Article

Not peer-reviewed version

The Impact of COVID-19 in Brazil Through Educational Neuroscience Lens

Camila G. Fonseca , Camila Dias , Marcus L. L. Barbosa , Maria Julia Hermida , Luiz Renato R. Carreiro , Alessandra G. Seabra *

Posted Date: 25 March 2025

doi: 10.20944/preprints202503.1870.v1

Keywords: executive functioning; academic performance; reading; writing; Covid-19 pandemic

Article

The Impact of COVID-19 in Brazil Through Educational Neuroscience Lens

Camila G. Fonseca [1], Camila Dias [1], Marcus L. L. Barbosa [2], Maria Julia Hermida [3], Luiz Renato R. Carreiro [1] and Alessandra G. Seabra [1,*]

[1] Post-graduation Program in Human Development Sciences, CCBS - Mackenzie Presbyterian University, Rua da Consolação, nº 930, CEP: 01302-907, São Paulo – SP, Brazil

[2] Post-graduation Program in Cultural Diversity and Social Inclusion, Feevale University, ERS-239, 2755 | Novo Hamburgo, RS, Brazil - ZIP Code 93525-075

[3] Instituto de Educación, Universidad Nacional de Hurlingham, Vergara 2222, PC 1688, Provincia de Buenos Aires, Argentina

* Correspondence: alessandra.seabra@mackenzie.br

Abstract: Background: Educational neuroscience has made important contributions to show how the Covid-19 pandemic impacted schooling. In countries like Brazil, with significant educational inequality, the suspension of in-person classes worsened these disparities, as low-income families faced difficulties accessing remote learning. **Methods:** This study evaluated executive functions (EF) and academic skills in reading, writing, and math for 178 public school students from 1st to 9th grade in São Paulo, Brazil, comparing them with pre-pandemic norms to assess possible differences. EF were assessed using the Hayling Test, Digit Span Task, and Verbal Fluency, while academic skills were measured by the School Performance Test II. To analyze differences between the sample of this study and the pre-pandemic normative samples, one-sample t-tests were performed. Due to the small sample size, segmented by school grade and age, the bootstrapping resampling method was used, and the effect size was measured with Cohen's d. **Results:** A one-sample *t*-test showed significant differences between times, with lower post-pandemic performance in verbal fluency (9 to 14 years old), working memory (10 to 14 years old), and inhibitory control across all age groups. Writing skills were lower from 5th to 8th grade and reading from 4th to 8th. Math skills were lower in 4th, 8th, and 9th grades. Better post-pandemic performance was seen in working memory (6 and 7 years old). **Conclusions**: Findings indicate that students in upper grades of elementary school during the pandemic were most impacted by the suspension of in-person teaching, highlighting the importance of schooling and the need for recovery efforts at these levels.

Keywords: executive functioning; academic performance; reading; writing; Covid-19 pandemic

1. Introduction

Schooling is a human experience with a strong impact on cognitive, neurological, and social development. Enrolling and remaining in formal education brings profound changes in child development [1], such as the strong promotion of cognitive control that occurs with elementary schooling in children aged 5 to 7 years [2]. In addition, there are specific effects, such as the impact of learning to read on neurological functioning and cognitive skills like phonological processing and visual perception [3–5], as well as the impact of learning mathematics and related concepts, such as geometry, object recognition, and the automatization of calculation processes, on neurological and cognitive functioning [6–8].

Although educational quality is crucial for all, children from lower socioeconomic status are at higher risk of receiving education of lower quality. Higher socioeconomic status often provides access to better educational resources, supportive learning environments, and greater motivation, all of which enhance academic performance [9]. Conversely, students from lower socioeconomic

 doi:10.20944/preprints202503.1870.v1

backgrounds face limited access to learning materials, stimulation at home, and higher exposure to stress, which can hinder their academic and cognitive success [10]. In the last decades, educational neuroscience has shown how brain function and structure, shaped by socioeconomic status, are one of the main pathways for the impact of socioeconomic status on education [11] and cognitive outcomes [10]. Those results are especially relevant for countries in the Global South, such as Brazil, in which poverty rates are high and educational outcomes are low.

The COVID-19 pandemic and the consequent disruption of in-person education was one of the major recent events with a strong impact on schooling [12]. The impact was due not only to lack of schooling but also because in the cases in which schooling continued in a virtual form, the quality of education was not guaranteed. For example, Engzell et al. found that students made little or no progress in learning during the closure [13]. During the pandemic, educational neuroscience became crucial for identifying the neurocognitive effects of schooling disruption as well as intervention targets. Specifically, educational neuroscience during remote teaching helped to explore educational practices [14], to improve educational practices [15], train teachers [16], and to measure the impact of educational disruption on neurodevelopment [17].

Although all children suffered the consequences of the pandemic in the short and the long term, the most vulnerable populations suffered more, even when some compensatory measures were taken [18]. Logically, children who do not have access to the internet and a large-screen device, have poorly educated parents, and do not have a quiet space to study were more affected [19]. In consequence, school closures in all countries are likely to have sharpened existing disparities as socioeconomic status is positively associated with children's ability to adjust to remote learning [20].

About this last point, overall studies have found that educational suspension had effects on cognition as well as on academic achievement. For example, a systematic review analyzed articles published between March 1, 2020, and April 30, 2021, to investigate the general effects of school closures on student performance in elementary and high school [21]. The authors highlighted that, due to remote learning, students' development of academic competencies and skills could be affected by up to one-tenth of a standard deviation, potentially resulting in a lifetime income loss of 2.7% to 4.6%. As a consequence, the study suggested a global economic loss of 2.56 billion euros or 1.3% of future gross domestic product. Importantly, although the COVID-19 pandemic interrupted regular schooling across almost the entire world, a more intense effect was observed on countries with fewer financial resources. For example, while 95% of 15-year-olds in Denmark, Slovenia, Norway, Poland, and Iceland had access to a computer and internet in 2018, only about 50% of 15-year-olds in Mexico had access to a computer and internet for remote learning [20].

Specifically in Brazil, an Emergency Remote Learning model was implemented, and about 5.5 million Brazilian children had limited or no access to education during this period [22]. According to data from INEP [23], Brazil was one of the countries where schools remained closed the longest, with an average of 279 days closed in 2020 and an additional 103 days in 2021.

There were few studies conducted in Brazil analyzing the impact of the pandemic. One group of studies analyze the scores in standardized tests of academic achievement obtained after the school closure ended. For example, in the 2022 Programme for International Student Assessment (PISA), which evaluates 15-year-old students' knowledge in mathematics, reading, and science, Brazilian students showed declines in all three subjects [24]. During remote learning, the assessment showed that 38% of students (OECD average: 34%) had difficulty understanding school assignments at least once a week, and about 30% (OECD average: 24%) struggled to find someone to help them with schoolwork. In another study, data from the 2021 Basic Education Assessment System (Saeb) showed declines in student performance, correlated with the impact of the COVID-19 pandemic on Brazilian education [25]. Results indicated that the greatest drop occurred in written language in the second year of elementary school, where the average score fell from 750 points in 2019 to 725.9 points in 2021, about half a standard deviation. In mathematics, there was also a decline, though less significant, from 750 to 741.6 points. In later school years, the biggest declines occurred in mathematics, with fifth- and ninth-grade students showing score drops of 11 and 7 points, respectively, compared to

 doi:10.20944/preprints202503.1870.v1

2019. In Portuguese, there was a drop of 6.6 points for fifth graders and 2.2 points for ninth graders [23].

A second group of correlational studies analyzed what ages were most impacted. For example, Alves et al. carried out a longitudinal study with students from the second to the fifth grade of elementary school in Minas Gerais [26], aiming to assess reading fluency during the remote learning period. The findings indicated that second-grade students suffered the greatest negative impact due to school closures and achieved lower results in March 2022 compared to the same period in the previous year (the beginning of the COVID-19 pandemic). This result suggests that the younger the children the most impacted their academic achievement. This is possibly because older students, in the final years of elementary school or in high school, seem to be more familiar with technology and, therefore, more autonomous [27–29].

A third type of studies addressed the impact of the pandemic, comparing the pre-pandemic norms with the post-pandemic scores obtained by high socioeconomic status children. For example, in a study conducted with children in grades 1 to 5 of a private elementary school in a city of medium to high socioeconomic status in the interior of the state of São Paulo [30], the results showed significantly lower performance compared to the pre-pandemic normative sample. The declines were observed in arithmetic for 3rd, 4th, and 5th grades and in writing for 2nd, 4th, and 5th grades.

To worsen the situation, in addition to the deficits observed in academic learning, some studies have also suggested cognitive deficits, specifically in EF [31–33]. EF refers to a set of cognitive processes related to the control and management of cognition and behavior [34]. These include basic components such as inhibition (IN), working memory (WM), and cognitive flexibility (CF), as well as complex components like planning [35]. EF is strongly related to academic success, affecting the learning process, and, in the long term, lower EF levels are predictors of academic difficulties and school dropout [36–39]. Brazilian studies have also demonstrated the relationship between EF and school subjects [40–42], such as mathematics, reading, and writing [39,43,44].

Campos, Seabra and Carreiro longitudinally followed students in the early years of elementary school before and during the pandemic, at the beginning and end of 2020 [45]. They observed an increase in complaints about PE-related problems among students. In another Brazilian study, after schools reopened, 117 students from 1st and 2nd grades in a public school had their neuropsychological functions assessed. The results pointed to a high prevalence of children in the literacy phase showing alert states or deficits in orientation, memory, attention, language, visuospatial skills, arithmetic skills, and verbal fluency [46].

In this context, it is evident that school is a highly stimulating environment for human development, and therefore, ensuring access to education and the quality of teaching is essential [47,48]. Despite these findings, there are still no studies in Brazil aimed at describing potential EF and academic losses across different school years to identify the most affected grades and thus enable more targeted intervention efforts. Therefore, this study aimed to contribute to map executive functioning and reading, writing, and math skills in Brazilian students from 1st to 9th grade after the pandemic, comparing them with the pre-pandemic normative data of the assessment instruments used to determine possible performance discrepancies. Importantly, we will explore that from an educational neuroscience perspective. The scarcity of national studies on this topic in the Global South and the importance of educational monitoring as part of an evidence-based policy justify this study, whose results may contribute to guiding future projects designed to mitigate some of the learning losses caused by the remote learning period.

2. Materials and Methods

2.1. Participants

Initially, 193 elementary school children from three public schools in two cities of the Greater São Paulo area participated in the study, with 72 students from the city of Santo André and 111 students from the city of Embu das Artes. The sample was selected for convenience. All children from

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 March 2025 doi:10.20944/preprints202503.1870.v1

these schools were invited to participate; however, certain diagnoses were used as exclusion criteria based on school records, including Attention Deficit Hyperactivity Disorder, Intellectual Disability, Autism Spectrum Disorder, and Specific Learning Disorder.

Subsequently, after analyzing the results, participants with an intellectual level potentially indicative of undiagnosed intellectual disability were excluded. Specifically, exclusion criteria included scores below the 5th percentile on the Raven's Colored Progressive Matrices test, for participants aged 6 to 10 years; and an intelligence quotient below 70, according to results from the Wechsler Abbreviated Scale of Intelligence [WASI], for participants aged 11 and older. Based on this criteria, fifteen participants were excluded from the sample.

The participants' ages ranged from 6 to 14 years (M=10; SD=5.65), with 55.62% female and 44.38% male. Regarding grade level, 8.44% were in 1st grade, 10.11% in 2nd and 3rd grades, 12.92% in 4th grade, 14.04% in 5th grade, 12.36% in 6th grade, 11.80% in 7th grade, 10.67% in 8th grade, and 9.55% in 9th grade.

Data collection occurred in the second semester of 2023 (from September to November) and the first semester of 2024 (from May to July). Table 1 presents the school grade of the study participants during the pandemic period (2020 and 2021) and at the time of data collection (2023 and 2024).

Table 1. Participants' school year at the time of data collection and during the pandemic period.

School year at the time of data collection	Data collection conducted in 2023	Data collection conducted in 2024	School year in 2020 (1st year of the pandemic)	School year in 2021 (2nd year of the pandemic)	School year overall during the pandemic
1 grade	X		Preschool	Pre-kindergarten	Preschool - Pre-kindergarten
2 grade	X		Pre-kindergarten	kindergarten	Pre-kindergarten - kindergarten
3 grade	X		kindergarten	1 grade	kindergarten - 1 grade
4 grade	X		1 grade	2 grade	1 - 2 grade
5 grade	X		2 grade	3 grade	2 - 3 grade
6 grade		X	2 grade	3 grade	2 - 3 grade
7 grade		X	3 grade	4 grade	3 - 4 grade
8 grade		X	4 grade	5 grade	4 - 5 grade
9 grade	X		6 grade	7 grade	6 - 7 grade
9 grade		X	5 grade	6 grade	5 - 6 grade

The city of Santo André has an average monthly salary for formal workers of approximately US$ 625.92 [49]. In the 2023 Basic Education Development Index (IDEB), the city scored 6.5 out of 10 points in the early years of elementary education in public schools and 5.2 out of 10 points in the final years [23]. Embu das Artes has an average monthly salary for formal workers of approximately US$ 650.03 [49]. The IDEB for the early years of elementary education in public schools is 6.2 out of 10 points in the early years and 5.0 out of 10 points in the final years [23]. Both cities have IDEB close to the average for the State of São Paulo (6.2 in the initial grades and 5.1 in the final grades).

In March 2020, in-person classes were suspended for all children. Regular school attendance was resumed in February 2022, following government guidelines.

2.2. Instruments

The following instruments were used to evaluate child cognitive performance:

- Digit Span Task (DST): Assesses short-term verbal memory (Forward Order - FO) and working memory (Backward Order - BO). The examinee's task is to repeat sequences of digits in either forward or backward order. The test was administered individually, and the measures used were total correct responses (sum of both orders). This task is standardized for the Brazilian

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 March 2025 doi:10.20944/preprints202503.1870.v1

population and there is evidence of validity for ages 4 to 10 years [50]. In this study, this instrument was used with children up to 10 years old. For this task the minimum possible raw score is zero and the maximum possible raw score is 16.

- Digit Span Subtest from the Wechsler Intelligence Scale for Children - WISC IV: Assesses short-term verbal memory (Forward Order - FO) and working memory (Backward Order - BO). The examinee's task is to repeat sequences of digits in either forward or backward order. The test was administered individually, and the measures used were total correct responses (sum of both orders). This task is standardized for the Brazilian population and has demonstrated validity for individuals aged 6 years to 16 years and 11 months [51]. In this study, this instrument was used with children aged 11 and older. For this task the minimum possible raw score is zero and the maximum possible raw score is 16.

- Free Verbal Fluency (FVL): Assesses linguistic-mnemonic processes related to lexical search and components of executive functions, such as cognitive flexibility, inhibition, working memory, and search strategy organization. In this individually administered task, the examinee must say as many words as possible within a given time (two and a half minutes), respecting the guidelines to keep their eyes closed and not say proper names or numbers. This task is standardized for the Brazilian population and its validity was probed with individuals aged 6 to 12 years [52]. In this study, for participants older than the normative sample, data corresponding to age 12 were used only to determine whether, even when compared to younger children, there could be indicators of difficulty in these cognitive skills. For this instrument, the minimum possible raw score is zero and the maximum raw score is equivalent to the number of correct answers.

- Hayling Test (HT): The HT is divided into two parts, A and B, which assess, respectively, linguistic aspects and EF (such as cognitive flexibility and inhibitory control), as well as processing speed. In this individually administered task, the participant must, in Part A, complete the sentences with words that fit appropriately in the context, as quickly as possible. In Part B, the objective is to complete the sentences with words unrelated to the context presented. There are two versions, both with evidence of validity and standardization for the Brazilian population: Children's Hayling Test (CHT), used with individuals aged 6 to 12 years [53], and Adult's Hayling Test (AHT), from age 13 onwards [54]. Part A is only a basal analysis to assess EF in Part B, in this study we used only measures related to Part B. The measures used were execution time in Part B, which is the sum of the reaction time in seconds of all items, and the number of errors in Part B. For CHT the minimum possible raw score is zero and the maximum possible raw score is 10, but for AHT the minimum possible raw score is zero and the maximum possible raw score is 15.

School achievement was evaluated with the following instruments.

- School Performance Test II (TDE II): The TDE II aims to assess basic skills in reading, writing, and arithmetic. There is evidence of validity for this test, which has also been standardized for the Brazilian population, with students from the first to the ninth year of elementary school [55]. Below is a brief description of each part:

- **Writing Subtest**: Consists of a list of 40 words that are read one by one to the students, and they must write them down. There is one version for 1st to 4th grade and another for 5th to 9th grade. The test was administered collectively, with time being measured, and scoring was interrupted after 10 consecutive errors or "don't know" responses. The measures used were the score and the duration of the task. For this task the minimum possible raw score is zero and the maximum possible raw score is 40, in both versions.
- **Reading Subtest**: Composed of a list of 36 words for 1st to 4th grade, and 33 words for 5th to 9th grade, which the examinee must read aloud individually. The time was recorded, and scoring was interrupted after 10 consecutive errors or "don't know" responses. The measures used were the score and the duration of the task. For students in grades 1 to 4 the minimum possible raw score is zero and the maximum possible raw score is 36, but for students in grades 5 to 9 the minimum possible raw score is zero and the maximum possible raw score is 33.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 March 2025 doi:10.20944/preprints202503.1870.v1

- **Arithmetic Subtest**: Consists of a list of 37 exercises for 1st to 5th grade, and 43 for 6th to 9th grade, which the examinee must solve. The test was administered individually for children from 1st to 3rd grade and collectively for other participants, according to the manual's guidelines. The time was recorded, and scoring was interrupted after 10 consecutive errors or "don't know" responses. The measures used were the score and the duration of the task. For students in grades 1 to 5 the minimum possible raw score is zero and the maximum possible raw score is 37, but for students in grades 6 to 9 the minimum possible raw score is zero and the maximum possible raw score is 43.

To check inclusion criteria we administered the following tests:

- Raven's Coloured Progressive Matrices (CPM): The CPM assesses general intelligence through visual puzzles designed to evaluate pattern recognition. It is organized in three parts, which are arranged in increasing difficulty. There is evidence of validity and it was standardized for the Brazilian population, specifically for individuals aged 5 to 11 years [56]. In this study, this instrument was administered to children from 1st to 5th grade to screen for significant intellectual deficits as an exclusion criterion.

- Wechsler Abbreviated Scale of Intelligence (WASI): This is a brief intelligence assessment tool. The Vocabulary and Matrix Reasoning subtests were individually administered, to estimate general cognitive functioning. There is evidence of the validity for this test, which is also standardized for the Brazilian population, with normative study covering individuals aged 6 to 89 years [57]. In this study, it was used for children from 6th grade onwards to screen for significant intellectual deficits as exclusion criteria.

2.3. Data Collection Procedures

The project was approved by the Research Ethics Committee of the proposing institution. Authorization was obtained from the school directors, the students' guardians and the students themselves assented for participation in the research. The assessments were divided into three sessions, held at the school in a suitable location, and were carried out individually or in groups, following the application guidelines of each test. At the conclusion of the analysis, individual data and the overall research results were shared with the respective guardians of the students. The application followed a fixed order, first session: WASI or Raven's Coloured Progressive Matrices (according to the student's age at the time of the test), FVF, Hayling Test, Digit Tasks and Reading (from TDE-II); second session: individual (1st to 3rd grade) and collective (from 4th grade) application of the Writing Subtest (TDE-II); third session: individual (1st to 3rd grade) and collective (from 4th grade) application of the Arithmetic Subtest (TDE-II).

2.4. Data Analysis Procedures

Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to analyze sociodemographic data and characterize the participants. Additionally, mean and standard deviation were employed to describe data across age groups or school grades in the pre-pandemic period (based on instrument norms) and the post-pandemic period (based on data collected in this study), considering each task and dependent variable separately [58].

To examine potential differences between the sample in this study and the normative samples established in the pre-pandemic period, as described in the test manuals, one-sample t-tests were conducted [58]. Given the small sample size for each school grade and age, comparative analyses also included confidence intervals for the differences, estimated using the bootstrapping resampling procedure (1,000 resamplings, BcA - Bias-Corrected and Accelerated, with a 95% confidence interval). The BcA bootstrapping method was used to mitigate issues related to the lack of normal data distribution due to the small sample size, improve the accuracy of confidence intervals, and correct biases and asymmetries in the distribution of estimates [59].

Furthermore, effect size was calculated using Cohen's d [60] to quantify the magnitude of the differences, applying the following criteria: $d > 0.80$ = large effect; $d = 0.50$ = medium effect; $d = 0.20$ =

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 March 2025 doi:10.20944/preprints202503.1870.v1

small effect. A significance level of $p < 0.05$ was considered statistically significant. All analyses were conducted using IBM SPSS Statistics software (version 27.0).

3. Results

Tables 2–9 present the participants' performance in terms of descriptive statistics (mean and standard deviation), as well as the normative data, and the *t*-tests results. The executive function measures are presented by age, while the academic performance measures are presented by school year because the respective test manuals grouped the normative sample data this way.

Regarding working memory performance comparisons, assessed using the Digit Span Test (see Table 2), significant differences were observed at all ages except for participants aged 8 and 9 years. The confidence interval in the bootstrap analysis supported these findings. Notably, students aged 6 and 7 years performed significantly better than the normative samples of the instrument. The effect size in these comparisons ranged from large to medium, respectively. In contrast, students aged 10 to 14 years performed significantly worse than the pre-pandemic norms, with effect sizes ranging from small to medium.

Table 2. Student's t-test of the effect of group (sample from this study x normative sample) on scores in a measure of working memory (DST and Digit Span Subtest from WISC-IV).

Age (n)	Pré-pandemic standard [a]	Post-pandemic performance	t	df	Sig [c]	Mean Difference	BCa 95% Confidence interval of the difference		d
	Mean (SD)	Mean (SD)					Lower	Higher	
6 (n=8)	6.82 (------)[b]	9.00 (2.45)	2.517	7	0.040	2.180	0.305[e]	3.680[e]	0.890
7 (n=18)	8.22 (------)[b]	9.28 (1.99)	2.250	17	0.038	1.058	0.113	1.947	0.530
8 (n=12)	9.76 (------)[b]	9.58 (1.73)	-0.354	11	0.730	-0.177	-0.927	0.657	-0.102
9 (n=26)	10.94 (------)[b]	11.19 (2.62)	0.490	25	0.628	0.252	-0.517	1.022	0.096
10 (n=27)	11.62 (------)[b]	10.22 (2.04)	-3.553	26	<0.001	-1.398	-2.139	-0.546	-0.684
11 a 13 [e] (n=69)	14.67 (------)[b]	12.71 (2.22)	-7.343	68	<0.001	-1.960	-2.554	-1.308	-0.884
14 (n=18)	16.19 (------)[b]	14.71 (3.47)	-2.475	17	0.024	-2.023	-3.134	-0.801	-0.583

Note: [a] Reference of the origin of the standard [50,51]; [b] The Standard Deviation was not reported by the authors; [c] Significance of the t-test for one sample (2 tails); d Confidence Interval of the Difference for bootstrap comparison based on 1000 bootstrap samples; d = Cohen's d (effect size); e Based on 999 samples. [e] The ages of 11 to 13 are grouped because the instrument's manual presents the averages this way.

Regarding verbal fluency, when comparing the current mean with the normative mean of the Verbal Fluency Test (Table 3), statistically significant differences were observed in the results of participants aged 9 to 14 years. These differences were corroborated by the confidence interval in the bootstrap analysis, with the current sample showing poorer performance compared to pre-pandemic norms across all ages. In all those cases, the effect sizes ranged from medium to large, with the most pronounced differences observed in students aged 11 to 14 years. It is important to note that, for verbal fluency measures, the norms for 12-year-olds were used to compare participants aged 13 and 14 due to the absence of norms for this age group. Even when compared to younger age norms, the present sample of 13- and 14-year-olds performed worse than the normative mean.

 doi:10.20944/preprints202503.1870.v1

Table 3. Student's t-test of the effect of group (sample from this study vs. normative sample) on the score in the Free Fluency Verbal measure (FVL).

Age (n)	Pré-pandemic standard [a] Mean (SD)	Post-pandemic performance Mean (SD)	t	df	Sig [b]	Mean Difference	BCa 95% Confidence interval of the difference Lower	BCa 95% Confidence interval of the difference Higher	d
6 (n=8)	23.68 (11.39)	24.00 (3.93)	0.230	7	0.824	0.320	-2.180	2.445	0.081
7 (n=18)	28.10 (13.12)	33.22 (12.86)	1.690	17	0.109	5.122	-1.155	11.844	0.398
8 (n=12)	31.18 (13.52)	27.75 (9.35)	-1.270	11	0.230	-3.430	-7.597	1.320	-0.367
9 (n=26)	40.28 (14.25)	32.81 (13.90)	-2.742	25	0.011	-7.472	-11.742	-2.731	-0.538
10 (n=27)	46.00 (12.64)	36.74 (13.63)	-3.530	26	0.002	-9.259	-13.556	-4.520	-0.679
11 (n=28)	50.47 (20.11)	33.03 (13.16)	-7.008	27	<0.001	-17.434	-22.357	-11.937	-1.324
12 (n=23)	52.36 (16.35)	32.74 (13.41)	-7.013	22	<0.001	-19.621	-25.113	-14.268	-1.462
13 e 14[e] (n=36)	52.36 (16.35)	32.83 (14.42)	-8.124	35	<0.001	-19.527	-24.462	-13.356	-1.354

Note: [a] Reference of the source of the standard [52]; [b] Significance of the one-sample t-test (2 tails); [c] Confidence Interval of the Difference for bootstrap comparison based on 1000 bootstrap samples; d = Cohen's d (effect size).[e] The ages of 13 and 14 are grouped because the instrument's manual presents the averages this way.

In terms of errors on the Hayling Test (see Table 4), which measures cognitive flexibility and inhibitory control, statistically significant differences were observed between participants aged 7, 9, 10, 11, 12, 13, and 14, with the present study sample showing lower performance (i.e., higher number of errors) compared to pre-pandemic normative means. The effect size also ranged from medium to large, indicating the relevance of the differences. In the group of 6-year-old participants, although the p-value ($p = 0.056$) did not reach the conventional statistical significance threshold ($p < 0.05$), the bootstrap analysis, combined with a large effect size, suggests potential practical significance. As mentioned previously, this result indicates that the small sample size ($n = 8$) may have compromised the statistical power of the analysis.

Table 4. Student's t-test of the effect of group (sample of this study x normative sample) on error score in measure of inhibitory control/cognitive flexibility (Hayling B).

Age (n)	Pré-pandemic standard [a] Mean (SD)	Post-pandemic performance Mean (SD)	t	df	Sig [b]	Mean Difference	BCa 95% Confidence interval of the difference Lower	BCa 95% Confidence interval of the difference Higher	d
6 (n=8)	7.25 (1.39)	8.00 (0.93)	2.291	7	0.056	0.750	0.250[d]	1.250[d]	0.810
7 (n=18)	5.95 (1.70)	7.27 (1.45)	3.892	17	<0.001	1.328	0.661	2.050	0.917
8 (n=12)	5.58 (1.55)	6.25 (2.18)	1.065	11	0.310	0.670	-0.413	1.670	0.307
9 (n=26)	4.65 (2.01)	6.50 (1.39)	6.773	25	<0.001	1.850	1.388	2.275	1.328
10 (n=27)	4.60 (2.14)	6.33 (1.92)	4.687	26	<0.001	1.733	1.184	2.326	0.902
11 (n=28)	4.57 (1.79)	5.71 (2.27)	2.662	27	0.013	1.144	0.359	1.859	0.503
12 (n=23)	3.78 (1.59)	4.65 (1.37)	3.056	22	0.006	0.872	0.437	1.307	0.637
13 e 14 (n=36)	4.01 (2.28)	5.86 (3.06)	3.626	35	<0.001	1.851	0.879	2.796	0.604

 doi:10.20944/preprints202503.1870.v1

Note: [a] Reference of the source of the standard [53,54]; [b] Significance of the one-sample t-test (2 tails); [c] Confidence Interval of the Difference for bootstrap comparison based on 1000 bootstrap samples; d = Cohen's d (effect size).

Regarding the comparisons involving the analysis of reaction time from the Hayling B Test, which also provides measures of cognitive flexibility and inhibitory control, the results revealed significant differences in the participants aged 10 to 12 years (Table 5). In these groups, the participants presented faster performance compared to the normative means. These results were corroborated by the confidence intervals obtained in the bootstrap analyses. In these comparisons, the effect sizes ranged from medium to large. For the 6-year-old group, although the p value (p = 0.171) did not reach the conventional level of statistical significance (p < 0.05), the analysis of the bootstrap confidence interval and the average effect size indicate the presence of a relevant difference. This discrepancy may reflect a Type II error, possibly due to the small sample size (n = 8), which compromises the statistical power of the analysis [61].

Table 5. Student´s t-test of the effect of goup (sample of this study x normative sample) on time score (seconds) in a measure of inhibitory control/cognitive flexibility (Hayling B).

Age (n)	Pré-pandemic standard [a]	Post-pandemic performance	t	df	Sig [b]	Mean Difference	BCa 95% Confidence interval of the difference [c]		d
	Mean (SD)	Mean (SD)					Lower	Higher	
6 (n=8)	57.39 (17.76)	81.00 (43.77)	1.526	7	0.171	23.610	1.543	52.052	0.539
7 (n=18)	42.35 (18.58)	54.55 (33.57)	1.542	17	0.141	12.206	-.701	26.788	0.364
8 (n=12)	54.16 (16.37)	48.25 (20.94)	-0.977	11	0.349	-5.910	-18.430	7.007	-0.282
9 (n=26)	41.18 (17.35)	39.69 (21.20)	-0.358	25	0.724	-1.488	-8.861	7.578	-0.070
10 (n=27)	43.79 (17.82)	30.24 (13.32)	-5.283	26	<0.001	-13.549	-17.805	-8.935	-1.017
11 (n=28)	41.08 (10.49)	28.98 (18.10)	-3.535	27	0.001	-12.092	-17.828	-4.595	-0.668
12 (n=23)	36,23 (9.53)	26.96 (8.96)	-4.962	22	<0.001	-9.270	-12.208	-6.078	-1.035
13 e 14 (n=36)	52.95 (19.21)	41.04 (24.68)	1.170	35	0.250	4.813	-3.710	14.268	0.195

Note: [a] Reference of the source of the standard [53,54]; [b] Significance of the one-sample t-test (2 tails); [c] Confidence Interval of the Difference for bootstrap comparison based on 1000 bootstrap samples; d = Cohen's d (effect size).

Writing ability was assessed by the Writing Subtest of the TDE-II. As shown in Table 6, students from 5th to 8th grade showed statistically significant differences between the means, with weaker post-pandemic performance. These results were corroborated by the confidence intervals of the bootstrap analysis. The effect size ranged from medium to large in these comparisons.

Table 6. Student's t-test of the effect of group (sample of this study x normative sample) on writing measure (Writing Subtest TDE-II).

School year (n)	Pré-pandemic standard [a]	Post-pandemic performance	t	df	Sig [b]	Mean Difference	BCa 95% Confidence interval of the difference		d
	Mean (SD)	Mean (SD)					Lower	Higher	
1 (n=15)	5.18 (8.49)	5.53 (5.48)	0.249	14	0.807	0.353	-1.647	2.820	0.064
2 (n=18)	14.91 (10.67)	15.55 (9.53)	0.287	17	0.774	0.646	-3.577	4.979	0.068
3 (n=18)	25.70 (7.31)	22.88 (9.85)	-1.210	17	0.243	-2.811	-8.422	2.075	-0.285

 doi:10.20944/preprints202503.1870.v1

4 (n=23)	27.76 (7.44)	28.00 (7.77)	0.148	22	0.884	0.240	-3.462	3.558	0.031
5 (n=25)	10.62 (6.88)	5.84 (5.30)	-4.505	24	<0.001	-4.780	-6.474	-2.846	-0.901
6 (n=22)	14.41 (7.38)	10.45 (7.86)	-2.360	21	0.028	-3.955	-7.223	-.365	-0.503
7 (n=21)	19.18 (7.86)	11.47 (8.15)	-4.327	20	<0.001	-7.704	-11.228	-3.703	-0.944
8 (n=19)	20.81 (7.41)	11.31 (6.51)	-6.352	18	<0.001	-9.494	-11.932	-7.073	-1.457
9 (n=17)	21.52 (8.67)	17.41 (10.10)	-1.677	16	0.113	-4.108	-8.814	0.951	-0.407

Note: [a] Reference of the source of the standard [55]; [b] Significance of the one-sample t-test (2 tails); [c] Confidence Interval of the Difference for bootstrap comparison based on 1000 bootstrap samples; d = Cohen's d (effect size).

For the word reading score, assessed using the TDE-II Reading Subtest, students from 5th to 8th grades performed significantly lower than expected when compared to pre-pandemic norms, which was corroborated by the bootstrap analysis confidence interval and the observed mean effect sizes (Table 7). In the 4th grade, although the p-value (p = 0.058) did not reach the conventional level of statistical significance, the bootstrap analysis, combined with a robust effect size, indicates a potential practical significance. This finding suggests that the sample size limitation may have influenced the results of the t-test analysis and, therefore, that the bootstrapping method was necessary to confirm the results. Regarding the execution time in this reading subtest (Table 8), only the 2nd grade performed faster compared to the normative mean, a result that was corroborated by the bootstrap analysis. The effect size of this comparison was large.

Table 7. Student's t-test of the effect of group (sample of this study x normative sample) on reading measure, raw score (TDE reading).

School year (n)	Pré-pandemic standard [a]	Post-pandemic performance	t	df	Sig [b]	Mean Difference	BCa 95% Confidence interval of the difference		d
	Mean (SD)	Mean (SD)					Lower	Higher	
1 (n=15)	8.55 (13.38)	12.00 (10.95)	1.220	14	0.243	3.450	-1.408	8.441	0.315
2 (n=18)	23.62 (13.96)	26.77 (11.01)	1.216	17	0.241	3.158	-2.251	7.658	0.287
3 (n=18)	32.84 (4.81)	31.00 (8.91)	-0.876	17	0.393	-1.840	-7.206	1.581	-0.206
4 (n=23)	34.29 (4.75)	33.17 (2.67)	-2.002	22	0.058	-1.116	-2.290	-0.203	-0.417
5 (n=25)	28.06 (4.29)	25.76 (4.17)	-2.754	24	0.011	-2.300	-3.740	-0.740	-0.551
6 (n=22)	28.78 (4.07)	24.72 (5.86)	-3.241	21	0.004	-4.053	-6.529	-1.871	-0.691
7 (n=21)	29.69 (3.08)	27.23 (3.97)	-2.828	20	0.010	-2.452	-4.261	-0.909	-0.617
8 (n=19)	30.50 (2.42)	27.26 (5.39)	-2.616	18	0.018	-3.237	-5.564	-1.278	-0.600
9 (n=17)	30.52 (2.01)	29.11 (3.82)	-1.513	16	0.150	-1.402	-3.226	0.294	-0.367

Note: [a] Reference of the source of the standard [55]; [b] Significance of the one-sample t-test (2 tails); [c] Confidence Interval of the Difference for bootstrap comparison based on 1000 bootstrap samples; d = Cohen's d (effect size).

 doi:10.20944/preprints202503.1870.v1

Table 8. Student's t-test of the effect of group (sample from this study x normative sample) on reading measure, time (TDE reading).

School year (n)	Pré-pandemic standard [a] Mean (SD)	Post-pandemic performance Mean (SD)	t	df	Sig [b]	Mean Difference	BCa 95% Confidence interval of the difference Lower	Higher	d
1 (n=15)	189.33 (139.39)	198.40 (124.89)	0.281	14	0.783	9.070	-63.967	97.226	0.073
2 (n=18)	155.44 (152.83)	103.94 (50.49)	-4.327	17	<0.001	-51.495	-70.753	-30.051	-1.020
3 (n=18)	71.68 (43.35)	90.44 (71.99)	1.106	17	0.284	18.764	-9.349	57.208	0.261
4 (n=23)	49.38 (19.01)	54.43 (17.79)	1.362	22	0.187	5.054	-1.946	13.318	0.284
5 (n=25)	97.48 (27.37)	108.76 (55.02)	1.025	24	0.315	11.285	-4.975	30.985	0.205
6 (n=22)	89.21 (29.80)	96.13 (55.26)	0.587	21	0.563	6.920	-11.289	28.044	0.125
7 (n=21)	77.13 (20.70)	81.83 (35.04)	0.615	20	0.546	4.701	-11.251	20.655	0.134
8 (n=19)	70.88 (18.51)	75.64 (25.45)	0.816	18	0.425	4.765	-5.734	15.144	0.187
9 (n=17)	60.11 (15.27)	75.70 (44.32)	1.451	16	0.166	15.594	-3.120	38.858	0.352

Note: [a] Reference of the source of the standard [55]; [b] Significance of the one-sample t-test (2 tails); [c] Confidence Interval of the Difference for bootstrap comparison based on 1000 bootstrap samples; d = Cohen's d (effect size).

Regarding arithmetic, a skill assessed by the Arithmetic Subtest of the TDE-II, 8th and 9th grade students performed worse than the pre-pandemic normative averages, a result corroborated by the confidence interval obtained in the bootstrap analysis, with large effect sizes for both groups (Table 9). In the group of 4th grade students, although the p-value ($p = 0.066$) did not reach the conventional threshold of statistical significance ($p < 0.05$), both the bootstrap confidence interval and the effect size suggest the presence of practical relevance, with lower performance in the current sample. This finding indicates that the reduced sample size may have compromised the statistical power, making it difficult to detect significant differences even in the face of a trend of lower performance than the standardized data. Likewise, the groups of 1st, 2nd, and 5th grade students presented non-significant p-values; however, subsequent analyses – through bootstrap confidence intervals and effect sizes (d ranging from 0.410 to 0.484) – suggest that the sample limitation may have masked the practical relevance of the results [60], which indicate superior performances in the current sample compared to pre-pandemic norms.

Table 9. Student's t-test of the effect of group (sample of this study x normative sample) on arithmetic measure, raw score (arithmetic TDE).

School year (n)	Pré-pandemic standard [a] Mean (SD)	Post-pandemic performance Mean (SD)	t	df	Sig [b]	Mean Difference	BCa 95% Confidence interval of the difference Lower	Higher	d
1 (n=15)	8.07 (3.81)	9.40 (2.74)	1.876	14	0.082	1.330	0.063	2.530	0.484
2 (n=18)	12.91 (4.27)	14.55 (3.71)	1.880	17	0.077	1.646	0.034	3.090	0.443
3 (n=18)	19.67 (4.10)	18.88 (3.77)	-0.879	17	0.392	-0.781	-2.614	0.997	-0.207
4 (n=23)	23.73 (3.35)	22.08 (4.06)	-1.938	22	0.066	-1.643	-3.121	-0.252	-0.404
5 (n=25)	25.00 (5.18)	26.48 (3.60)	2.052	24	0.051	1.480	0.040	2.800	0.410
6	8.37	7.95	-0.380	21	0.708	-0.415	-2.188	1.572	-0.081

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 25 March 2025 doi:10.20944/preprints202503.1870.v1

(n=22)	(6.03)	(5.13)							
7 (n=21)	12.75 (7.01)	10.09 (6.01)	-2.022	20	0.057	-2.655	-5.309	0.332	-0.441
8 (n=19)	16.26 (9.48)	7.84 (5.03)	-7.286	18	<0.001	-8.418	-10.049	-6.418	-1.672
9 (n=17)	16.00 (8.18)	8.70 (6.66)	-4.510	16	<0.001	-7.294	-10.052	-4.059	-1.094

Note: [a] Reference of the source of the standard [55]; [b] Significance of the one-sample t-test (2 tails); [c] Confidence Interval of the Difference for bootstrap comparison based on 1000 bootstrap samples; d = Cohen's d (effect size).

Table 10 presents a comparative summary of the significant results obtained in this study when comparing the post-pandemic data with pre-pandemic normative data. Executive function measures are presented by age, while academic performance measures are presented by school year, since the respective test manuals grouped the normative data of the sample in this way. It should be noted that for score measures, the higher the value, the better the performance (top of the table). Conversely, for error and time measures, the higher the value, the worse the performance (bottom of the table).

Table 10. Comparative summary of the significant results comparing post-pandemic data with pre-pandemic normative data for different ages and school years across various indices of the instruments that assess executive function skills.

	AGE								
RAW SCORE	**6**	**7**	**8**	**9**	**10**	**11**	**12**	13	14
Working Memory – (Digit)	>*	>*			<	<	<	<	<
FVerbal Fluency – (FVL)				<	<	<	<	<	<
	SCHOOL YEAR								
RAW SCORE	1	2	3	4	5	6	7	8	9
Writing					<	<	<	<	
Reading				<*	<	<	<	<	
Arithmetic	>*	>*		<*	>*			<	<
	AGE								
TIME / ERROR	6	7	8	9	10	11	12	13	14
Hayling B - time	<*				>	>	>		
Hayling B - error	<*	<		<	<	<	<	<	<
	SCHOOL YEAR								
TIME / ERROR	1	2	3	4	5	6	7	8	9
Reading- time		>							

< indicates that the current sample performed statistically worse than the normative sample (p<0,05). > indicates that the current sample performed statistically better than the normative sample (p<0,05). * Score whose bootstrap analysis suggested potential statistical significance.

4. Discussion

The present study compared child cognition (short-term verbal memory, working memory, verbal fluency, cognitive flexibility, inhibitory control, processing speed) and cognitive achievement (reading, writing, and arithmetic) performance after the COVID-19 pandemic with the norms established for these variables before, by age and school grade. Specifically, our results showed EF and academic losses across 1st to 9th school years in Brazil, a population underrepresented in educational neuroscience literature.

Overall, we have found that in the majority of the tests, children showed lower scores after the pandemic than before, especially between 10 and 13 years (i.e., between 5th and 8th grade). No difference was observed at age 8 (i.e., 3rd grade). This general result is in line with previous studies showing that the suspension of in-person education impacted negatively on child cognitive development and academic achievement [12,13,17,21], and also with studies conducted in Brazil [23–26]. As others have proposed, limitations such the lack of computers or internet access as well as the difficulty understanding school assignments jointly with the problems to find someone to help with schoolwork, were reported in Brazil as potential explanations for the decrease in achievement [24,25]. However, the findings showing a higher number of differences in the oldest children and the higher grades contrast with studies conducted in the country. For example, Alves and collaborators [26] analyzed children across 2nd to 5th grades of elementary school and found an impact of classes-suspension in reading fluency only in the 2nd grade children, but they analyzed a sample coming from private high socioeconomic-status schools. Instead, the schools in our study were from middle-to-low socioeconomic status contexts. It has been proposed that older students, in the final years of elementary school or in high school, seem to be more familiar with technology and, therefore, more autonomous, taking most advantage from virtual classes [27–29]. However, if socioeconomic conditions impede access to computers or to the internet, technology familiarity would not have any effect. Future studies should analyze how the family socioeconomic level can interact with the student's age to produce different impacts on reading.

One strength of our study is the number of tests implemented, and it is also an example of how educational neuroscience has contributed to a very detailed evaluation of the impact of the pandemic. In an analysis of the findings for each test, our results revealed a significant decline in the average verbal fluency performance, especially among participants aged 9 to 14 years, and remarkably, when compared to younger age norms. This result aligns with investigations conducted in Brazil, which reported an increase in complaints of difficulties related to EF among students in the early years of Elementary School [45]. Furthermore, Ribeiro, Celeste, and Reis [46] found that 48.72% of children enrolled in the 1st and 2nd years of Elementary School, after the pandemic period, presented scores indicating warnings or deficits in verbal fluency. In sum, our results suggest that class-suspension is associated with lower vocabulary (number of words acquired by individuals).

Regarding the scores obtained in working memory, we found a similar trend: a significant decline was observed when comparing the current average with the normative average, particularly among older students. The decrease in working memory associated with the pandemic has been observed in previous studies [46,62] and it has been suggested that might be linked with the anxiety produced by the lockdown [62]. Conversely, the fact that students aged 6 and 7 achieved scores higher than the pre-pandemic norm, contrasted with the findings of the study conducted in Brazil by Ribeiro, Celeste, and Reis [46], whose results indicated that 62.4% of the children in the first and second years of Elementary School showed scores indicative of deficit in working memory. Remarkably, a study conducted in Ethiopia compared test results applied to groups before and after school closures, demonstrating higher scores in working memory and non-verbal intelligence in the group assessed after the return to in-person school activities [63]. Future studies should clarify the reason for these differences.

In relation to inhibitory control, with the exception of 8-year-old students, all other participants had a higher number of errors than the expected normative average. Conversely, they showed faster performance than expected according to the guidelines established before the pandemic, but this is not interpreted as an improvement given that the higher speed is associated with a worse achievement in the task. The high number of errors is in line with previous evidence showing similar results [45]. Daily screen use has been suggested as one of the factors decreasing inhibition in American school-age children [63], but in Brazil, only 31% of public elementary school students had a computer/ tablet and broadband at home [64], and therefore, more evidence is needed to explain the relationship between these factors in Global South countries.

Regarding educational outcomes, our results generally replicate previous findings [13]: the pandemic negatively affected academic achievement across various educational areas, mainly in 5th and 8th grades. Studies [see 18 for a review] indicate that prolonged educational disruption has resulted in attenuated learning gains. Further, if that impact was significant in countries from the Global North [13], and the most remarkable effects were for those already at risk for educational disparities [18,19], we might expect a bigger effect in countries from the Global South such as Brazil, which is actually what we found. Among the factors explaining those effects, the direct lack of educational opportunities, as well as the stressors produced by the lockdown were suggested as important variables [17].

Specifically, we found that in reading and writing tests, children had lower scores after the pandemic, between 5th and 8th grade. It is important to emphasize that these students, during the pandemic, were in the process of literacy development and/or in the early years of elementary education. Our results corroborate the ones obtained by Santos [30] which revealed significantly lower performance compared to pre-pandemic standards among 2nd, 4th, and 5th-grade students from high socioeconomic status schools, showing that in this area the pandemic impacted across all economic levels. We have also observed that 2nd grade students were faster post-pandemic, although that result might be due to particularities of the evaluated sample such as the homogeneity (the standard deviation is small in comparison with standard deviation of 1st year students as well as with the norm). However, the general trend indicated that the pandemic affected negatively reading and writing achievements. Brazilian studies conducted with children in the early years of elementary school also highlighted learning gaps related to reading comprehension and fluency [26]. About writing, it has been suggested that the use of digital platforms did not allow for the stimulation of students' motor skills [65]. This situation had already been anticipated by authors who discussed the potential risks associated with low-quality education resulting from remote learning [17] and by studies showing similar results with big sample sizes [13,63].

Regarding arithmetic skills, the results are the opposite: at some grades, they improved after the pandemic, but in other ones, they decreased. Specifically, at 1st, 2nd and 5th grade, children improved after the pandemic. Instead, 4th, 8th, and 9th-grade students showed a significant decline in performance when compared to pre-pandemic normative averages. This last result agrees with the one obtained by Santos [30], which identified a decline in the academic performance of students in 3rd, 4th, and 5th grades, when comparing their results to the instrument's normative standards. However, the result of the improvement for the first years is unexpected, and also contradictory with studies involving big samples [13,66]. Future studies should confirm our results.

In summary, the results obtained in the assessment of academic skills are generally consistent with data from national [24] and international [25] educational evaluations, which indicated a decline in student performance. This phenomenon is closely associated with the impact of the Covid-19 pandemic, particularly in countries such as Brazil which kept educational institutions closed for extended periods and faced significant challenges in implementing remote learning [23]. In the face of humanitarian crises and natural disasters, the disruption of access to the educational system can lead to long-term consequences, even with the implementation of compensatory measures [18].

The contribution of this work was to add data on the effects of the pandemic on children from the Global South. The strength is that the administration of various tests led us to explain in high detail the impact, according to age or grade, and to the cognitive or educational process. However, this study also has limitations, especially the low sample size. Although statistical procedures (bootstrapping) were implemented to mitigate issues related to the small sample size, it is important to state that these results are not generalizable (we used a convenience sample) and that future studies are needed to determine exactly the long-term impact of the pandemic on child cognitive and educational outcomes.

Author Contributions: Conceptualization: A.G.S., C.G.F., C.D., L.R.R.C., M.J.H.; Methodology: A.G.S., C.G.F., C.D., L.R.R.C.; Validation: A.G.S., C.G.F.; C.D.; Formal Analysis: M.L.L.B., A.G.S.; Investigation: C.G.F., C.D.; Resources: A.G.S., L.R.R.C.; Data Curation: A.G.S., L.R.R.C.; Writing – Original Draft Preparation: C.G.F.; C.D.; Writing – Review & Editing: A.G.S., C.G.F., C.D., L.R.R.C., M.L.L.B., M.J.H.; Visualization, A.G.S., L.R.R.C., M.L.L.B., M.J.H.; Supervision, A.G.S.; Project Administration, A.G.S.; Funding Acquisition, A.G.S., L.R.R.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Fundo Mackenzie de Pesquisa e Inovação – MackPesquisa, Universidade Presbiteriana Mackenzie; Conselho Nacional de Desenvolvimento Científico e Tecnológico CNPq; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001", research grant number 12/2021 PDPG Impactos da Pandemia, establishing the Rede RecuperaBR.

 doi:10.20944/preprints202503.1870.v1

Institutional Review Board Statement: The Institutional Ethics Committee of the Pontificia Universidade Católica do Rio Grande do Sul, Porto Alegre-RS, Brazil, approved the study CAAE: 63658122.1.1001.5336, approval date: 11 November, 2022. The experiment was carried out in accordance with the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from parents of all subjects involved in the study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

EF	Executive functions
INEP	Instituto Nacional de Estudos e Pesquisa Educacionais Anísio Teixeira
PISA	Programme for International Student Assessment
SaeB	Basic Education Assessment System
IN	Inhibition
WM	Working memory
CF	Cognitive flexibility
IDEB	Basic Education Development Index
DST	Digit Span Task
WISC IV	Wechsler Intelligence Scale for Children
FVL	Free Verbal Fluency
HT	Hayling Test
CHT	Children's Hayling Test
AHT	Adult`s Hayling Test
TDE II	School Performance
CPM	Raven`s Coloured Progressive Matrices
WASI	Wechsler Abbreviated Scale of Intelligence

References

1. Goldberg, H. Growing brains, nurturing minds: Neuroscience as an educational tool to support students' development as life-long learners. Brain Sciences. **2022**, **12**, 1-12. https://doi.org/10.3390/brainsci12121622
2. Brod, G.; Bunge, S. A.; Shing, Y. L. Does one year of schooling improve children's cognitive control and alter associated brain activation? *Psychological Science.* **2017**, *28*, 967-978. https://doi.org/10.1177/0956797617699838
3. Dehaene, S. The massive impact of literacy on the brain and its consequences for education. *Human Neuroplasticity and Education.* **2011**, *117*, 19-32.
4. Dehaene, S.; Pegado, F.; Braga, L. W.; Ventura, P.; Filho, G. N.; Jobert, A.; Dehaene-Lambertz G.; Kolinsky R.; Morais J.; Cohen, L. How learning to read changes the cortical networks for vision and language. *Science.* **2010**, *330*, 1359-1364. https://doi.org/10.1126/science.1194140
5. Dehaene, S.; Cohen, L.; Morais, J.; Kolinsky, R. Illiterate to literate: Behavioural and cerebral changes induced by reading acquisition. *Nat Rev Neurosci.* **2015**, *16*, 234–244. https://doi.org/10.1038/nrn3924
6. Spelke, E.; Lee, S.A.; Izard, V. Beyond core knowledge: Natural geometry. *Cogn Sci*. **2010,** *34*, 863-884. https://doi.org/10.1111/j.1551-6709.2010.01110.x
7. Wirebring, L. K.; Lithner, J.; Jonsson, B.; Liljekvist, Y.; Norqvist, M.; Nyberg, L. Learning mathematics without a suggested solution method: Durable effects on performance and brain activity. *Trends in Neuroscience and Education.* **2015**, *4*, 6-14. https://doi.org/10.1016/j.tine.2015.03.002
8. Zamarian, L.; Ischebeck, A.; Delazer, M. Neuroscience of learning arithmetic—Evidence from brain imaging studies. *Neuroscience & Biobehavioral Reviews*. **2009**, *33*, 909-925. https://doi.org/10.1016/j.neubiorev.2009.03.002
9. Vadivel, B.; Alam, S.; Nikpoo, I.; Ajanil, B. The impact of low socioeconomic background on a child's educational achievements. *Education Research International*, **2023**, *2023*, Article 6565088, 1-11. https://doi.org/10.1155/2023/6565088

10. Blair, C.; Raver, C. C. Poverty, stress, and brain development: New directions for prevention and intervention. *Academic Pediatrics.* **2016**, *16*, S30–S36. https://doi.org/10.1016/j.acap.2016.01.010
11. Hair, N.L.; Hanson, J.L.; Wolfe, B.L.; Pollak, S.D. Association of Child Poverty, Brain Development, and Academic Achievement. *JAMA Pediatr*. **2015**, *169*, 822-829. https://doi.org/10.1001/jamapediatrics.2015.1475
12. United Nations Children's Fund - UNICEF. *Where are we on education recovery?* Available online: https://www.unicef.org/lac/media/32546/file/Where-are-we-in-education-recovery.pdf (accessed on 8 March 2025).
13. Engzell, P.; Frey, A.; Verhagen, M. D. Learning loss due to school closures during the COVID-19 pandemic. *Proc. Natl. Acad. Sci.* **2021,** *118*, e2022376118. https://doi.org/10.1073/pnas.2022376118
14. Doukakis, S.; Sfyris, P.; Niari, M.; Alexopoulos, E. Exploring educational practices in emergency remote teaching: The role of educational neuroscience. In *2021 IEEE Global Engineering Education Conference (EDUCON),* Viena, Austria, 21-23 April 2021. https://doi.org/10.1109/EDUCON46332.2021.9454143
15. Tortella, G. R.; Seabra, A. B.; Padrão, J.; Diaz-San Juan, R. Mindfulness and other simple neuroscience-based proposals to promote the learning performance and mental health of students during the COVID-19 pandemic. *Brain Sciences.* ***2021,*** *11*, 1-20. https://doi.org/10.3390/brainsci11050552
16. Hachem, M.; Daignault, K.; Wilcox, G. (2022, May. Impact of educational neuroscience teacher professional development: Perceptions of school personnel. *Frontiers in Education.* ***2022***, *7*, 912827. https://doi.org/10.3389/feduc.2022.912827
17. Colvin, M. K.; Reesman, J.; Glen, T. Altered trajectories: Considering the long-term impact of educational disruption during the COVID-19 pandemic on neurodevelopment and a call to action for neuropsychology. *Archives of Clinical Neuropsychology.* ***2024,*** *39*, 305–312. https://doi.org/10.1093/arclin/acae021
18. Andrabi, T.; Daniels, B.; Das, J. Human capital accumulation and disasters: Evidence from the Pakistan earthquake of 2005. RISE Working Paper Series, 20/039. **2020** https://doi.org/10.35489/BSG-RISE-WP_2020/039
19. Rao, N.; Fisher, P. A. The impact of the COVID-19 pandemic on child and adolescent development around the world. *Child Development*, ***2021***, *92*, 738-748. https://doi.org/10.1111/cdev.13653
20. OECD. Securing the recovery, ambition, and resilience for the well-being of children in the post-COVID-19 decade, *OECD Policy Responses to Coronavirus (COVID-19)*. Available online: https://doi.org/10.1787/0f02237a-en. (accessed on 8 March 2025).
21. Hammerstein, S.; König, C.; Dreisörner, T.; Frey, A. Effects of COVID-19-related school closures on student achievement: A systematic review. *Frontiers in Psychology*, ***2021*** *12*, 74628. https://doi.org/10.3389/fpsyg.2021.746289
22. UNDIME – União Nacional dos Dirigentes Municipais de Educação. Caderno de orientação ao dirigente municipal de educação: Fundamentos, políticas e práticas. Available online: https://undime.org.br/uploads/documentos/phpdS3X2e_5ff3095864840.pdf (accessed on 8 March 2025).
23. Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira [INEP]. Available online: https://download.inep.gov.br/censo_escolar/resultados/2023/apresentacao_coletiva.pdf (accessed on 8 March 2025).
24. OECD. PISA 2022 Results (Volume I): The State of Learning and Equity in Education. Available online: https://doi.org/10.1787/53f23881-en (accessed on 8 March 2025).
25. Folha de São Paulo. O que o Saeb revelou sobre os efeitos da Covid-19 na educação. Available online: https://www1.folha.uol.com.br/opiniao/2022/09/o-que-o-saeb-revelou-sobre-os-efeitos-da-covid-19-na-educacao.shtml(accessed on 8 March 2025).
26. Alves, L. M.; Carvalho, I. M.; Dos Santos, L. F.; De Lima Ribeiro, G.; Freire, L. D. S. C.; De Oliveira Martins-Reis, V.; Labanca, L.; Celeste, L. C. Reading fluency during the COVID-19 pandemic: a longitudinal and cross-sectional analysis. *Arquivos de Neuro-psiquiatria.* **2022**, *80*, 994-1003.
27. Fonseca, R. P.; Sganzerla, G. C.; Enéas, L. V. (2020). Fechamento das escolas na pandemia de COVID-19: impacto socioemocional, cognitivo e de aprendizagem. *Debates em Psiquiatria*. **2020**, *10*, 28-37. https://revistardp.org.br/revista/article/view/23

28. Panagouli, E.; Stavridou, A.; Savvidi, C.; Kourti, A.; Psaltopoulou, T.; Sergentanis, T. N.; Tsitsika, A. School performance among children and adolescents during COVID-19 pandemic: A systematic review. *Children*. **2021**, *8*, 1134. https://doi.org/10.3390/children8121134
29. Trotta, E.; Serio, G.; Monacis, L.; Carlucci, L.; Marinelli, C. V.; Petito, A.; Celia, G.; Bonvino, A.; Calvio, A.; Stallone, R.; Esposito, C.; Fantinelli, S.; Sulla, F.; Di Fuccio, R.; Salvatore, G.; Quarto, T.; Palladino, P. The effects of the COVID-19 pandemic on Italian primary school children's learning: A systematic review through a psycho-social lens. *PLoS ONE*. ***2024***, *19*, e0303991. https://doi.org/10.1371/journal.pone.0303991
30. Santos, M. C. C. *Leitura, escrita e aritmética após a pandemia: Estudo com uma escola privada de ensino fundamental I*. Tese de mestrado, Programa de Pós-Graduação da Universidade Presbiteriana Mackenzie. São Paulo, 2024.
31. Davies, C.; Hendry, A.; Gibson, S. P.; Gliga, T.; McGillion, M.; Gonzalez-Gomez, N. Early childhood education and care (ECEC) during COVID-19 boosts growth in language and executive function. *Infant and Child Development*. **2021**, *30*, e2241. https://doi.org/10.1002/icd.2241
32. Chambonnière, C.; Fearnbach, N.; Pelissier, L.; Genin, P.; Fillon, A.; Boscaro, A.; Bonjean, L.; Bailly, M.; Siroux, J.; Guirado, T.; Pereira, B.; Thivel, D.; Duclos, M. Adverse Collateral Effects of COVID-19 Public Health Restrictions on Physical Fitness and Cognitive Performance in Primary School Children. *International journal of environmental research and public health*. **2021**, *18*, 11099. **https://doi.org/10.3390/ijerph182111099**
33. Lavigne-Cervan, R.; Costa-López, B.; Juárez-Ruiz de Mier, R.; Sánchez-Muñoz de León, M.; Real-Fernández, M.; Navarro-Soria, I. Implications of the online teaching model derived from the COVID-19 lockdown situation for anxiety and executive functioning in Spanish children and adolescents. *International Journal of Environmental Research and Public Health*. **2021**, *18*, 10456. https://doi.org/10.3390/ijerph181910456
34. Pandey, A.; Hale, D.; Das, S.; Goddings, A. L.; Blakemore, S. J.; Viner, R. M. Effectiveness of Universal Self-regulation-Based Interventions in Children and Adolescents: A Systematic Review and Meta-analysis. *JAMA pediatrics*. **2018**, *172*, 566–575. https://doi.org/10.1001/jamapediatrics.2018.0232
35. Diamond, A. Executive functions. *Annual Review of Psychology*. **2013**, 64, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750
36. Duncan, G. J.; Dowsett, C. J.; Claessens, A.; Magnuson, K.; Huston, A. C.; Klebanov, P.; Pagani, L. S.; Feinstein, L.; Engel, M.; Brooks-Gunn, J.; Sexton, H.; Duckworth, K.; Japel, C. School readiness and later achievement. *Developmental Psychology*. ***2007***, *43*, 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428
37. Eisenberg, N.; Fabes, R. A.; Guthrie, I. K.; Reiser, M. Dispositional emotionality and regulation: Their role in predicting quality of social functioning. *Journal of Personality and Social Psychology***. 2000**, *78*, 136–157. https://doi.org/10.1037/0022-3514.78.1.136
38. Vitaro, F.; Brendgen, M.; Larose, S.; Trembaly, R. E. Kindergarten Disruptive Behaviors, Protective Factors, and Educational Achievement by Early Adulthood. *Journal of Educational Psychology*. **2005**, *97*, 617–629. https://doi.org/10.1037/0022-0663.97.4.617
39. Dias, N. M.; Seabra, A.G. Funções executivas: desenvolvimento e intervenção. *Temas sobre desenvolvimento*. **2013,** *19*, 206-212.
40. Corso, H. V.; Sperb, T. M.; Salles, J. F. Comparação Entre Maus Compreendedores e Bons Leitores em Tarefas Neuropsicológicas. *Psicologia em Pesquisa*. **2013**, *7*, 37-49. https://doi.org/10.5327/Z1982-1247201300010005
41. Fonseca, G. U. da S.; Lima, R. F.; Ims, R. E.; Coelho, D. G.; Ciasca, S. M. Evidências de validade para instrumentos de atenção e funções executivas e relação com desempenho escolar. *Temas em Psicologia*. **2015**, *23*, 843-858. https://doi.org/10.9788/TP2015.4-04
42. León, C. B. R.; Rodrigues, C. C.; Seabra, A. G.; Dias, N. M. Funções executivas e desempenho escolar em crianças de 6 a 9 anos de idade. *Revista Psicopedagogia*. **2013**, *30*, 113-120.
43. Flor, C. M.; Campos, A. P. S. de; Maia, S. A. A.; Seabra, A. G. Funções Executivas: Correlação entre Dois Inventários e Desempenho Acadêmico em Matemática. *Avaliação Psicológica*. **2020**, *19*, 268-276. https://doi.org/10.15689/ap.2020.1903.15546.05

44. Braak, D.; Lenes, R.; Purpura, D. J.; Schmitt, S. A.; Storksen, I. Why do early mathematics skills and reading achievement? The role of executive function. *Journal of Experimental Child Psychology*. **2022**, 214, 105306. https://doi.org/10.1016/j.jecp.2021.105306
45. Campos, A. P. S. de; Seabra, A. G.; Carreiro, L. R. R. Funções executivas e saúde mental em estudantes durante a pandemia de COVID-19. *Revista Psicopedagógica*. **2023**, *40*, 159-167. https://doi.org/10.51207/2179-4057.20230014
46. Ribeiro, M. R. C. P.; Celeste, L. C.; Reis, V. O. M. The neuropsychological functions of schoolchildren after the reopening of Brazilian schools during the COVID-19 pandemic. *Codas*. **2023**, *36*, e20230013. https://www.scielo.br/j/codas/a/ryKtnNfNrXCfWC9BJq8jrrD/?lang=pt
47. Brito, G.; Leon, C.; Ribeiro, C.; Trevisan, B.; Dias, N.; Seabra, A. Evidence-Based Practices in a Social Project: Promotion of Executive Functions in Children from Northeastern Brazil, Journal of Cognition and Development. **2022**, *23*, 712-731. https://doi.org/10.1080/15248372.2022.2100396
48. Zelazo, P.D.; Blair, C.B.; Willoughby, M.T. *Executive Function: Implications for Education (NCER 2017-2000)*. National Center for Education Research: Washington, DC, USA, 2016. https://ies.ed.gov/ncer/pubs/20172000/pdf/20172000.pdf.
49. Istituto Brasileiro de Geografia e Estatística. Available online: https://cidades.ibge.gov.br/brasil/sp/santo-andre/panorama (accessed on 8 March 2025).
50. Dias, N. M.; Mecca, T. P. Tarefa span de dígitos: descrição e instruções gerais. In *Avaliação Neuropsicológica Cognitiva: memória de trabalho*; Memnon: São Paulo, Brasil, 2019; Volume 4, pp. 122-127.
51. Wechsler, D. Escala Wechsler de Inteligência para Crianças: (WISC-IV): manual de instruções para aplicação e avaliação; Pearson Clinical Brasil: São Paulo, Brasil, 2013.
52. Jacobsen, G.; Prando, M. L.; Pureza, J.; Gonçalves, H. A.; Siqueira, L. S.; Moraes, A. L.; Fonseca, R. P. Tarefas de fluência verbal livre, fonêmica e semântica de crianças. In *Tarefas para avaliação neuropsicológica: avaliação de linguagem e funções executivas em crianças.* Fonseca, R.P.; Prando, M. L.; Zimmermann, N. (Orgs.); Memnon: São Paulo, Brasil, 2016; Volume 1, pp. 26-45.
53. Siqueira, L. S.; Gonçalves, H. A.; Pagliarin, K. C.; Prando, M. L.; Jacobsen, G. M.; Pureza, J.; Moraes, A. L.; Fonseca, R. P. Teste Hayling Infantil: aplicação, registro, pontuação e dados normativos. In *Tarefas para avaliação neuropsicológica: avaliação de linguagem e funções executivas em crianças.* Fonseca, R. P.; Prando, M. L.; Zimmermann, N. (Orgs.); Memnon: São Paulo, Brasil, 2016, Volume 1, pp. 66-87.
54. Mothes, L.; Kristensen, C. H.; Grassi-Oliveira, R.; Fonseca, R. P.; Argimon, I. I. L.; Irigary, T. Q. Childhood maltreatment and executive functions in adolescents. *Child and Adolescent Mental Health*. **2016**, *23*, 75-84. https://doi.org/10.1111/camh.12119
55. Stein, L. M.; Giacomoni, C. H.; Fonseca, R. P. *TDE II: teste de desempenho escolar* (Vol. 1). Vetor: São Paulo, Brasil, 2019.
56. Raven, J.; Raven, J. C.; Court, J. H. *Matrizes progressivas coloridas de Raven: CPM*. Pearson:.São Paulo, Brasil, 2018.
57. Wechsler, D. *Escala Wechsler Abreviada de Inteligência – WASI: manual;* Casa do Psicólogo: São Paulo, Brasil, 2014.
58. Mergulhão, R. C.; de Fátima Pina, M.; Pestana, M. Análise de Dados para Ciências Sociais e da Saúde: a Complementaridade do Python, Jasp, Jamovi e IBM-SPSS. Silabo, 2025.
59. Efron, B. Better Bootstrap Confidence Intervals. *Journal of the American Statistical Association*. **1987,** *82*, 171–185. https://doi.org/10.1080/01621459.1987.10478410
60. Cohen, J. Statistical Power Analysis for the Behavioral Sciences, 2nd ed; Routledge: New York, 1988.
61. Button, K. S.; Ioannidis, J. P.; Mokrysz, C.; Nosek, B. A.; Flint, J.; Robinson, E. S.; Munafò, M. R. Power failure: why small sample size undermines the reliability of neuroscience. *Nature reviews Neuroscience.* **2013**, 14, 365–376. https://doi.org/10.1038/nrn3475
62. Ahmed, T. A. E.; Seleem, H. A. I.; Elsayed, G. M. Y.; Housen, N. T. E.; Sofy, N. M. R. Impact of anxiety caused by the Covid-19 Pandemic on the cognitive activities of primary school students. *Multicultural Education*. **2021,** *7*.
63. Chen, Y. Y.; Yim, H.; Lee, T. H. Negative impact of daily screen use on inhibitory control network in preadolescence: A two-year follow-up study. *Developmental Cognitive Neuroscience*. **2023,** *60*, 101218.

 doi:10.20944/preprints202503.1870.v1

64. Malta Campos, M.; Vieira, L. F. (2021). COVID-19 and early childhood in Brazil: Impacts on children's well-being, education and care. *European Early Childhood Education Research Journal.* **2021**, *29*, 125-140.
65. Adam, G.; Bosco, F. H. The Impact of Covid-19 Pandemic to the Formation of Students Skill Dimension in Elementary School. *Jurnal Elementaria Edukasia*. **2023,** *6*, 693-707.
66. Schult, J.; Mahler, N.; Fauth, B.; Lindner, M. A. Did students learn less during the COVID-19 pandemic? Reading and mathematics competencies before and after the first pandemic wave. *School effectiveness and school Improvement*. **2022**, *33*, 544-563.