Copy of geometric drawings in children from 4 to 6 years old: a kinematic analysis

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Abstract. The acquisition and development of prerequisites for writing, in preschool age, is essential, as are copy drawings. Objective: To study the relationship between different kinematic variables (process) in children between 4 and 6 years old. Methodology: A cross-sectional observational study was carried out, with a descriptive and correlational research. 110 children participated in the study, 42 children aged 4 years, 44 aged 5 years, and 24 aged 6 years. Results: Process variables vary according to age and drawings, but in some situations in a heterogeneous way. Conclusion: The analysis of the process of copy drawings provides more detailed information about the handwriting readiness of each child. Its relevance in preschool age is significant, as it can lead to a preventive action, whether diagnostic or intervention. It is important, that in the future children with graphomotor difficulties could be included in the sample to help us to define their graphomotor characteristics.

1. Introduction

Learning to write is an important factor not only for self-esteem, as well as for the child's academic success, with handwriting playing an important role, as it can be seen as a reflection of the child's individual abilities (Feder & Majnemer, 2007). The learning process of handwriting is a lengthy process, which results from the efficient development of a variety of cognitive processes and skills, such as visual perception, spatial orientation, motor coordination, manual dexterity, which begins with drawing, and spontaneous scribbling (Albaret & Santamaria, 1996; Feder & Majnemer, 2007; Payne & Isaacs, 2012). The process of learning handwriting has particular importance in the child's holistic development, since the child spends a lot of time at school on tasks that require handwriting skills. Children of the age of 2 start with scribbling and subsequently circular movements, drawing spirals, and immediately following imitating geometric shapes, namely, vertical lines, horizontal lines, and circles. After acquiring this competence, the child begins to combine simple drawings creating more complex drawings, with greater precision (Beery & Beery, 2006; Feder & Majnemer, 2007; Payne & Isaacs, 2012).
The ability to copy pictures will give the child a greater probability of success in the handwriting learning process (Beery & Beery, 2006; Weil & Amundon, 1994) while lacking this ability is an important part of early dysgraphia detection (Devillaine et al., 2021).

In a kinematic analysis, data can be organized into three dimensions: a) temporal, such as duration and reaction time (i.e., the latency between the stimulus onset and the beginning of the movement); b) ~~,~~ kinematics, such as the speed of the trace, pen pressure, and the degree of movement automation, through the different segments; and c) the spatial dimension, namely the vertical and horizontal stroke dimensions (Teulings & Schomaker, 1993; Accardo et al., 2013; Lin et al., 2015). This analysis becomes suitable as a complementary test as it allows differentiating between tracing patterns that show in a superficial analysis of the static product no perceptible differences but allow a more detailed analysis when inspecting the kinematics (Rosenblum, Weiss, & Parush, 2004).

Accardo et al. (2013) found that in the drawing of horizontal lines the speed increased with the level of education, while for the vertical lines, the speed remained constant across the years of schooling. As previously mentioned, the focus of this study is the pre-writing phase, since few studies were carried out with a focus on graphomotor skills, using a visual-motor integration test.

2. Methods

2.1. Participants

In the present study, 110 children participated in 3 age groups: 4-, 5-, and 6-year-old (Table 1). They were recruited through contact with several colleges and private institutions in the western Algarve region. Exclusion criteria were children with neurological injuries (e.g., cerebral palsy, epilepsy); psychiatric disorders; behavioral disorders; problems of hearing and vision; referral to Special Education services.

Table 1. The 3 age groups of the participants.

Age (y)	Age range (months)	N	#Boys	#Girls
4	55.55±0.45	42	18 (43%)	24 (57%)
5	66.32±0.57	44	21 (48%)	23 (52%)
6	75.92±0.51	24	10 (42%)	14 (58%)
All	64.3±8.4	110	49 (45%)	61 (55%)

2.2. Approach and procedure

The nine drawings that are part of Beery's visual-motor integration development test (Beery & Beery, 2006) (See Figure 1, Drawings 7 to 15) were copied by each child. Movements were recorded using an inking pen on a x-y digitizing tablet that was cover by a sheet of paper and that was connected via USB to a MS Windows laptop computer running MovAlyzeR® software (version 6.1, NeuroScript, LLC; Tempe, AZ, USA). The tablet had an active surface area of 32.51 cm x 20.32 cm, a device resolution of .0005 cm and a sampling frequency of 100 Hz.

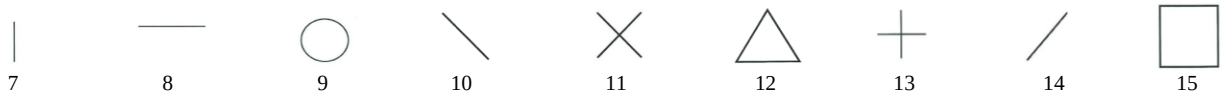


Figure 1. Drawings 7 to 15 copied from Beery & Beery (2006)

2.3. Extracted features

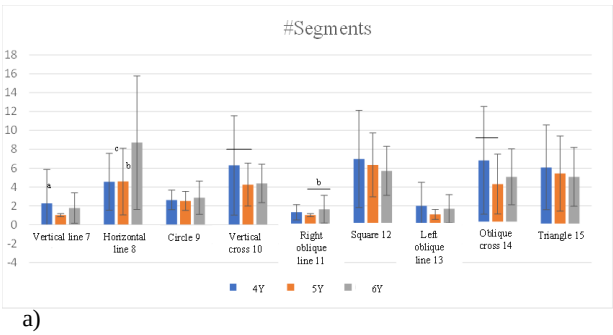
In the present study we focused on the following variables: a) number of segments (i.e., total number of strokes that the child performs to draw a figure); b) reaction time (i.e., the time interval between the stimulus and the beginning of the trace, measured in seconds); c) duration (i.e., the time interval between the first instant of the first segment, and the last instant of the last segment, in seconds); and d) axial pen pressure (i.e., the average value of the force in tablet units exerted on the paper) (NeuroScript, 2016).

2.4. Statistics

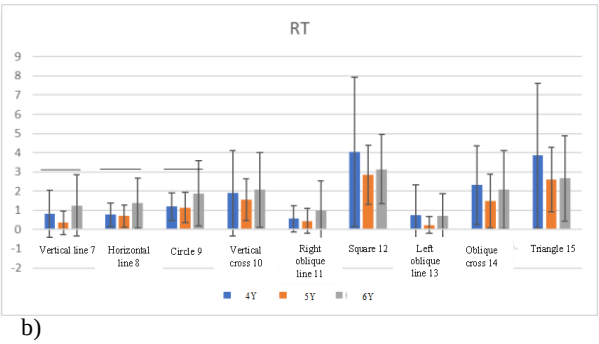
Comparative analysis between the age groups, the ANOVA test was used, with a Bonferroni post-test. The relationship between the variables was established, through Pearson correlations for the 4- and 5-year-olds and Spearman correlations for the 6-year-olds. The significance value taken into account in the present study was $p<0.05$.

3. Results

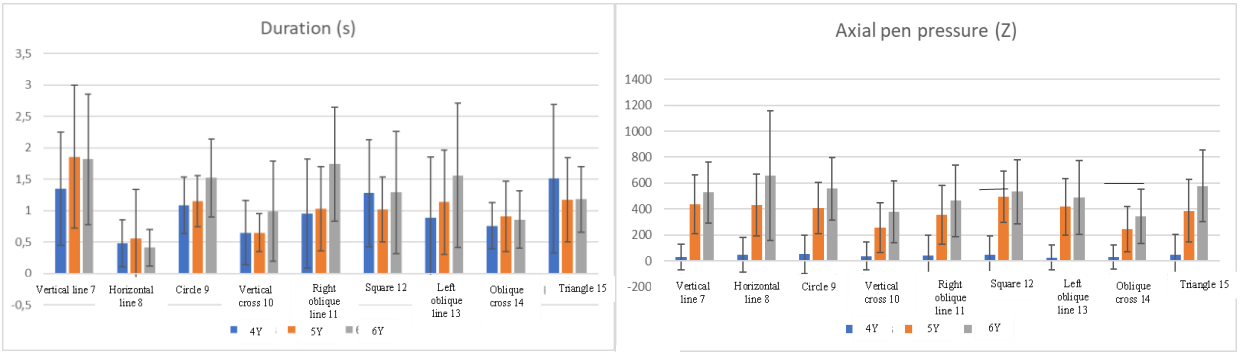
At the level of product analysis in the copy of the 9 VMI drawings, in the 4-year-olds group, none of the drawings were copied with 100% success, whereas in the 5 and 6-year-olds group in the simpler drawings (like the vertical line, horizontal, and circle) the success rate was 100%. At the level of process variables, it can be observed its progress across ages (figure 2).



a)



b)



c) d)

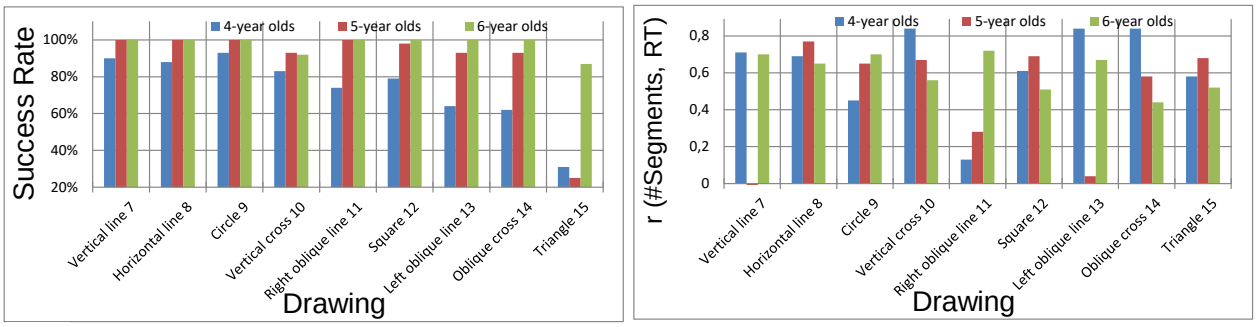
Figure 2. Characterization of the variables number of segments (a), reaction time (b), duration (c) and axial pen pressure, by age

[a] significant difference between the 4 and 5-year-olds group, $p<0.05$

[b] significant difference between the 5 and 6-year-olds group, $p<0.05$

[c] significant difference between the 4 and 6-year-olds group, $p<0.05$

The number of segments and reaction time are correlated: the longer the reaction time, the greater the number of segments to copy a drawing. This holds within each of the age groups and within each of the drawings. As previously mentioned, the number of segments per drawing is an indication that the drawing pattern is not internalized in the child (Accardo et. al, 2013), i.e., a greater number of segments corresponds to a drawing pattern less automated and internalized, so it is expected that the reaction time that the child needs to plan the drawing will increase.



a) b)

Figure 3. Success rate (a) and the correlation r between the number of segments and the reaction time to start copying (b) for the Drawings 7 to 15 copied from Beery & Beery (2006). Correlation higher than 0.44 were significant (p<0.05).

4. Discussion

Even though a figure was copied "correctly", it is noticeable through the analysis of the process variables that there are several factors that will need further analysis. This confirms the relevance of this type of process analysis as mentioned before by Rosenblum et al. (2004), as it will allow distinguishing, differentiating, and analyzing aspects that are not visible by observing of the result, in this case, the copy of the figure.

5. Conclusions

We found that the number of segments and reaction time are significantly correlated. It seems as if the children either prepare a drawing pattern for a longer time during the reaction-time period and then will be able to produce the drawing in fewer strokes or start quicker with the drawing but then will need to program additional strokes during drawing.

To evaluate visuomotor performance we should not only examine the product but also the process. The analysis of the process of copying drawings provides more detailed information about the handwriting readiness of a child. Its relevance in preschool age is significant, as it can provide early signs that preventive action by

diagnostic or intervention should be done. In the future we will also examine children with graphomotor difficulties to help us to better define their graphomotor characteristics.

References

Accardo, A. P., Genna, M., & Borean, M. (2013). Development, maturation and leaning influence on handwriting kinematics. *Human Movement Science, Human movement science, 32,* 136-146.

Albaret, J.-M., & Santamaria, M. (1996). Utilisation des digitaliseurs dans l'étude des caractéristiques motrices de l'écriture. *Evolutions Psychomotrices (Paris), 33*, 115-119.

Athènes, S., Sallagoity, I., Zanone, P.-G., & Albaret, J.-M. (2004). Evaluating the coordination dynamics of handwriting. *Human Movement Science, 23*, pp. 621-641.

Beery, K. E., & Beery, N. A. (2006). Beery VMI - Administration, Scoring and Teaching Manual 5th Edition. Pearson.

Devillaine, L.; Lambert, R.; Boutet, J.; Aloui, S.; Brault, V.; Jolly, C.; Labyt, E. (2021). Analysis of Graphomotor Tests with Machine Learning Algorithms for an Early and Universal Pre-Diagnosis of Dysgraphia. *Sensors, 21,* 7026. https://doi.org/10.3390/s21217026

Feder, K. P., & Majnemer, A. (2007). Handwriting development, competency, and intervention. *Developmental Medicine, Child Neurology, 49*(4), pp. 312-317.

Kaiser, M.-L., Albaret, J.-M., & Doudin, P.-A. (2007). Relationship between visual-motor integration eye-hand coordination, and quality of handwriting. *Journal of Occupational Therapy, Schools & Early Intervention, 2*(2), pp. 87-95. doi:10.1080/19411240903146228

Kambas, A., Fatouros, Y., Christoforidis, C., Venetsanou, F., Papageorgiou, P., Giannakidou, D., & Aggeloussis, N. (2010). The effects of psychomotor intervention, on visual-motor control as a graphomotor aspect in preschool age. *European Psychomotricity Journal, 3*(1), pp. 54-61.

Lin, Q., Luo, J., Wu, Z., Shen, F., & Sun, Z. (2015). Characterization of fine motor development: Dynamic analysis of children's drawing movements. *Human Movement Science, 40*, pp. 163-175.

MacDonald, M., Lipscomb, S., McClelland, M. M., Duncan, R., Becker, D., Anderson, K., & Kile, M. (2016). Relations of preschoolers' visual-motor and object manipulation skills with executive function and social behavior. *Research Quarterly for Exercise and Sport, 87,* 396-407. doi:10.1080/02701367.2016.1229862

Marr, D., Cermak, S., Cohn, E. S., & Henderson, A. (2003). Fine motor activities in head start and kindergarten classrooms. *American Journal of Occupational Therapy, 57*(5), pp. 550-557.

NeuroScript. (2016). NeuroScript.net/movalyzer. Retrieved from NeuroScript.net: https://www.neuroscript.net/movalyzer.php

Payne, V. G., & Isaacs, L. D. (2012). *Human Motor Development.* Mc Graw Hill - Connect Learn Succeed.

Rosenblum, S., Weiss, P. L., & Parush, S. (2004). Handwriting evaluation for developmental dysgraphia: process versus product. *Reading and writing: An interdisciplinary journal, 17,* 433-458.

Teulings, H.-L., & Schomaker, L. R. (1993, outubro). Invariant properties between stroke features in handwriting. *Acta Psychologica, 82(1-3),* 69-88.

Weil, M. J., & Amundson, S. J. (1994, dezembro). Relationship between visuomotor and handwriting skills of children in kindergarten. *The American Journal of Occupational Therapy, 48,* 982-988.

Wicki, W., Lichtsteiner, S. H., Geiger, A. S., & Muller, M. (2014). Handwriting fluency in children. *Swiss Journal of Psychology, 73* (2), pp. 87-96.