ESTUDOS EM DESENVOLVIMENTO MOTOR DA CRIANÇA XVI

MOTOR DEVELOPMENT STUDIES OF THE CHILD XVI

Eds.

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EDIÇÕES ISMAI

O XVIII Seminário do Desenvolvimento Motor em Crianças (XVIII SDMC) procura, assim, abordar questões práticas e refletir sobre aspetos conceptuais para que os especialistas deste ramo do saber estejam bem preparados para enfrentar os problemas da aprendizagem, do desenvolvimento e do controle motor.

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UNIVERSIDADE DA MAIA

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Edição Centro de Publicações / Universidade da Maia
Centro de Investigação em Desporto, Saúde e Desenvolvimento Humano [UID/04045/2020]

Coordenação Editorial Pedro Almiro Neves
Eduardo Cordeiro Gonçalves

Apoio Fundação para Ciência e a Tecnologia FCT

Design/Execução Grafhic Production

Tiragem 150 exemplares

Depósito legal 523998/23

ISBN 978-989-53655-5-5

ANO DE EDIÇÃO NOVEMBRO DE 2023

FINE MOTRICITY IN FINGER TAPPING TEST WITH CHILDREN: VARIABILITY ANALYSIS WITH LYAPUNOV EXPONENT

MOTRICIDADE FINA NO TESTE DE BATIDAS DO DEDO COM CRIANÇAS: ANÁLISE DA VARIABILIDADE COM EXPOENTE DE LYAPUNOV

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Abstract

Recent advancements in nonlinear methodologies have allowed deeper analysis of motor control during development. This study aimed to analyse the evolution of the fine motor skills in children aged 6 to 9 years old through the Lypaunov Exponent (LyE). It was asked to 60 children (M=8,141±1,064 years) to perform the finger taping test, 6 trials in each hand, starting with their preferred one. An inertial sensor was attached to the index finger to collect three-dimensional angular velocity. The LyE values were calculated per child, hand, and movement axis. The results highlighted a notable distinction between the 6- and 7-year-old and the 8- and 9-year-old, aligned with the different phases of motor development. The older ones presented higher variability, which can reflect their greater proficiency in this fine motor task, due to their extensive practice at school context. LyE analysis seems to be sensitive to changes that occur during different phases of motor development.

Keywords: Dynamic systems; variability; motor development; fine motricity; finger taping test.

Resumo

Recentes avanços nas metodologias não lineares permitiram uma análise mais profunda do controlo motor durante o desenvolvimento. Este estudo teve como objetivo analisar a evolução da motricidade fina em crianças dos 6 aos 9 anos de idade através do Expoente de Lyapunov (LyE). Foi pedido a 60 crianças (M=8,141±1,064 anos) que realizassem o teste de batidas do dedo, 6 tentativas em cada mão, começando pela sua preferida.

Foi colocado um sensor inercial no dedo indicador para recolher a velocidade angular tridimensional. Valores de LyE foram calculados por criança, mão e eixo de movimento. Os resultados evidenciaram uma distinção notável entre as crianças de 6 e 7 anos e as de 8 e 9 anos, o que está de acordo com as diferentes fases de desenvolvimento motor. Os mais velhos apresentaram maior variabilidade, o que pode refletir a sua maior proficiência nesta tarefa motora fina, devido à sua prática extensiva no contexto escolar. A análise de LyE parece ser sensível às mudanças que ocorrem durante as diferentes fases do desenvolvimento motor.

Palavras-chave: Sistemas dinâmicos; variabilidade; desenvolvimento motor; motricidade fina; teste de batidas do dedo.

INTRODUCTION

Motor development and learning can be differently understood through the lens of the dynamic systems theory, which views the individual as a complex dynamic system constantly evolving through the interaction (e.g., experiences, learning) with the environment (1). Human growth and motor development are unique, complex and phased processes, being always influenced by the child's environment. During the early phases of development, specifically in elementary teaching, the school environment encourages frequent practice of fine motor skills, such as drawing, tracing, and writing. Therefore, studying the progression of fine motor skill tasks during this period would be insightful. Recent advancements in nonlinear measures have allowed for a deeper analysis of motor control, namely during development, with a specific focus on the process and quality of movement (2). One of these measures is variability. Variability is a characteristic inherent to the human movement system, supporting the exploration of different motor solutions involving various system elements (e.g., motor units, muscles, joints, limbs, movement axis and planes) to execute tasks effectively and adapted to the surrounding environment (3). The largest Lyapunov Exponent (LyE) is a reliable nonlinear technique to access variability. It measures the rate of how the orbits converge or diverge within the system. A periodic signal would have a LyE equal to 0, a positive value indicates diverging orbits, and a negative value suggests converging orbits (4). In this sense, the present study aimed to analyse the evolution of the fine motor skills, namely its variability, between 6 and 9 years old, through LyE.

METHODOLOGY

Sample

Sixty children, aged 6 to 9 years, participated in the study (M=8,141±1,064 years; 6 years=12, 5♀; 7 years=19, 10♀; 8 years=14, 4♀; 9 years=15, 6♀). Informed consent and assent were obtained.

Procedures and Instruments

The finger tapping test (FTT) was applied, with hand resting on a stable table, to perform as many taps as possible with index finger for 10 seconds (5, 6). Each participant performed 6 trials per hand, starting with the preferred hand, the one used for writing. To collect three-dimensional (3D) angular velocity, operated through a specific program designed for this purpose, was used a custom inertial sensor (IMU), MEMS, model MPU9250, placed over the distal phalanx of the index finger and secured by a rubber finger (Figure 1).

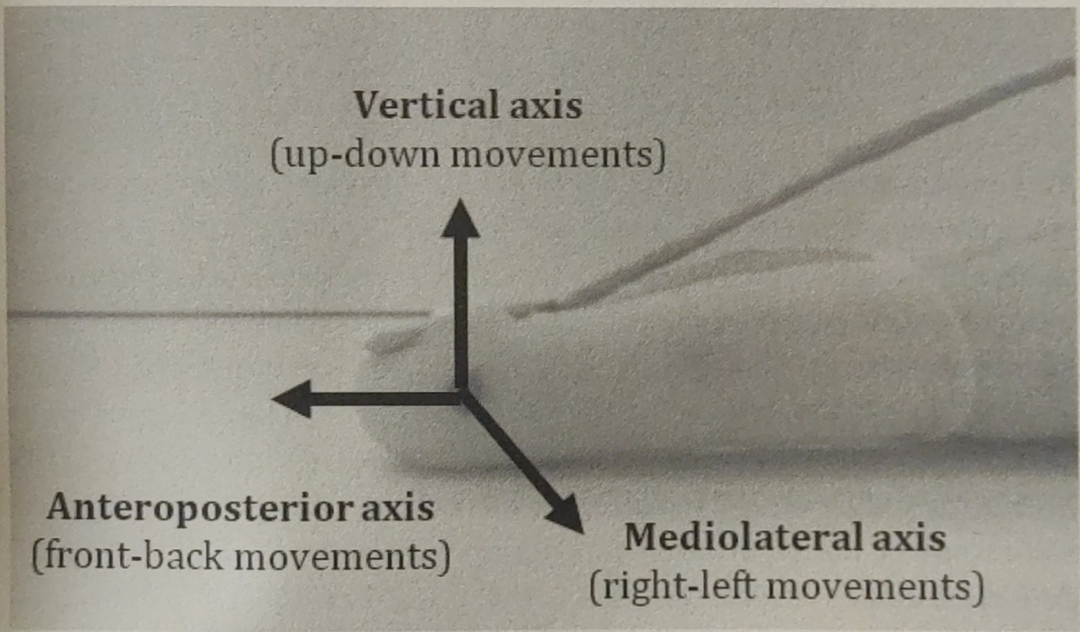

Figure 1. Illustrative image of the sensor placement and movement axes.

Data and Statistical Treatments

The LyE values were calculated based on the angular velocity per child, hand and axis, through Wolf's logarithm, in a customized Matlab routine (7). Statistical treatment made with IBM-SPSS, version 24. Normal distribution was tested and not assumed. Non-parametric tests were performed for comparison between all ages, in hands and axes (Kruskall-Wallis- H), between paired ages for the same variables

(Mann-Whitney- U) and, within the same age between hands (Wilcoxon- Z), with effect sizes estimations (*r*) for significant differences; for significance value of 0.05.

RESULTS

Comparisons between ages

For the entire sample, differences occurred in all LyE values across mediolateral (ML), anteroposterior (AP) and vertical (V) axes; and, for preferred and non-preferred hands (Table 1).

Table 1. Statistical values of LyE for ML, AP and V axis, per hand and age; and for comparison between ages (H).

Hand	Axis	6	7	8	9	Test Statistics	
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	H	Sig.
Preffered	ML	5,546±1,495	5,640±1,560	7,164±2,045	7,479±2,107	70,596	0.001
	AP	7,159±7,252	6,628±4,979	7,884±7,905	8,122±5,933	14,146	0.003
	V	5,993±2,837	5,420±2,655	7,160±2,470	9,346±6,844	51,500	0.001
Non-preffered	ML	4,905±1,247	4,945±1,496	6,464±1,761	6,464±1,596	85,422	0.001
	AP	6,492±6,296	5,580±3,594	8,611±9,319	7,971±5,793	18,048	0.001
	V	4,969±3,455	4,535±2,175	7,034±4,516	6,273±2,876	41,399	0.001

When paired ages were compared, the 6- and 7-year only differed significantly in the preferred hand for the vertical axis (U=3369, Z=-2.055, p=0.040, r=-0.151), while the 8- and 9-year did not differ significantly in any hand or axis. Participants from the 6-year-old, when compared with those from the 8- and 9-year-old, in the preferred hand, revealed significantly less variability in the ML axis (U=1465, Z=-5,542., p<0.001, r=-0.444; U=1492, Z=-5.892, p<0.001, r=-0.463, respectively), in the AP axis (only with 9-years, Z=-3.330, p=0.001, r=-0.262), and in the V axis (U=2105, Z=-3.267, p=0.001, r=-0.262; U=2071, Z=-3.940, p<0.001, r=-0.310, respectively); the same tendency was observed in the non-preferred hand for the ML axis (U=1231, Z=-6.304, p<0.001, r=-0.506; U=1192, Z=-6.903, p<0.001, r=-0.542), AP axis (U=2424, Z=-2.023, p<0.001, r=-0.163; U=2454, Z=-2.649, p=0.008, r=-0.208), and V axis (U=1794, Z=-4.284, p<0.001, r=-0.163; U=2046, Z=-4.025, p<0.001, r=-0.316). The same pattern of differences was found between the 7-year-old with the 8- and 9-year-old. In the preferred hand, the 7-years revealed significantly lower variability for the ML axis (U=2515, Z=-5.704, p<0.001, r=-0405.; U=2473, Z=-6.346, p<0.001, r=-0.444), AP axis (only with 9-years-old, U=3837, Z=-3.088, p=0.002, r=-0.216), and V axis (U=2678, Z=-5.295, p<0.001, r=-0.376; U=2532, Z=-6.206, p<0.001, r=-0.434); the same tendency was also observed in the non-preferred hand for the ML axis

(U=2277, Z=-6.148, p<0.001, r=-0.439; U=2283, Z=-6.739, p<0.001, r=-0.473), AP axis (U=3526, Z=-2.965, p=0.003, r=-0.212; U=3568, Z=-3.648, p<0.001, r=-0.256), and V axis (U=, Z=-., p<0.00, r=-0.; U=3135, Z=-4.714, p<0.001, r=-0.331).

Comparisons between hands, within the same age

Several significant differences in LyE values were found between hands, with the preferred hand showing greater variability than the non-preferred (Table 2).

Table 2. Comparison of LyE values between hands (Z), per age.

Group	Axis	Preffered	Non-preffered	Test Statistics		
		Mean±SD	Mean±SD	Z	Sig.	Effect size
6	ML	5,546±1,495	4,905±1,247	-3.176	0.001	-0.374
	V	5,993±2,837	4,969±3,455	-3.395	0.001	-0.400
7	ML	5,640±1,560	4,945±1,496	-3.852	0.001	-0.361
	AP	6,628±4,979	5,580±3,594	-2.308	0.021	-0.216
8	ML	7,164±2,045	6,464±1,761	-2.606	0.009	-0.284
9	ML	7,479±2,107	6,464±1,596	-3.619	0.001	-0.381
	V	9,346±6,844	6,273±2,876	-4.05	0.001	-0.427

DISCUSSION

The presence of significant differences between ages, in all movement's axes, reflects the sensitivity of the LyE technique in the variability's analysis for this fine motor task. When we analyse these differences between paired ages in more detail, a clear distinction between the 6 and 7 years with the 8 and 9 years is detected (Tables 1-2). This age-grouping of variability's data fits over the phases of motor development. Some authors argue that 2nd childhood, the fundamental motor development phase, takes place between 2 and 6/7 years old; followed by 3rd childhood, the next phase of specialization and combination of skills which ends at 9/10 years old (8). When looking at the 3rd childhood (8 -9 years), children become more variable, i.e., presents positive and higher LyE values, especially in their preferred hand. In more traditional theories, the variability was seen as error or noise. Nevertheless, presently, it is seen as an crucial part of the system's developmental dynamics (2). Considering that the LyE value can also be interpreted as the system's ability or inability to adapt to the environment and task (9), this greater variability in the older ages may reflect their greater proficiency in this fine-motor task. This could be attributed to their extensive practice within the school context, leading them to explore a wider range of motor solutions when faced with the FTT task, i.e., to perform as many touches as possible during the 10 seconds. This hypothesis is further supported by the fact that the preferred hand, which is used for writing and dominates in fine motor skills tasks, exhibited greater variability compared to the non-preferred hand, both within and across all ages.

CONCLUSION

The present results highlighted the potential for analysis of fine motor skills during growth using FTT and variability's nonlinear methods. The LyE seems to be sensitive to changes in the phases of motor development.

Funding

The work of Cristiana Mercê and Marco Branco was partly supported by the Portuguese Foundation for Science and Technology under Grant UIDB/00447/2020 to CIPER – Centro Interdisciplinar de Estudo da Performance Humana (unit 447). David Catela received partial support from the Portuguese Foundation for Science and Technology. UIDP/04748/2020 - under Grant UIDB/04748/2020 to CIEQV - Centro de Investigação em Qualidade de Vida.

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