assessment tool for attention, too.

Subjects with ADHD (experimental group) showed increment in mean values from 2nd to 4th semicircle for velocity, acceleration, stroke speed and jerk and decrement in stroke time, NCA and NCV from 1st to 4th semicircle (Fig.2). Control group showed opposite trends for these kinematic parameters. Regarding handwriting quality writing of children with ADHD become more fast, smoothed and more automated with time [15]. Albeit semicircle tracing was relatively simple task, with no particular accuracy demands, this result is opposite to earlier researches which suggest that children with ADHD write slower and more inaccurate than on average developed children [16, 17]. This can be explained with no accuracy demands and the lack of visual feedback, so speed-accuracy trade-off was minimal and the lack of error monitoring was not evident (characteristic of children with ADHD [17]), respectively. Also we found no significant difference between groups in the axial pressure, while the fact that children with ADHD showed its stabilization after the 1st semicircle, is opposite to the results from the literature [16, 17].

V. Conclusion

In our study children with ADHD do not deviate significantly from graphic rules compared to the control group. According to the analyzed kinematic features in the task where requirements for accuracy are insignificant, children with ADHD write faster and smoother from the 2nd to 4th semicircle, which is in contrast with control group of TDC. We must emphasize that the sample size in this study was small and all results need to be reinforced with further research on a greater sample, including female subjects. Question "whether lack of attention and lack of error monitoring are disadvantageous in all the situations" stays still open.

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