

# ESTUDOS EM DESENVOLVIMENTO MOTOR DA CRIANÇA XVI

MOTOR DEVELOPMENT  
STUDIES OF THE CHILD XVI



Eds.

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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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# RECURRENCE QUANTIFICATION ANALYSIS DURING THE FINGER TAPPING TEST IN CHILDREN OF THE PRIMARY SCHOOL

## ANÁLISE DA QUANTIFICAÇÃO DA RECORRÊNCIA DURANTE O TESTE DE BATIMENTO DOS DEDOS EM CRIANÇAS DO PRIMEIRO CICLO DO ENSINO BÁSICO

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### Abstract

The Recurrence Quantification Analysis (RQA), applied to fine motor skills in children, may be used to observe the behavior of the state of the child, which allows to study and understand the process that he/she is going through. This study aims to analyze the evolution of the fine motor skills between 6 and 9 years old. An inertial sensor was used to collect 3D data during FTT from 60 primary school children and was calculated Recurrence (REC) and Determinism (DET) of the collected time series. Results shows a decrease of REC and DET along ages and higher values in non-preferred hand. RQA shows great sensibility to evaluate fine motor skills and its visible an onset of differentiation between hands through these ages.

**Keywords:** Recurrence quantification analysis; FTT; children; fine motor skills.

### Resumo

A Análise de Quantificação de Recorrência (RQA), aplicada à motricidade fina em crianças, pode ser utilizada para observar o comportamento do estado da criança, o que permite estudar e compreender o processo pelo qual ela está a passar. Este estudo tem como objetivo analisar a evolução da motricidade fina entre os 6 e os 9 anos de idade. Um sensor inercial foi utilizado para recolher dados 3D durante a FTT de 60 crianças do ensino primário, e foi calculada a Recorrência (REC) e o Determinismo (DET) das séries temporais recolhidas. Os resultados mostram uma diminuição da REC e do DET ao longo das idades e valores mais elevados na mão não preferida. O RQA mostra uma grande

sensibilidade para avaliar a motricidade fina e é visível um início de diferenciação entre mãos ao longo das idades.

**Palavras-chave:** Análise de quantificação de recorrência; FTT; crianças; habilidade motora fina.

## INTRODUCTION

The Recurrence Quantification Analysis (RQA) is a dynamical technique used to study patterns in behavioral science data (1). A system is considered dynamical if it behaves deterministically, meaning that we can predict its state based on its initial conditions (2). From the perspective of lifespan motor development, the human being can be considered a dynamic system, due to the ability to adapt motor tasks to achieve a goal, regardless of their organic level (growth, maturation, etc.), the external environment, and/or the motor skill they perform, i.e., the initial conditions (3, 4). In this sense, we wonder whether the patterns of fine motor skills change in children during the Primary School, considering that they are in an environment where the practice of this type of motor skills is regularly trained, among others, e.g., through writing and drawing. The objective of this study is to analyze the evolution of the fine motor skills between 6 and 9 years old through RQA, having as reference the non-preferable hand.

## METHODOLOGY

### Sample

Sixty children of which 12 6-year-olds, 19 7-year-olds, 14 8-year-olds, and 15 with 9-year-old (Table 1). Informed consents and assents were obtained. Collections were made in school context.

Table 1. Sample characterization of body mass and height per age group.

	Body Mass	Height
Age 6	28,07±6,49 Kg	122,94±4,83 Cm
Age 7	26,85±3,08 Kg	126,78±3,59 Cm
Age 8	29,51±4,11 Kg	132,13±6,59 Cm
Age 9	35,95±10,80 Kg	134,28±6,93 Cm

### Task, Procedures and Protocols

To assess fine motor skills was used the Finger Tapping Test (FTT) protocol (5), which is described as a test of motor speed, and consists in performing the maximum number of taps in a surface during, at least, five periods of 10 seconds.

with both hands. To assess the movement of the fingers, a small inertial sensor was placed on the tip of the second finger, collecting 3D angular velocity at a sample rate of 160Hz.

### Data Processing

A custom-based MatLab routine was prepared to proceed with data analysis of the collection files. Raw angular velocity data were filtered with a 4<sup>th</sup> order Butterworth digital lowpass filter, at 30Hz cutoff frequency. To calculate recurrence rate (REC) and determinism rate (DET) of the time series, the delay and the number of embedding dimensions were computed through pre-existing routines (6). Kruskal-Wallis and U-Mann-Whitney test were used to compare ages and Wilcoxon test were used to compare hands.

### RESULTS

In general, the REC decreases over the ages, especially with the execution of FTT with the preferred hand, having statistical differences for sagittal and frontal planes. Considering the non-preferred hand, a more variable behavior is visible, maintaining statistical differences for the frontal and transverse plane between most age groups, and only with differences between the 6- and 9-year-old group for the sagittal plane (Table 2).

Table 2. Descriptive and inferential statistics of REC between groups of age, per hand and plane of motion.

	Group	Mean	St-Dev	Min	Max	Dif. to which ages
<b>Preferred hand Sagittal Plane</b>	Age 6	0.430	0.328	0.102	2.799	U=2291;p=0.009 <sup>(6)</sup> U=1687;p=0.000 <sup>(9)</sup>
	Age 7	0.383	0.207	0.084	1.639	U=3851;p=0.019 <sup>(6)</sup> U=2878.5; p=0.000 <sup>(9)</sup>
	Age 8	0.356	0.284	0.064	2.165	U=2291;p=0.009 <sup>(6)</sup> U=3851;p=0.019 <sup>(7)</sup> U=2873; p=0.006 <sup>(9)</sup>
	Age 9	0.254	0.108	0.068	0.637	U=1687;p=0.000 <sup>(6)</sup> U=2878.5; p=0.000 <sup>(7)</sup> U=2873; p=0.006 <sup>(8)</sup>
<b>Preferred hand Transverse Plane</b>	Age 6	0.179	0.317	0.026	2.819	
	Age 7	0.139	0.148	0.026	1.042	
	Age 8	0.143	0.203	0.025	1.882	
	Age 9	0.132	0.109	0.021	0.444	

	Group	Mean	St-Dev	Min	Max	Dif. to which ages
Preferred hand Frontal Plane	Age 6	0.284	0.322	0.039	2.438	U=2752;p<0.001 <sup>(7)</sup> U=2002;p<0.001 <sup>(8)</sup> U=1897;p=0.000 <sup>(9)</sup>
	Age 7	0.181	0.167	0.035	1.193	U=2752;p<0.001 <sup>(6)</sup> U=4287;p=0.044 <sup>(7)</sup>
	Age 8	0.187	0.218	0.030	1.853	U=2002;p<0.001 <sup>(6)</sup>
	Age 9	0.152	0.123	0.023	0.642	U=1897;p=0.000 <sup>(6)</sup> U=4287;p=0.044 <sup>(7)</sup>
Non-Preferred hand Sagittal Plane	Age 6	0.447	0.423	0.159	2.898	U=2592;p=0.029 <sup>(6)</sup>
	Age 7	0.385	0.363	0.122	3.474	
	Age 8	0.437	0.692	0.056	6.020	
	Age 9	0.710	2.543	0.055	25.347	U=2592;p=0.029 <sup>(6)</sup>
Non-Preferred hand Transverse Plane	Age 6	0.159	0.230	0.040	1.839	U=1917;p<0.001 <sup>(8)</sup> U=2303;p=0.002 <sup>(9)</sup>
	Age 7	0.124	0.154	0.019	1.391	U=3690;p=0.011 <sup>(8)</sup>
	Age 8	0.203	0.682	0.027	5.113	U=1917;p<0.001 <sup>(6)</sup> U=3690;p=0.011 <sup>(7)</sup>
	Age 9	0.164	0.392	0.026	3.649	U=2303;p=0.002 <sup>(6)</sup>
Non-Preferred hand Frontal Plane	Age 6	0.292	0.334	0.047	1.996	U=2341;p<0.020 <sup>(8)</sup> U=2536;p=0.018 <sup>(9)</sup>
	Age 7	0.241	0.272	0.044	2.512	
	Age 8	0.280	0.679	0.039	5.765	U=2341;p<0.020 <sup>(6)</sup>
	Age 9	0.476	1.658	0.037	14.438	U=2536;p=0.018 <sup>(6)</sup>

DET presents great amount of differences between ages, usually with higher values of determinism in 6 years group and lower values for 9 years group for both hands. The analysis of REC for task execution between the two hands, shows differences in 9 years group regarding flexion/extension of the finger ( $Z=-3.394$ ,  $p<0.001$ ); in 8 years group regarding the rotation of the finger ( $-2.101$ ,  $p<0.02$ ), and in 7 years group regarding the adduction/abduction of the finger ( $-2.259$ ,  $p<0.02$ ), with higher values of recurrence rate in non-preferred hand (Table 3).

Table 3. Descriptive and inferential statistics of DET between groups of age, per hand and plane of motion.

	Group	Mean	Standard Deviation	Minimum	Maximum	Dif. to which ages
Preferred hand Sagittal Plane	Age 6	61.553	11.961	34.270	96.536	U=1872; p<0.001 <sup>(8)</sup> U=1381; p=0.000 <sup>(9)</sup>
	Age 7	63.458	11.313	35.038	92.491	U=2492; p=0.000 <sup>(8)</sup> U=1966; p=0.000 <sup>(9)</sup>
	Age 8	52.578	13.449	24.493	96.204	U=1872; p<0.001 <sup>(6)</sup> U=2492; p=0.000 <sup>(7)</sup> U=2893; p=0.008 <sup>(9)</sup>
	Age 9	47.185	13.408	18.245	78.841	U=1381; p=0.000 <sup>(6)</sup> U=1966; p=0.000 <sup>(7)</sup> U=2893; p=0.008 <sup>(8)</sup>
Preferred hand Transverse Plane	Age 6	36.875	19.038	2.389	91.755	U=1941; p<0.001 <sup>(8)</sup> U=2250; p=0.001 <sup>(9)</sup>
	Age 7	33.184	17.404	5.808	91.954	U=3392; p=0.000 <sup>(8)</sup> U=4229; p=0.031 <sup>(9)</sup>
	Age 8	25.428	17.390	3.254	91.839	U=1941; p<0.001 <sup>(6)</sup> U=3392; p=0.000 <sup>(7)</sup>
	Age 9	26.641	12.524	1.176	59.290	U=2250; p=0.001 <sup>(6)</sup> U=4229; p=0.031 <sup>(7)</sup>
Preferred hand Frontal Plane	Age 6	42.108	17.050	5.502	92.534	U=2325; p=0.013 <sup>(8)</sup> U=2104; p=0.000 <sup>(9)</sup>
	Age 7	41.476	16.032	12.598	93.420	U=2492; p=0.000 <sup>(8)</sup> U=3412; p=0.000 <sup>(9)</sup>
	Age 8	35.533	17.589	5.405	96.484	U=2325; p=0.013 <sup>(6)</sup> U=2492; p=0.000 <sup>(7)</sup>
	Age 9	31.637	13.369	2.756	81.516	U=2104; p=0.000 <sup>(6)</sup> U=3412; p=0.000 <sup>(7)</sup>
Non-Preferred hand Sagittal Plane	Age 6	65.184	11.190	44.472	98.668	U=2180; p=0.004 <sup>(8)</sup> U=1706; p=0.000 <sup>(9)</sup>
	Age 7	64.638	12.027	35.608	97.082	U=3728; p=0.002 <sup>(8)</sup> U=2862; p=0.000 <sup>(9)</sup>
	Age 8	59.205	13.093	22.517	98.235	U=2180; p=0.004 <sup>(6)</sup> U=3728; p=0.002 <sup>(7)</sup> U=2885; p=0.010 <sup>(9)</sup>
	Age 9	54.835	15.539	21.199	99.204	U=1706; p=0.000 <sup>(6)</sup> U=2862; p=0.000 <sup>(7)</sup> U=2885; p=0.010 <sup>(8)</sup>
Non-Preferred hand Transverse Plane	Age 6	41.832	18.967	11.015	95.985	U=1526; p<0.001 <sup>(8)</sup> U=1676; p=0.000 <sup>(9)</sup>
	Age 7	37.797	18.280	4.632	94.763	U=2867; p=0.000 <sup>(8)</sup> U=3146; p=0.000 <sup>(9)</sup>
	Age 8	26.967	18.002	3.236	98.457	U=1526; p<0.001 <sup>(6)</sup> U=2867; p=0.000 <sup>(7)</sup>
	Age 9	27.769	22.128	4.800	93.373	U=1676; p=0.000 <sup>(6)</sup> U=3146; p=0.000 <sup>(7)</sup>

	Group	Mean	Standard Deviation	Minimum	Maximum	Dif. to which ages
Non-Preferred hand Frontal Plane	Age 6	45.397	19.394	8.759	93.706	U=2232; p<0.007 <sup>(6)</sup> U=2522; p=0.016 <sup>(7)</sup>
	Age 7	44.229	18.272	9.399	94.294	U=3574; p=0.004 <sup>(8)</sup> U=4051; p=0.013 <sup>(7)</sup>
	Age 8	37.535	18.543	5.927	98.895	U=2232; p<0.007 <sup>(6)</sup> U=3574; p=0.004 <sup>(7)</sup>
	Age 9	38.970	20.731	7.824	97.717	U=2522; p=0.016 <sup>(6)</sup> U=4051; p=0.013 <sup>(7)</sup>

The comparison of the DET between in both hands reveals differences for 6- 8- and 9-years groups for sagittal plane (respectively,  $Z=-2.340$ ,  $p<0.02$ ;  $-3.845$ ,  $p<0.001$ ;  $-4.022$ ,  $p<0.001$ ), only for 7 years group in transverse plane ( $Z=-2.101$ ,  $p<0.05$ ), and only for 9 years group in frontal plane ( $Z=-2.662$ ,  $p<0.01$ ).

## DISCUSSION

The RQA applied to this task, aims to observe the behavior of the state of a system (child), which allows to study and understand the process that the system it's going through (7). Poincaré (8), when presenting the three-body problem, indicated that after a sufficiently long but finite time, the bodies revisited the same phase space. In this sense, the REC quantifies the repetition or return of an event, pattern, or behavior over time, which is a fundamental property of deterministic dynamical systems, and is a characteristic of nonlinear or chaotic systems (7). Because the body systems continue to evolve throughout the late childhood, in 9 years old the lower REC and DET observed may be due to greater motor efficiency, and therefore the defreezing of degrees of freedom. Consequently, RQA seems to be a sensitive indicator for the detection of system changes, since many differences between ages were found, specially, in DET values. Additionally, these differences allows to verify the possibility of two developmental subphases, namely between 6/7 years and 8/9 years of age, corroborating what has been pointed out by Cordovil and Barreiros (9) about 2nd and 3rd childhood. The few differences between hands point to greater care during execution with the non-preferred hand, especially at higher ages, revealing an onset of differentiation between hands, probably caused by greater specialization of hand of execution and hand of support, and ongoing maturation of neuromotor systems.

## CONCLUSION

The use of FTT to evaluate fine motor skills show great sensibility through RQA to detect changes during late child development. A significant decrease in the values of REC and DET shows a carefree execution of fine motor tasks, especially periodic ones as is the case of this task. An onset of differentiation between hands is detected especially in higher ages, which may be caused by greater execution of fine movements with preferred hand and support actions of the non-preferred hand, and ongoing maturation of neuromotor systems.

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