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**IMPACT OF COVID-19 ON READING AND ARITHMETIC ACCORDING TO
SCHOOL LEVEL AND SOCIOECONOMIC STATUS: A COMPARISON OF PRE-
AND POST-PANDEMIC COHORTS**

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ABSTRACT

The differential impact of extreme environmental disruptions on learning, such as the COVID-19 pandemic, highlights the need for ongoing research to understand these effects within specific cultural contexts, informing both remedial and preventive strategies. This study examined how the pandemic's impact on learning outcomes varied by school level and socioeconomic status (SES) by comparing the academic performance of pre- and post-pandemic cohorts of Brazilian children. A total of 688 students from 3rd to 5th grade participated. Results indicated significantly lower academic performance in the post-pandemic cohort, demonstrating the pandemic's influence on learning. When controlling for SES, 3rd grade students showed the largest performance gap in reading tasks, while higher grade levels were associated with smaller reading deficits. Conversely, older students exhibited greater gaps in number transcoding skills. SES was a significant risk factor, with lower SES students showing larger performance gaps in both reading and number transcoding tasks. These findings underscore the vulnerability of children in early grades, particularly those from disadvantaged backgrounds, to educational disruptions. Future research should account for children's

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contextual factors to better understand the long-term effects of the pandemic on learning and to inform the development of targeted mitigation strategies.

Keywords: COVID-19; Reading Skills; Mathematics Skills; Environmental Influences.

INTRODUCTION

The occurrence of environmental disruptions, such as extreme weather events, natural disasters, and humanitarian crises, highlights the urgent need for research that examines their impact on multiple aspects, including children's cognitive and academic outcomes. According to a recent report by United Nations International Children's Emergency Fund (UNICEF), in 2024, one in seven students worldwide experienced some form of educational disruption due to extreme environmental events (UNICEF, 2025). Even when academic performance setbacks following disruptive events appear modest, they can have substantial cumulative consequences given the large number of students affected (Sidik 2025). Moreover, students' performance often fails to fully recover after such incidents, suggesting potentially long-lasting effects (Sidik 2025).

Investigating the impact of extreme events on learning aligns with the United Nations Sustainable Development Goals (SDGs), which aim to ensure quality education, reduce inequalities, and promote health and well-being among children (Bhutta et al., 2021). A meaningful way to advance this agenda is by analyzing past large-scale disruptive events to better understand how they have affected children's learning processes, the risk and protective factors involved, and the strategies that have proven most effective in identifying and supporting vulnerable students.

The COVID-19 pandemic caused an unprecedented disruption in formal school settings across the world, interrupting traditional face-to-face teaching as a measure to slow the virus spread. In response, remote learning was implemented across diverse cultural contexts with varying degrees of efficacy, fundamentally altering children's academic experiences during this period (Estrada et al., 2022; Molnár & Hermann, 2023; Storey & Zhang, 2024). As expected, this shift negatively affected children's learning processes, resulting in an overall learning deficit of 0.43 standard deviations in reading and 0.41 in mathematics (Betthäuser et al., 2023;



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Hammerstein et al., 2021; Storey & Zhang 2024). The impact varied according to contextual factors, including socioeconomic status (SES), age and school level, and the duration of school closures and remote learning (Estrada et al., 2022; Jakubowski et al., 2025; Storey & Zhang, 2024).

Research consistently demonstrates that children from low SES backgrounds experience academic disparities compared to their higher SES peers, often due to limited access to quality education, resources, and intellectual stimulation opportunities (Kim et al., 2019; Piccolo & Noble, 2019; Piccolo et al., 2016; Wolf & McCoy, 2019). Additionally, SES-related stressors such as unstable living conditions, limited healthcare access, and food insecurity can adversely affect cognitive development and learning (Masarik & Conger, 2017). The pandemic exacerbated these disparities, as school closures and remote learning disproportionately affected students from disadvantaged backgrounds. Reduced access to in-person instruction, technology, and internet connectivity during lockdowns widened existing educational gaps, making it more challenging for low SES students to maintain learning continuity (Jakubowski et al., 2025; McCoy et al., 2021).

Beyond SES, age and school level also moderated the magnitude of learning loss. A systematic review by Panagouli et al. (2021) found that younger students and those with neurodevelopmental disorders experienced greater learning deficits. A meta-analysis further indicated that younger students in early elementary grades were more negatively affected than older students (König & Frey, 2022). Therefore, evidence suggests that younger children from low SES backgrounds were the most vulnerable to educational disruptions during the pandemic (Betthäuser et al., 2023; Engzell et al., 2021; Hammerstein et al., 2021; Panagouli et al., 2021).

Lockdown duration was another moderating factor. Even in countries with the shortest school closures, such as the Netherlands (eight weeks), students' performance declined approximately three percentile points (0.08 standard deviations; Engzell et al., 2021). Globally, the average duration of school closure was 14 weeks; in Brazil, it reached up to 40 weeks (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2023), the longest among Organization for Economic Co-operation and Development (OECD) countries.



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Moreover, countries with the lowest Programme for International Student Assessment (PISA) 2018 reading scores had the longest school closures, suggesting that students with pre-existing learning gaps had fewer learning opportunities during the pandemic (OECD, 2021).

In Brazil, nearly 1.1 million school-age children and adolescents were not enrolled in school before the pandemic. By November 2020, this number had increased fivefold to over 5 million (UNICEF, 2021). Although academic performance had been gradually improving prior to the pandemic (INEP, 2020), significant learning gaps persisted, especially among public school students from low SES backgrounds (OECD, 2021). Considering this pre-pandemic scenario and Brazil's prolonged school closures, a widening of learning gaps was expected. However, to date, few empirical studies have systematically examined the pandemic's impact on Brazilian students' learning outcomes across different grades, skills, and contextual factors. Some studies have begun to address this question, focusing on specific skills, grades, or regions (Alves et al., 2023; Bartholo et al., 2023; Fonseca et al., 2025; Lichand et al., 2022; Miranda & Baum, 2024; Starling-Alves et al., 2023).

Alves et al. (2023) conducted cross-sectional and longitudinal studies on students from 2nd to 5th grades. The cross-sectional study showed a significant difference only in 2nd grade cohorts of 2020 and 2021, with pre-pandemic students outperforming their pandemic counterparts in reading accuracy. The longitudinal study indicated improvements in fluency and accuracy from March to December 2020, but declines in March 2021, potentially associated with school closures during summer vacation. Miranda and Baum (2024) similarly found persistent learning losses from 2020 to 2021 after school reopening.

Fonseca et al. (2025) reported declines in writing (5th–8th grades), reading (4th–8th grades), and mathematics (4th–9th grades), particularly among students who had been in early grades in 2020. Starling-Alves et al. (2023) observed a one-year delay in reading comprehension and fluency among post-pandemic 2nd to 4th graders compared to pre-pandemic peers. However, this study did not assess arithmetic skills or the interaction between school disruptions, SES, and grade level. Bartholo et al. (2023) examined preschool and early primary students, reporting learning losses of 0.23–0.25 standard deviations, with low SES



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children learning only 48% of expected content compared to 65% for the overall sample. Lichand et al. (2022) analyzed data from national reading and mathematics proficiency from middle and high school students enrolled in 2019 and 2020, and evidenced significant declines, with students achieving only 27.5% of in-person learning equivalence.

In summary, Brazilian students generally experienced negative effects on academic skills due to the pandemic, with low SES students disproportionately affected. Understanding how contextual factors interacted with the pandemic's impact is essential for designing effective strategies to mitigate persistent learning gaps stemming from COVID-19 school closures, as well as for developing tailored preventive measures to address future environmental disruptions. Therefore, the main goal of this study was to examine how the pandemic's impact on learning outcomes differed according to school level and SES, by comparing the academic performance of pre- and post-pandemic cohorts of Brazilian children. Specifically, we assessed number transcoding and word/pseudoword reading accuracy among elementary school students from 3rd to 5th grade.

1. First, we aimed to compare the academic performance of the two cohorts and examine the contribution of school level to performance differences, controlling for SES. We hypothesize that post-pandemic students will perform worse than pre-pandemic students in both reading and number transcoding tasks across all assessed grades. Moreover, the largest performance gap is expected among third graders, who began elementary school at the onset of the pandemic (2020), reflecting their increased vulnerability to educational disruption (König & Frey, 2022; Paganouli et al., 2021).
2. Second, we aimed to assess how SES contributes to performance differences between pre- and post-pandemic cohorts, both overall and by grade. We hypothesize that students from low SES backgrounds in the post-pandemic cohort will show significantly lower scores than their high SES peers, indicating that high SES serves as a protective factor against pandemic-related learning losses, regardless of the academic skill assessed (Bartholo et al., 2023; McCoy et al., 2021).



MATERIALS AND METHODS

Participants

A total of 688 public-school students participated in this study. Data for this study was extracted from two cohorts conducted pre- and post- the COVID-19 pandemic. The pre-pandemic cohort consisted of 461 children from 3rd to 5th grade ($M_{age} = 9.03$; $SD = 0.90$; 55.3% female), and the post-pandemic cohort consisted of 227 children from 3rd to 6th grade ($M_{age} = 9.78$; $SD = 1.22$; 47.6% female). In both cohorts, a convenience sample was used. Researchers reached out to local public schools, inviting them to participate in the research projects. Schools that expressed interest authorized the research team to invite students and parents to participate in the study. The absence of uncorrected sight and/or hearing impairments, as well as the absence of psychological, psychiatric and/or neurological diagnosis as reported by the parents were considered inclusion criteria. The sociodemographic characteristics of the sample are presented in Table 1.

Table 1.

Pre- and post-pandemic cohorts' sociodemographic characteristics

	Pre-pandemic N (%)	Post-pandemic N (%)
Grade		
3 rd	156 (33.8)	59 (26.0)
4 th	251 (54.4)	70 (30.8)
5 th	54 (11.7)	98 (43.2)
State		
Rio Grande do Sul	113 (24.5)	119 (52.4)
Minas Gerais	348 (75.5)	108 (47.6)
Socioeconomic Status (SES)		



Higher-Middle Class/High SES	224 (48.6)	120 (52.9)
Lower-Middle Class/Low SES	237 (51.4)	107 (47.1)
Educational Level (family's main provider)		
Illiterate/Incomplete Elementary School	5 (1.1)	12 (5.3)
Elementary School/Incomplete Junior High	33 (7.2)	24 (10.6)
Junior High/Incomplete Senior High School	88 (19.3)	33 (14.5)
High School/Incomplete Bachelor's	250 (54.8)	101 (44.5)
Bachelor's Degree	80 (17.5)	57 (25.1)

Instruments

Children's Development Questionnaire. The researchers designed this questionnaire to characterize the children's developmental, educational, and clinical history. It includes questions about developmental delays, school attendance, diagnoses, treatments, and medication use.

Brazilian Economic Classification Criterion (ABEP, 2022). The Brazilian Criterion classifies families into six socioeconomic categories (A, B1, B2, C1, C2, D-E). The classification is based on the householder's educational level and the number of home resources, such as vehicles, computers, and other home appliances. Level D-E represents a low SES, levels C1 and C2 represent the lower-middle class, levels B1 and B2 represent the higher-middle class, and level A represents a high SES. Equivalent versions of the Brazilian Criterion were administered at each assessment period (pre and post pandemic).

Word/Pseudoword Reading Task (Salles et al., 2017). The task consists of 39 words (20 regular words and 19 irregular words) and 20 pseudowords controlled by regularity, length, frequency, and lexicality. For each correctly read word, the child received one point, while incorrect reading earned zero points. A total score was calculated based on the number of correct and incorrect responses. Given that this task was structured to present words in order of increasing difficulty, an interruption criterion was adopted. Children were instructed to stop if



they made 20 consecutive errors (i.e., the child read incorrectly 20 words in a row). For each subsequent word that was not presented, the child also received 0 points. The test has validity and reliability evidence, as well as standardized norms by age and school level for Brazilian students from 6 to 12 years old.

Number Transcoding Task (Gomides et al., 2021). The shortened version of the Number Transcoding Task was administered. The task consists of 34 numbers from two to four digits the children must write under dictation in the Arabic format, with no time limit. For each correctly written number, the child received one point, while incorrectly written numbers earned zero points. A total score was calculated based on the number of correct and incorrect responses. Considering that the numbers were presented in order of increasing syntax complexity, an interruption criterion was adopted. Children were requested to stop if they made 12 consecutive errors (i.e., the child wrote incorrectly 20 dictated numbers). For each subsequent number that was not presented, the child also received 0 points. This task presents evidence of validity, reliability, and standardized norms for students from 3rd to 5th grade.

Design and Procedures

This study has a cross-sectional, quasi-experimental design, as it compares the performance of two cohorts, each with non-randomized samples. Data collection and analysis were managed by two research centers located in the Brazilian states of Rio Grande do Sul and Minas Gerais. Both the pre- and post-pandemic cohorts reported in this study were part of larger projects investigating the performance of Brazilian school-age children in reading and mathematical abilities.

In the pre-pandemic cohort, data collection took place between 2010 and 2016, whereas for the post-pandemic cohort, data were collected from May to December 2022. The time gap between cohorts is justified by two main factors. First, in the years preceding the pandemic, Brazilian students' overall academic performance showed stagnation, with no significant improvements observed (INEP, 2020). Although modest gains were noted in reading and arithmetic, these changes were not statistically meaningful. Second, apart from international



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assessments such as PISA, Brazil lacks evidence-based standardized evaluation policies capable of consistently and systematically assessing students' academic performance nationwide. This absence of robust and continuous assessment policies substantially limits the availability of data for research on learning outcomes.

In the pre-pandemic project (protocol numbers 1.023.371 and 939.562), children completed a battery of tasks measuring basic cognitive functions (e.g., executive functions) as well as reading and mathematical abilities (e.g., word and pseudoword reading and numerical transcoding). The post-pandemic research project (protocol number 51814321.0.0000.5334) aimed to analyze the impact of the pandemic on children's academic skills and socioemotional development. For the purposes of this article, we specifically focused on the results from word/pseudoword reading and number transcoding.

Participation in the research projects was conditional upon obtaining written informed consent from parents and oral or written assent from students. All children were evaluated individually by trained psychologists or graduate students. Parents were provided with the Children's Development Questionnaire, along with the Brazilian Economic Classification Criterion (ABEP, 2022) to complete at home, and students returned the completed forms to the researchers. Subsequently, children were individually assessed in person at their schools. In the pre-pandemic cohort, the original paper-and-pencil version of the instruments was administered, whereas in the post-pandemic cohort, the computerized version was administered on tablets using the REDCap platform (Harris et al., 2009).

Families who completed their participation in the research projects received individualized reports on their child's performance in the administered tasks. Children who demonstrated low performance were referred to specialists for comprehensive neuropsychological assessment and/or targeted interventions.

Pilot Study

A pilot study was conducted to test the computerized version of the instruments on the post-pandemic sample. The study included 17 children (5 girls and 12 boys) enrolled in grades 3 to 6 from both public and private schools. Results indicated the need to establish interruption



criteria for the reading and transcoding tasks. For the word/pseudoword reading task, an interruption criterion of 20 consecutive errors was set, while for the transcoding task, the criterion was set at 12 consecutive errors. Additionally, the reading task was specifically adapted for 3rd grade students, with stimuli modified from lowercase to uppercase letters.

Data Analysis

The software SPSS 26 was used for data analysis. Given that the study sample consisted of two cohorts, efforts were made to proportionally match participants' characteristics in terms of SES and gender. Consequently, both the pre- and post-pandemic cohorts had a balanced distribution of participants by SES and gender across each grade level. Since the study focused on contextual rather than individual factors, specific characteristics like gender were excluded from the analysis procedures. This decision is justified as individual factors were outside the study's scope, and preliminary analyses indicated no significant performance differences by gender.

Regarding regional aspects, the study sample included students from two states (Rio Grande do Sul and Minas Gerais). Due to an uneven distribution of participants across certain grade levels, it was not feasible to proportionally pair students by state within each school level. Given the reduced number of students in the post-pandemic cohort and the absence of significant differences in reading and arithmetic performance between the two regions in recent educational censuses (INEP, 2022), the decision was made to analyze the performance of students from both states as a single group. Additionally, due to the smaller number of older students in the post-pandemic sample, 5th grade ($n = 57$) and 6th grade ($n = 41$) students were combined into a single group, as preliminary analyses revealed no significant performance differences were observed between these grade levels.

Descriptive analyses were performed to characterize the groups' performance on administered tasks. Preliminary analyses of normality, variance, and covariance homogeneity were conducted to verify the assumptions for both univariate and multivariate analyses. Children's scores on regular word reading, irregular word reading and pseudoword reading were strongly correlated ($r = .80$), therefore they were included in a multivariate analysis model.



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Even though the number transcoding scores were moderately correlated to the reading scores ($r = .50$), due to the distinctive nature of this skill in relation to reading, children's performance in this task was analyzed in a separate univariate analysis.

A multivariate analysis of covariance (MANCOVA; 2 [pre and post pandemic] x 3 [3rd, 4th, and 5th grade]) was conducted to assess the pandemic's effect on regular, irregular and pseudowords reading performances per school grade adjusting for the children's SES (covariable). Additionally, a univariate analysis of covariance (ANCOVA; 2 [pre and post pandemic] x 3 [3rd, 4th, and 5th grade]) was performed to assess the pandemic's effect on children's number transcoding performance per school grade controlling their SES (covariable). MANCOVA and ANCOVA's effect sizes (η_p^2) were interpreted as: .01 = weak, .06 = medium, .14 = large (Richardson, 2011).

For the multivariate and univariate analyses, the sample's SES was divided into two groups according to the Brazilian Criterion distribution. About half of the pre and post pandemic samples were allocated in the A, B1 and B2 categories, and the other half were allocated in the lower SES categories (C1, C2, D-E). Therefore, the children's SES was analyzed as a dichotomous variable, in which one group represented the higher-middle class and high SES students, and the other represented the lower-middle class and low SES students.

Post-hoc analysis (Bonferroni correction) for the main effects and interaction effects were conducted for ANCOVA and MANCOVA results. Due to the non-normal data distribution and the results of the Levene's and Box M tests, which showed the ANCOVA and MANCOVA assumptions were not met, bootstrapping procedures (1000 resampling; 95 CI Bca) were implemented to improve results' reliability (Haukoos & Lewis, 2005). Pillai's trace was used to interpret MANCOVA's results as it is more robust to violations of model assumptions.

Finally, four separate ANOVAs (4 [pre-pandemic high SES, pre-pandemic low SES, post-pandemic high SES and post-pandemic low SES] x 3 [3rd, 4th, and 5th grade]) were performed to better understand the SES influence on the pandemic and student's grade effects for each task (regular and irregular word reading, pseudoword reading and number



transcoding). Bootstrapping procedures and Bonferroni corrections were also implemented in these post-hoc analyses.

RESULTS

Cohorts' reading and number transcoding performances by school level

A multivariate analysis of covariance (MANCOVA) was conducted to analyze the pandemic's effect on word/pseudoword reading per school grade, and a univariate analysis of covariance (ANCOVA) was conducted to analyze the pandemic's effect on number transcoding per school grade, both controlling for children's SES. Table 2 describes the pre and post pandemic cohorts' performances in the word/pseudoword reading task and number transcoding task.

Table 2.

Pre- and post-pandemic cohorts' reading and number transcoding performances

Task	Grade	Pre-pandemic cohort			Post-pandemic cohort		
		M (SD)	Mdn	Range	M (SD)	Mdn	Range
Regular Words	3 rd	18.12 (3.18)	19	0-20	14.58 (5.93)	17	0-19
	4 th	19.00 (2.07)	19	0-20	16.86 (4.80)	18	0-19
	5 th	19.28 (1.02)	20	16-20	17.84 (3.35)	19	0-19
Irregular Words	3 rd	16.21 (3.86)	17	0-20	12.69 (6.43)	15	0-20
	4 th	18.17 (2.66)	19	1-20	16.33 (5.38)	18	0-20
	5 th	18.36 (2.32)	19	11-20	17.90 (3.78)	19	0-20
Pseudowords	3 rd	16.48 (3.50)	17	0-20	13.29 (6.26)	16	0-20
	4 th	17.23 (2.60)	18	0-20	15.03 (5.37)	17	0-20



	5 th	17.59 (1.94)	18	14-20	15.95 (3.87)	17	0-20
	3 rd	20.53 (11.63)	20	0-34	18.39 (11.39)	16	0-34
Number	4 th	29.85 (7.48)	33	4-34	25.87 (10.52)	31	0-34
Transcoding	5 th	30.78 (6.76)	33	4-34	27.07 (9.34)	32	0-34

Note. Mdn = Median; M = Mean; SD = Standard deviation.

Figure 1 illustrates MANCOVA's and ANCOVA's main results and post-hoc analysis. The multivariate test yielded significant results for both factors: the assessment period (pre- or post-pandemic; Pillai's trace = .09, $F(3, 688) = 22.046$, $p = .001$, $\eta_p^2 = .09$) and children's grade (Pillai's trace = .13, $F(6, 688) = 14.863$, $p = .001$; $\eta_p^2 = .07$), with medium effect sizes. In the multivariate model, the assessment period (pre- or post-pandemic) explained 9% of the variance on the compared groups' mean differences on reading performance, while the children's grade level explained 7%. Their interaction was also significant (Pillai's trace = .02, $F(6, 688) = 2.373$, $p = .02$, $\eta_p^2 = .01$), but with a weak effect size. Finally, the children's SES was a significant covariant in the model (Pillai's trace = .02, $F(3, 688) = 4.983$, $p = .002$; $\eta_p^2 = .02$), presenting a weak effect size. Providing support for the first hypothesis (H1), these findings indicate a significant influence of the pandemic on children's reading performance, as well as a significant interaction with their school grade when controlling for their SES. In-depth results describing the groups' mean differences values and significance are available in appendices Table A.1.

Similarly, ANCOVA's results showed significant effects for both factors: the assessment period (pre- or post-pandemic; $F(1, 688) = 15.226$, $p = .001$, $\eta_p^2 = .02$) and children's grade ($F(2, 688) = 50.723$, $p = .001$; $\eta_p^2 = .13$). On the other hand, in the univariate model, the assessment period (pre- or post-pandemic) had a weak effect size and explained only 2% of the variance on the compared groups' mean differences on number transcoding performance, while the children's grade level explained 13%, presenting a medium effect size.

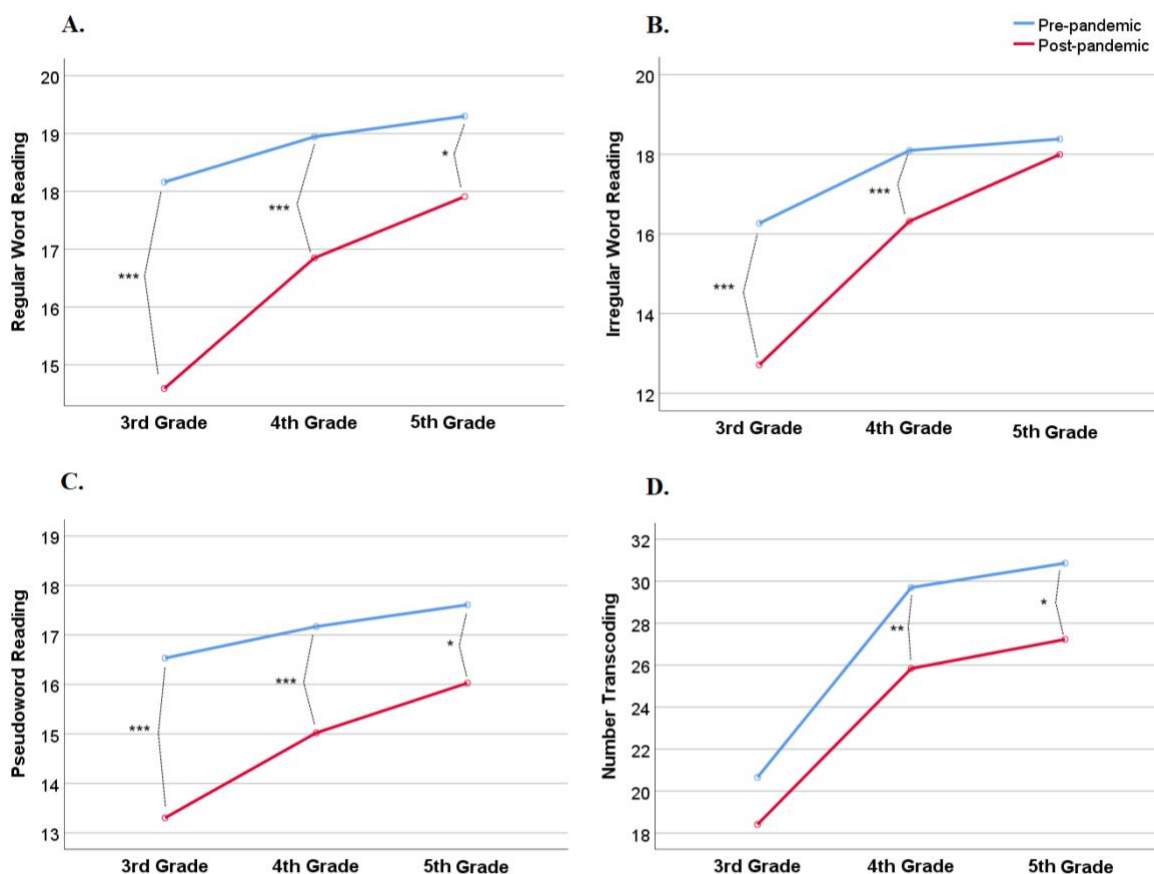


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In this model, their interaction was not significant ($F(2, 688) = .388; p = .67; \eta_p^2 = .01$). Finally, the children's SES was a significant covariant in the model ($F(1, 688) = 9.057; p = .003; \eta_p^2 = .01$), but with a weak effect size. These findings partially support the first hypothesis (H1) as they indicate a significant influence of the pandemic and children's school level in their number transcoding performance when controlling for students' SES, but the interaction between both factors (pandemic and school level) was not significant. In-depth results describing the groups' mean differences and significance are available in appendices Table A.2. To better explore this contrasting result, post-hoc analyses were conducted for both multivariate and univariate models.

Figure 1.

Pre- and post-pandemic cohorts' performances on word/pseudoword reading and number transcoding by school level



Note. A = Pre- and post-pandemic regular word reading performance by school grade; B = Pre- and post-pandemic irregular word reading performance by school grade; C = Pre- and post-pandemic pseudoword reading performance by school grade; D = Pre- and post-pandemic number transcoding performance by school grade; * $p < .05$; ** $p < .01$; *** $p < .001$.

MANCOVA's post-hoc analysis

Post-hoc analysis for the assessment period (pre- and post-pandemic) and school grade effects on word/pseudoword reading tasks are presented in complementary Table A.1. The assessment period was a significant factor in all reading tasks, and the post-pandemic reading performance was significantly lower than the pre-pandemic performance. On the other hand, the school grade effect was only significant between 3rd and 4th grade, and between 3rd and



5th grade, as no significant difference was observed between 4th and 5th grade performances on the reading tasks.

Furthermore, post-hoc analysis for the interaction effects evidenced higher mean differences between the pre- and post-pandemic in 3rd grade students for all three reading tasks. Corroborating the first hypothesis (H1), this result suggests that younger children's reading skills were the most affected by the pandemic. Additionally, 5th grade students had the lower mean differences between the pre- and post-pandemic groups, and no significant difference was found for this schooling range in the irregular word reading task.

ANCOVA's post-hoc analysis

Post-hoc analysis for the assessment period (pre- and post-pandemic) and school grade effects on the number transcoding task are presented in complementary Table A.2. The assessment period was a significant factor in children's transcoding performance, and the post-pandemic performance in this task was significantly lower than the pre-pandemic performance. However, as observed on the reading tasks, the school grade effect was only significant between 3rd and 4th grade, and between 3rd and 5th grade, and no significant difference was found between 4th and 5th grade performances on the number transcoding task.

Additionally, post-hoc analysis for the interaction effects showed that post-pandemic 4th and 5th grade students scored significantly lower than their pre-pandemic peers in the transcoding task. In contrast, no differences were found in 3rd grade performance between the pre and post pandemic sample. Contrary to our expectations (H1), this result indicates that post-pandemic older students suffered a greater learning loss in the number transcoding skill in comparison to their younger peers.

Cohorts' reading and number transcoding performances by SES

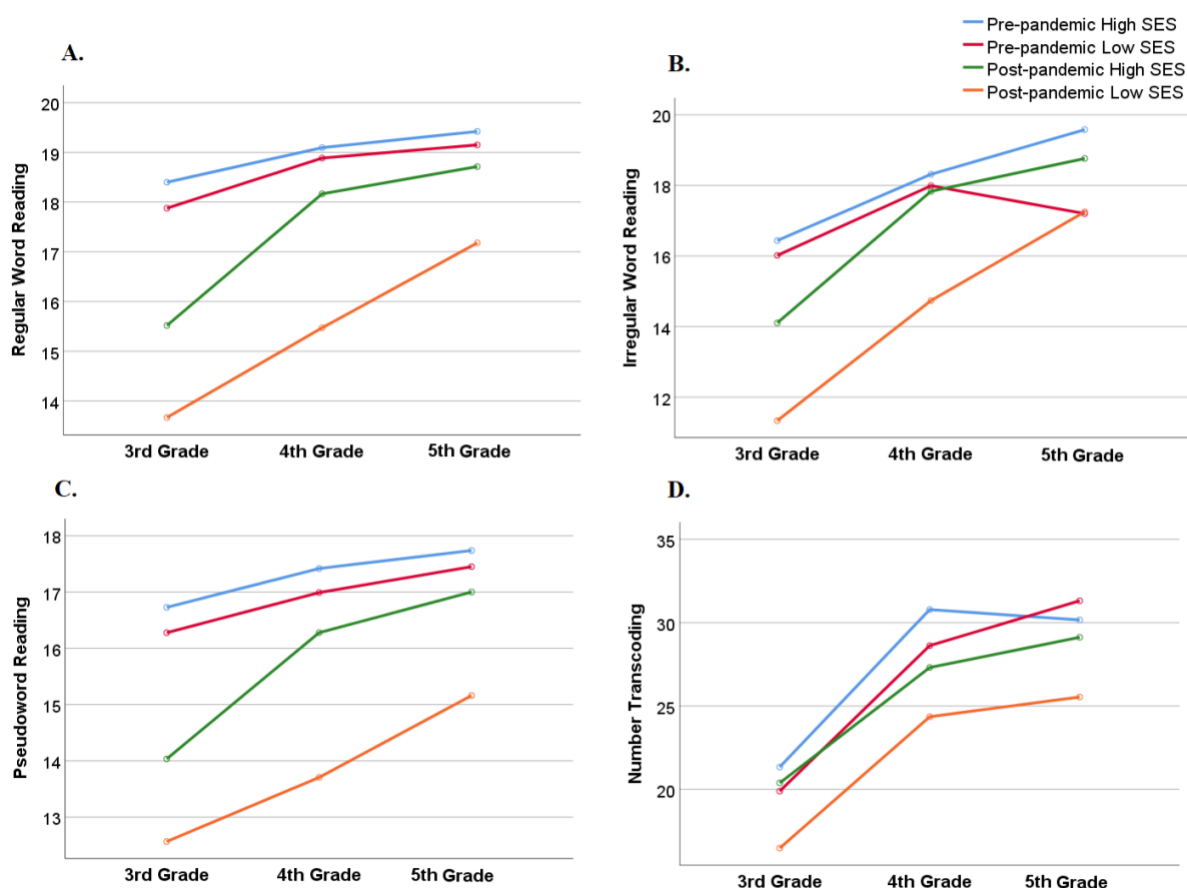
Separate ANOVAs were conducted for each task to analyze the effects of the pandemic and SES on word/pseudoword reading and number transcoding across school grades. Figure 2 presents the ANOVA results for each task. Since the univariate models included factors with multiple levels (4 [pre-pandemic high SES, pre-pandemic low SES, post-pandemic high SES



and post-pandemic low SES] x 3 [3rd, 4th, and 5th grade]), it was not possible to visually represent the significant interactions in the figure. Detailed results, including mean differences and significance levels for each group, are provided in appendices Tables A.3, A.4, A.5, and A.6.

Figure 2.

Pre- and post-pandemic cohorts' performances on word/pseudoword reading and number transcoding by SES across school levels



Note. A = Pre- and post-pandemic regular word reading performance by SES and school grade. B = Pre- and post-pandemic irregular word reading performance by SES and school grade; C = Pre- and post-pandemic pseudoword reading performance by SES and school grade; D = Pre-



and post-pandemic number transcoding performance by SES and school grade. In-depth results describing the groups' mean differences values and significance are available in appendices Tables A.3, A.4, A.5 and A.6.

Cohorts' regular word reading performances by SES and school level

The univariate test revealed significant results for both factors: assessment period (pre- or post-pandemic), separated by SES (low or high SES; $F(3, 608) = 25.781, p = .001, \eta_p^2 = .11$), indicating a medium effect size, and children's grade level ($F(2, 608) = 16.719, p = .001; \eta_p^2 = .05$), with a weak effect size. The interaction between these factors was not significant ($F(6, 608) = 1.540, p = .16; \eta_p^2 = .01$).

Post-pandemic students from both low and high SES backgrounds showed a significant decline in regular word reading performance compared to their pre-pandemic peers with similar SES, supporting the second hypothesis (H2). Although both post-pandemic groups (low and high SES) had significantly lower scores, the performance gap was notably smaller among high SES students in the 4th and 5th grades, indicating a mitigating effect of their socioeconomic background on the pandemic's negative effect (corroborating H2).

However, no significant difference was found between post-pandemic 3rd graders from low and high SES backgrounds. These findings suggest that younger children, regardless of SES, were particularly affected in this task (corroborating H1). Additionally, high SES post-pandemic students scored significantly lower than their pre-pandemic counterparts, emphasizing the pandemic's adverse effect on academic performance even within the high SES group.

Cohorts' irregular word reading performances by SES and school level

The univariate test revealed significant results for both factors: assessment period (pre- or post-pandemic), separated by SES (low or high SES; $F(3, 608) = 18.163, p = .001, \eta_p^2 = .08$) and children's grade ($F(2, 608) = 35.931, p = .001; \eta_p^2 = .10$). Their interaction was significant ($F(6, 608) = 2.642, p = .01; \eta_p^2 = .02$), with a weak effect size.



Post-pandemic 3rd and 5th-grade students from high SES backgrounds scored significantly lower than their pre-pandemic peers. Among low SES students, post-pandemic 3rd and 4th graders showed lower scores compared to their pre-pandemic counterparts in this task. Similar to the regular word reading task, 3rd-grade children from both low and high SES backgrounds displayed the largest mean differences in the irregular word reading task. This result further emphasizes the first hypothesis (H1), highlighting the vulnerability of younger children to the negative influence of the pandemic on their academic performance.

Cohorts' pseudoword reading performances by SES and school level

The univariate test revealed significant results for both factors: assessment period (pre- or post-pandemic), separated by SES (low or high SES; $F(3, 608) = 19.198, p = .001, \eta_p^2 = .08$), with a medium effect size, and children's grade ($F(2, 608) = 9.126, p = .001; \eta_p^2 = .03$), with a weak effect size. Their interaction was not significant ($F(6, 608) = .694, p = .65; \eta_p^2 = .007$).

In this task, performance differences within the high SES group were observed only between pre- and post-pandemic 3rd-grade students, with no significant differences among 4th and 5th graders across the two periods. For the low SES group, however, post-pandemic students at all grade levels scored significantly lower than their pre-pandemic peers. These findings indicate that 4th and 5th-grade students from high SES backgrounds did not experience learning loss in pseudoword reading, while the pandemic's negative influence on this task was primarily observed among low SES 3rd graders. This supports the second hypothesis (H2), highlighting the role of contextual factors (SES and grade level) in the differential influence of the pandemic on learning outcomes.

Cohorts' number transcoding performance by SES and school level

The univariate test revealed significant results for both factors: assessment period (pre- or post-pandemic), separated by SES (low or high SES; $F(3, 608) = 7.524, p = .001, \eta_p^2 = .03$), with a weak effect size, and children's grade ($F(2, 608) = 50.390, p = .001; \eta_p^2 = .13$), with a medium effect size. Their interaction was not significant ($F(6, 608) = .383, p = .89; \eta_p^2 = .003$).



No significant difference was observed in the performance of 3rd-grade students pre- and post-pandemic, regardless of SES. Among 5th-grade students, only those from low SES backgrounds showed a significantly lower score compared to their pre-pandemic peers (supporting H2). Finally, the largest learning gap in number transcoding performance was found among 4th and 5th graders from low SES backgrounds when compared to the pre-pandemic sample. This indicates that older students from disadvantaged backgrounds presented the biggest performance gap on number transcoding after the pandemic.

DISCUSSION

This study aimed to analyze how the pandemic's impact on learning outcomes differed according to school level and SES, by comparing the academic performance of pre- and post-pandemic cohorts of Brazilian children. Overall, the post-pandemic cohort showed lower performance than the pre-pandemic cohort, with the largest gaps observed among younger students and those from low SES backgrounds, although the magnitude and nature of these gaps varied across academic skills.

Reading and number transcoding performances by school level

Consistent with our first hypothesis (H1), post-pandemic students performed significantly worse than pre-pandemic students on both reading and number transcoding tasks, highlighting the pandemic's negative influence on learning. The interaction between pandemic effects and grade level revealed differential impacts: younger children (3rd graders) exhibited the largest gaps in reading, while older children (5th graders) showed the smallest differences, with no significant gap in irregular word reading. Conversely, in number transcoding, older students (4th and 5th graders) were more affected, while 3rd graders showed no significant differences.

Third graders in the post-pandemic cohort began elementary school in 2020, at the onset of the pandemic, starting their literacy learning amid school closures and remote instruction. The absence of in-person schooling during this critical period likely hindered language



Revista AMazônica, LAPESAM/GMPEPPE/UFAM/CNPq- GPPFE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

development, leaving them more susceptible to reading deficits than older students who had already acquired foundational literacy skills (König & Frey, 2022; Paganouli et al., 2021). These results suggest that the pandemic's impact on reading depended on the school level during which students experienced educational disruptions, disproportionately affecting early-grade students transitioning from early childhood education to remote learning (Shatil & Share, 2003).

Considering that word-level reading skills can be analyzed by stimulus type (regular words, irregular words, and pseudowords), this study assessed students' reading performance across three different tasks to account for each type. The results showed a significant negative effect of the pandemic on reading for 3rd and 4th graders across all types, indicating broad learning gaps. In contrast, this effect was not observed for 5th graders, who showed no significant differences in reading irregular words in the post-pandemic cohort. Irregular word reading relies on the use of the lexical route (Coltheart, 2006; Gough & Tunmer, 1986), which develops with reading practice. Fifth graders are generally more likely to engage in independent reading than younger students, providing them with more opportunities to practice reading outside the classroom. Consequently, it appears that children in this age group, even without consistent access to formal education, were able to engage in alternative reading practices during the pandemic, contributing to the smaller learning gaps observed in their reading performance post-pandemic (Locke et al., 2021).

Regarding number transcoding, a greater performance gap was observed among 4th-grade students in the post-pandemic cohort, while no significant difference was found for 3rd graders when comparing performances across cohorts. Contrary to the initial hypothesis, the pandemic's detrimental influence on number transcoding was significant only among 4th and 5th graders. These findings align with those of Locke et al. (2021), who showed that students in earlier school levels experienced the least learning loss in mathematics during COVID-19.

As students progress in school, the complexity of math concepts increases, which can make it more challenging to retain learning gains. In this study, mathematical ability was assessed through a number transcoding task, a foundational math skill. Being able to manipulate



numbers and convert them from one format into another is one of the first steps in children's mathematical learning, typically starting in kindergarten (Lopes-Silva et al., 2014). From a neuropsychological perspective, it is expected that by 4th grade, most children will have fully acquired this skill (Lopes-Silva et al., 2014). Therefore, the higher incidence of errors in this basic math skill among 4th and 5th graders in the post-pandemic cohort suggests learning gaps, as these students experienced school closures and remote learning during the period when they would normally consolidate this skill.

Reading and number transcoding by socioeconomic status

Regarding SES, children from low SES backgrounds were more vulnerable to post-pandemic learning gaps in both reading and number transcoding, whereas high SES students showed smaller or no significant differences. These findings support our second hypothesis (H2) and align with previous research showing that socioeconomic disadvantages compound educational vulnerabilities during crises, through mechanisms such as reduced cognitive stimulation, limited access to resources, and increased household stress (Sheridan & McLaughlin, 2016; Bartholo et al., 2023; McCoy et al., 2021).

Specifically, 3rd grade students from low SES backgrounds showed the largest gaps in reading, while 5th graders from low SES families exhibited pronounced deficits in number transcoding. High SES appeared to serve as a protective factor, mitigating the pandemic's negative effects regardless of the specific skill assessed. These results underscore the critical interaction between age, grade level, and SES in determining learning outcomes during periods of educational disruption.

Integrating contextual factors and implications

The combined analysis of school level and SES highlights that the pandemic did not uniformly affect all students. Younger children, particularly those from disadvantaged backgrounds, were most at risk for learning losses, emphasizing their vulnerability (Bartholo et al., 2023; Engzell et al., 2021; McCoy et al., 2021). Of particular concern is the observed



Revista AMazônica, LAPESAM/GMPEPPE/UFAM/CNPq- GPPFE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

performance gaps on foundational skills such as reading and math (word/pseudoword reading and number transcoding), which are critical for developing more advanced skills like reading comprehension and problem-solving in later school years.

It is important to note that all participants in this study attended public schools, reflecting the Brazilian reality in which most children are enrolled in public education (80.4% in grades 1–5; 83% in grades 6–9; INEP, 2025). The public system faced substantial challenges in implementing effective remote teaching, with over 93% of schools unable to fulfill all mandated pedagogical activities during the pandemic (Comitê Gestor da Internet no Brasil [CGI], 2023). Moreover, Brazil experienced prolonged school closures, far exceeding the global average, intensifying the risk of widespread learning losses (UNESCO, 2023; Starling-Alves et al., 2023). These systemic challenges underscore the need for targeted interventions to support students most affected by educational disruptions.

FINAL CONSIDERATIONS

This study presented significant strengths, particularly in its inclusion of a diverse and considerably extensive sample who underwent individual in-person assessments. Our findings contribute empirical data on the negative influence of the pandemic on children's academic skills, highlighting the differential impact on learning based on school level and SES backgrounds. Studying this topic is crucial given the scarcity of research conducted in Brazil, a country that has experienced an extensive period of school closures and remote learning. Additionally, considering the Brazilian context, as well as that of other developing countries with substantial sociocultural disparities, the results emphasize the importance of incorporating contextual factors when analyzing events that may be detrimental to children's learning, such as natural disasters or other large-scale stressors. This approach allows for the identification of more vulnerable groups and facilitates the development of better-targeted mitigation strategies.

However, this study had some limitations. First, the cross-sectional design restricted the ability to draw conclusions regarding the direct effects of the pandemic on academic achievement, as it precluded establishing causal relationships or tracking changes over time.



Revista AMazônica, LAPESAM/GMPEPPE/UFAM/CNPq- GPPFE/UFAM/CNPq
ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

Second, by the time the post-pandemic sample was assessed in 2022, schools had resumed in-person activities, and improvements had been made in integrating regular classes with remote learning. Consequently, the performance gaps observed in this study, although significant, may underestimate the true impact of the pandemic, since children had access to in-person education and mitigation strategies during this period.

Third, this study considered only children's school level and SES as contextual factors, whereas other environmental characteristics may also have influenced the pandemic's effects on learning and could inform the development of more tailored mitigation strategies. Future research should explore additional contextual factors, as well as other aspects of reading and mathematics, such as reading comprehension and problem-solving skills. Moreover, studies should examine the role of individual characteristics, including students' gender, cognitive abilities, and socioemotional skills, in shaping the impact of extreme disruptions on learning.

In conclusion, this study provides empirical evidence on how the COVID-19 pandemic and the shift to remote learning may have differentially affected the reading and number transcoding skills of Brazilian students according to their SES and grade level. The findings revealed larger performance gaps in the post-pandemic cohort, particularly among younger students and those from lower socioeconomic backgrounds, underscoring the critical role of school level and SES in shaping learning outcomes. Continued research is essential to elucidate the medium- and long-term effects of the pandemic on children's academic development, highlighting the need for sustained interventions and targeted strategies to support students in the post-pandemic context.

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ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

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APPENDICES

Table A.1.

Assessment period (pre- or post-pandemic) and school grade effects on word/pseudoword reading performance

Reading Task	Main Effects	Compared Groups ($x - y$)	Mean Difference	CI (95% BCa)	
				Inferior	Superior



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	Period	Pre- pandemic	Post- pandemic	2.35****	1.73	2.97	
Regular Words			4 th	-1.52****	-2.36	-.67	
	School Grade	3 rd	5 th	-2.22****	-3.22	-1.23	
			4 th	5 th	-.70	-1.65	.23
	Period	Pre- pandemic	Post- pandemic	1.90***	1.18	2.62	
Irregular Words			4 th	-2.71***	-3.70	-1.73	
	School Grade	3 rd	5 th	-3.69****	-4.85	-2.54	
			4 th	5 th	-.98	-2.07	.11
	Period	Pre- pandemic	Post- pandemic	2.32***	1.61	3.02	
Pseudowords			4 th	-1.17**	-2.13	-.22	
	School Grade	3 rd	5 th	-1.90****	-3.02	-.77	
			4 th	5 th	-.72	-1.79	.34
Task	Interaction Effects	Compared Groups (x - y)		Mean Difference	CI (95% BCa)		
					Inferior	Superior	
Regular Words	3 rd	Pre- pandemic	Post- pandemic	3.57***	2.52	4.61	



	4 th	Pre-pandemic	Post-pandemic	2.09***	1.19	3.00
	5 th	Pre-pandemic	Post-pandemic	1.39*	.14	2.64
	3 rd	Pre-pandemic	Post-pandemic	3.55***	2.33	4.77
Irregular Words	4 th	Pre-pandemic	Post-pandemic	1.77***	.73	2.82
	5 th	Pre-pandemic	Post-pandemic	.38	-1.05	1.83
	3 rd	Pre-pandemic	Post-pandemic	3.22***	2.04	4.41
Pseudowords	4 th	Pre-pandemic	Post-pandemic	2.14***	1.12	3.17
	5 th	Pre-pandemic	Post-pandemic	1.58*	.16	2.99

Note. * $p < .05$; *** $p < .001$; BCa = Bias corrected accelerated; CI = confidence interval.

Table A.2.

Assessment period (pre- or post-pandemic) and school grade effects on number transcoding performance

Main Effects	Compared Groups ($x - y$)	Mean Difference	CI (95% BCa)	
			Inferior	Superior



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ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

Period	Pre-pandemic	Post-pandemic	3.24***	1.46	4.90
School Grade	3 rd	4 th	-8.24***	-10.32	-6.20
		5 th	-9.51***	-11.67	-7.30
		4 th 5 th	-1.27	-3.13	.61
Interaction Effects	Compared Groups (x - y)		Mean Difference	CI (95% BCa)	
				Inferior	Superior
3 rd	Pre-pandemic	Post-pandemic	2.24	-.94	5.42
4 th	Pre-pandemic	Post-pandemic	3.86**	1.08	6.60
5 th	Pre-pandemic	Post-pandemic	3.63*	1.15	6.03

Note. * $p < .05$; ** $p < .01$; *** $p < .001$; BCa = Bias corrected accelerated; CI = confidence interval.

Table A.3.

Pre- and post-pandemic regular word reading performance by SES and school grade

School Grade	Compared Groups (x - y)		Mean Difference	CI (95% BCa)	
				Inferior	Superior
3 rd	Pre-Pandemic High SES	Pre-Pandemic Low SES	.52	-.60	1.62



			Post-Pandemic High SES	2.88***	1.01	4.76
			Post-Pandemic Low SES	4.73***	2.36	7.37
Pre-Pandemic SES	Low	Post-Pandemic High SES	2.36**	.38	4.41	
		Post-Pandemic Low SES	4.21***	1.78	6.86	
	Post-Pandemic High SES	Post-Pandemic Low SES	1.85	-1.15	5.08	
	Pre-Pandemic SES	High	Pre-Pandemic Low SES	.20	-.30	.75
Post-Pandemic High SES			.92*	.33	1.64	
High		Post-Pandemic Low SES	3.62***	1.66	5.70	
		Low	Post-Pandemic High SES	.71	.11	1.42
Low	Post-Pandemic Low SES		3.41***	1.50	5.50	
	Post-Pandemic High SES	Post-Pandemic Low SES	2.69**	.64	4.86	



5 th	Pre-Pandemic SES	Pre-Pandemic Low SES	.27	-.35	.88
		Post-Pandemic High SES	.70**	.24	1.07
	Pre-Pandemic SES	Post-Pandemic Low SES	2.24***	1.23	3.42
		Post-Pandemic High SES	.43	-.16	.94
	Pre-Pandemic SES	Post-Pandemic Low SES	1.97***	.92	3.15
		Post-Pandemic High SES	1.53**	.56	2.66

Note. * $p < .05$; ** $p < .01$; *** $p < .001$.

Table A.4.

Pre- and post-pandemic irregular word reading performance by SES and school grade

School Grade	Compared Groups (x - y)	Mean Difference	CI (95% BCa)	
			Inferior	Superior
3 rd	Pre-Pandemic SES	Pre-Pandemic Low SES	.42	- .92 1.83
		Post-Pandemic High SES	2.33*	.21 4.62



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ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

4 th	Pre-Pandemic Low SES	Post-Pandemic Low SES	5.10***	2.71	7.84
		Post-Pandemic High SES	1.91	-.27	4.23
		Post-Pandemic Low SES	4.68***	2.15	7.41
	Post-Pandemic High SES	Post-Pandemic Low SES	2.77	-.28	6.25
	Pre-Pandemic High SES	Pre-Pandemic Low SES	.32	-.37	1.15
		Post-Pandemic High SES	.48	-.60	1.84
		Post-Pandemic Low SES	3.58**	1.60	5.53
	Pre-Pandemic Low SES	Post-Pandemic High SES	.15	-1.06	1.43
		Post-Pandemic Low SES	3.25**	1.24	5.37
		Post-Pandemic High SES	3.09*	.84	5.27
5 th	Pre-Pandemic High SES	Pre-Pandemic Low SES	2.37***	1.29	3.53



		Post-Pandemic High SES	.81*	.19	1.50
		Post-Pandemic Low SES	2.32***	1.17	3.70
Pre-Pandemic SES	Low	Post-Pandemic High SES	-1.56*	-3.14	-.17
		Post-Pandemic Low SES	-.50	-1.78	1.63
	High	Post-Pandemic High SES	1.51*	.27	2.96
		Post-Pandemic Low SES			

* $p < .05$; ** $p < .01$; *** $p < .001$

Table A.5.

Pre- and post-pandemic pseudoword reading performance by SES and school grade

School Grade	Compared Groups ($x - y$)		Mean Difference	CI (95% BCa)	
				Inferior	Superior
3 rd	Pre-Pandemic SES	Pre-Pandemic Low SES	.45	-.83	1.80
		Post-Pandemic High SES	2.69*	.55	4.82
		Post-Pandemic Low SES	4.16**	1.83	6.68



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ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

4 th	Pre-Pandemic SES	Low	Post-Pandemic High SES	2.24	.233	4.38
			Post-Pandemic Low SES	3.71**	1.41	6.38
		High	Post-Pandemic Low SES	1.46	-1.89	4.95
			Pre-Pandemic Low SES	.42	-.25	1.18
		High	Post-Pandemic High SES	1.14	.04	2.52
			Post-Pandemic Low SES	3.71***	1.16	6.06
	Pre-Pandemic SES	Low	Post-Pandemic High SES	.71	-.40	2.10
			Post-Pandemic Low SES	3.28**	1.00	5.65
		High	Post-Pandemic Low SES	2.57*	.11	5.12
			Pre-Pandemic Low SES	.28	-.88	1.58
		High	Post-Pandemic High SES	.73	-.20	1.70
			Pre-Pandemic High SES			



		Post-Pandemic Low SES	2.57***	1.26	3.87
Pre-Pandemic SES	Low	Post-Pandemic High SES	.45	-.75	1.54
		Post-Pandemic Low SES	2.28**	.72	3.83
	High	Post-Pandemic Low SES	1.83**	.51	3.20

* $p < .05$; ** $p < .01$; *** $p < .001$

Table A.6.

Pre- and post-pandemic number transcoding performance by SES and school grade

School Grade	Compared Groups (x - y)	Mean Difference	CI (95% BCa)	
			Inferior	Superior
3 rd	Pre-Pandemic Low SES	1.44	-2.12	5.23
	Pre-Pandemic High SES			
	Post-Pandemic High SES	.95	-3.96	6.09
	Post-Pandemic Low SES	4.86	.37	9.34
	Pre-Pandemic Low SES			
	Post-Pandemic High SES	-.49	-5.40	4.72



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ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

4 th	Post-Pandemic Low SES		3.41	-1.32	7.69
	Pos-Pandemic High SES	Post-Pandemic Low SES	3.91	-1.73	8.87
	Pre-Pandemic Low SES		2.16*	.35	4.20
	Pre-Pandemic High SES	Post-Pandemic High SES	3.47*	.68	6.60
	Post-Pandemic Low SES		6.43**	2.66	10.25
	Pre-Pandemic Low SES	Post-Pandemic High SES	1.31	-1.79	4.60
		Post-Pandemic Low SES	4.26*	.24	8.19
	Post-Pandemic High SES	Post-Pandemic Low SES	2.95	-1.75	7.76
	Pre-Pandemic Low SES		-1.15	-4.80	2.37
	Pre-Pandemic High SES	Post-Pandemic High SES	1.04	-3.13	4.66
5 th	Post-Pandemic Low SES		4.62*	.20	8.26



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ISSN 1983-3415 (versão impressa) - eISSN 2558 – 1441 (Versão digital)

Pre-Pandemic Low SES	Post-Pandemic High SES	2.19	-.77	5.56
	Post-Pandemic Low SES	5.77***	2.27	9.19
	Post-Pandemic High SES	3.58*	.04	6.72
	Post-Pandemic Low SES			

* $p < .05$; ** $p < .01$; *** $p < .001$