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Developmental Losses of Preschool Children Three Years into the COVID-19 Pandemic

Alejandro Vásquez-Echeverría[1,2] · Meliza Gónzalez[1,2] · Tianna Loose[3] · Matilda Ciganda[1,2] · Belén Díaz[1,2] · Maite Liz[1,2] · Clementina Tomás-Llerena[1,2] · Sylvana M Côté[3]

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Abstract
The COVID-19 pandemic and resulting mitigation measures have led to increased vulnerabilities in early child development. However, research is scarce and there are no studies on the persistence of these losses three years into the pandemic among young children. To fill in this gap, we examined census-like evaluations of school readiness carried out among preschoolers in Uruguay. The assessments were carried out among 5 cohorts of 5-year-olds: who were assessed prior to the pandemic (2018, 2019); during the pandemic (2020, 2021); and after the health emergency declaration ended in Uruguay (2022). A total of 180,984 teacher evaluations were included covering cognitive, motor and socio-emotional development, as well as attitudes toward learning. Overall, we found that scores in most spheres of child development decreased from before to during the pandemic in 2020 and 2021. In 2022, scores returned to pre-pandemic levels. Our findings suggest the recovery of developmental losses among cohorts of children in kindergarten took more than two years in a country that experienced a mild-to-moderate impact of the COVID-19 pandemic.

Keywords School readiness · COVID-19 · School closure · Child development · Preschool

Introduction

Mounting evidence suggests that the COVID-19 pandemic and resulting mitigation measures (e.g., school closures) were negatively associated with child development (Hammerstein et al., 2021; Gonzalez et al., 2022). Though findings among preschoolers are scarce, a recent study compared school readiness scores of preschool children from before (2018, 2019) to during the COVID-19 pandemic (2020, as schools reopened). The authors found significant decreases in most developmental domains assessed, namely cognitive and motor development, internalizing behaviors, and attitudes towards learning (range 0.13 – 0.27 standard deviations) with less pronounced losses among those with high socio-economic status (Gonzalez et al., 2022). Building on these findings, we aim to investigate levels of school readiness three years into the COVID-19 crisis. To study the long-term changes following the COVID-19 pandemic on early child development, we compared levels of school readiness from before the pandemic (2018, 2019) and to those observed over the course of the pandemic as mitigation measures progressively eased (2020, 2021) and ended (2022). The year 2022 represents the period after mitigation measures ended, hereafter referred to as '*post-pandemic period*'. Our study will help answer questions such as: How do levels of school readiness among preschoolers in 2021, two years after the onset of the pandemic, compare to levels observed in 2020 and to pre-pandemic levels? In 2022, after pandemic mitigation measures were over, did scores return to pre-pandemic levels?

The COVID-19 Pandemic and Child Development

There is solid evidence that the prevention and protection measures related to the COVID-19 pandemic are associated with declines in academic achievement and mental health

✉ Alejandro Vásquez-Echeverría
alejandro.vasquez@pedeciba.edu.uy

1 Interdisciplinary Center on Cognition in Teaching and Learning, Universidad de la República, Montevideo, Uruguay

2 Faculty of Psychology, Universidad de la República, Montevideo, Uruguay

3 École de Santé Publique, Université de Montréal, Montreal, Canada

among youth (Holla, 2023 for a review). Additionally, a limited number of studies suggest that motor development and motivation to learn were negatively impacted within the context of the pandemic. Notably, a systematic review found that academic achievement in primary and secondary education during remote learning was similar to those observed during summer recess, with remote education being comparable to no school (Hammerstein et al., 2021). Of note, the declines were slightly more pronounced among younger learners (Tomasik et al., 2021). For instance, in 2020 in the United States, 3rd to 8th grade students' mathematics scores were five to ten percentage points lower than those observed in 2019 (Kuhfeld et al., 2020). During an 8-week lockdown in the Netherlands, Engzell et al. (2021) found that scores on standardized tests of math, spelling and reading were 3 percentile points lower among school-age children exposed to lockdown in comparison to pre-pandemic levels, and these differences were more pronounced among children whose parents were less educated. In 2020 in Belgium, Maldonado and De Writte (2022) found that elementary school students' mathematics and language scores were 0.17–0.19 SD points lower than pre-COVID-19 levels. In Canada, Côté et al. found that scores in reading in grade 4 were 8 points lower in 2021 compared to 2019, with differences more pronounced among lower-performing children (up to 20 percentage points lower) (Cote et al., 2023).

Only a paucity of studies provides reliable information on changes related to mental health and motor development in preschool or kindergarten children. A systematic review on children and adolescents (including a few studies on preschool children) found that mental health symptoms increased levels from before to during the pandemic (Kauhanen et al., 2022). For instance, preschoolers in the United States showed increased depressive and externalizing symptoms during the lockdown in comparison to pre-COVID-19 levels, according to their mothers (Glynn et al., 2021). In Italy, mothers reported higher levels of emotional and self-regulation problems among young children during the pandemic (Di Giorgio et al., 2021). As for motor development, a study found marked decreases in motor skills among 6 to 9-year-olds from before to after the lockdown (Pombo et al., 2021). Lastly, a study found that academic motivation (e.g.: self-initiative to do homework, effort allocated to get higher grades) as reported by parents decreased from before to during the pandemic among 1st to 9th-grade students in Italy and Portugal (Zaccoletti et al., 2020).

Importantly, there is only one study focusing specifically on losses in school readiness using comprehensive developmental measures (Gonzalez et al., 2022). Further, the extent to which losses could persist during the second year of the pandemic (2021) and afterwards (2022) has never been investigated to our knowledge. Analyzing trends in school readiness during these years is crucial, as this construct comprises the key developmental skills, knowledge, and attitudes of young children that are related to a successful transition to primary school, later academic achievement, and life trajectories (Duncan et al., 2007; Williams et al., 2019). Gonzalez et al. (2022) showed that scores in school readiness were lower than expected during the 1st year of the pandemic, but it is unclear if these scores remain low two years into the crisis and after the health emergency declaration was over (2022). Initially, experts made alarming projections concerning putative losses in child social and cognitive development in the context of the pandemic related disruptions. For instance, McCoy et al. (2021) estimated that 10.75 million children were likely to fall "off track" as a result of early education services closures during the first 11 months of the pandemic. Bao et al. (2020) estimated kindergarteners' reading abilities would drop by 31% in nine months in the absence of formal in-person education. Educational researchers forecasted that math and reading achievement gaps among children from lower and higher socioeconomic status would change from 1.00 (pre-COVID) to 1.25–1.30 by Spring 2021, with similar predictions for 2022 (Bailey et al., 2021). These learning losses projections received some support for school-aged children (Betthäuser et al., 2023). However, empirical evidence supporting such important social and cognitive losses among preschool and kindergarten children is scarce. Further, and despite some variability among countries, the COVID-19 crisis has lasted longer than other previous global health-related events which would likely translate to a longer-lasting impact on learning and child development (Benner & Mistry, 2020). Furthermore, this prolonged period of crisis due to COVID-19 provoked normative life-course disruptions that may impact individuals differently depending on their age or developmental timing (National Academies of Sciences, Engineering, and Medicine, 2023; Settersten et al., 2020). In particular, early childhood and the transition to primary school are very sensitive periods of life because of, for example, rapid brain development as well as the societal expectations and educational demands children face (Benner & Mistry, 2020). Thus, persistent losses in school readiness may affect the well-being of large cohorts of children in the long term.

Based on these premises, we might expect that levels of school readiness observed among preschoolers during the first year of the pandemic (2020) will be comparable to those observed two years into the COVID-19 crisis (2021) and maybe even persist into 2022. It is critical to determine if cumulative detrimental effects are observed or if developmental recovery is taking place. Furthermore, it is relevant to examine if some interaction between socioeconomic status (SES) and developmental changes across this time occurred. The urgency and depth of remedial actions could be addressed with this information.

Context of the Current Study

Given the heterogeneous unfolding of the pandemic and varying government responses, potential changes in child development and learning as a result of pandemic related disruptions could vary substantially within and between contexts (Goudeau et al., 2021), and research should be contextualized accordingly. This study was conducted in Uruguay, a country in South America with a population of approximately 3.5 million. The preschool system in Uruguay (*Educación Inicial*) covers age 3, 4, and 5 classrooms (i.e., kindergarten) and is compulsory to attend starting at age 4 years. Uruguay has a long-established public education system that provides services to families at no cost. It covers approximately 82% of the enrollment of each cohort of preschoolers via a strong network of centers across the country, including remote rural areas and all socioeconomic districts. The school year runs from March to mid-December. In 2020, lockdowns were not mandatory but non-essential services (e.g., restaurants), borders (e.g., international flights), and schools were closed. A summary of the timeline of school closures is shown in Table 1. In 2020, face-to-face classes were conducted with adaptations based on the specific characteristics of each educational institution, taking into account the favorable sanitary conditions at that time (González et al., 2022). The average attendance per child was 50 days during the year across all preschool education, but exceptionally attendance for Age 4 and 5 classrooms was not mandatory because of the pandemic context. Thus, many children were supported via virtual lessons whereas others lost contact with schools. In 2021, there were still disruptions to in-person classes mostly during the first semester. On March 1, 2021, early education began without restrictions but was suspended on March 24, 2021 until May 3 2021, with varying disruptions across areas and centers thereafter (ANEP-DGEIP, 2022; Presidencia de la República, 2022) due to larger waves of infections. In 2021 5-year-olds attended 105.3 out of 158 school days on average, but attendance was lower in centers from less privileged districts, varying between 90.5 days for the lowest quintile and 110.4 in the highest quintile (ANEP-DGEIP, 2022). On April 5, 2022, the government declared an end to the state of national sanitary emergency due to the significant and continued decline in COVID-19 infections, coupled with a high vaccination rate among the population. In 2022, there were no disruptions to the school calendar and classes started normally on March 7th, 2022. In preschools, children attended on average 133 days out of 180 days schools were open (ANEP-DGEIP, 2023).

Concerning the country's economic performance, with the onset of the pandemic, unemployment increased, and GDP fell by 5.9% in 2020 (BCU, 2021). When restrictions eased, especially from the summer of 2021 onwards, GDP rose by 2.4% compared to 2020, and that trend continued in 2022 with an increase of 4,9% compared to 2021 (BCU, 2023). Aside from the pandemic and associated economic situation, there were no major changes in Uruguay or its education system from 2018 to 2022. Minor changes in the country were all improvements and would lead to underestimating effect sizes. These included a gradual decrease in the number of births (from approximately 49,000 in 2015 to 32,000 in 2022) that led to a reduction in preschools class

Table 1 Schedule for the return to face-to-face classes for Early childhood Education in Uruguay (for years 2020, 2021, 2022) and average of days taught per year

Year	Days taught (M)	Date	Characteristics
2019	184		
2020	80.6		
		March 1st	First day of classes. Mandatory and face-to-face
		March 16th	Suspension of face-to-face classes
		June 15th	Face-to-face classes return in early childhood education (optional assistance)
		October 13th	Mandatory classes are retaken from pre-kinder onwards
2021	158		
		March 1st	First day of classes. Mandatory and face-to-face
		March 24th	Suspension of face-to-face classes
		May 3rd	Face-to-face classes return in early childhood education
		June 21th	Mandatory classes are retaken from pre-kinder onwards
2022	180		
		March 6th	First day of classes. Mandatory and face-to-face
		April 5th	Decree ending the state of emergency
		December 16th	Last day of the academic year. Mandatory and face-to-face

Note: Data extracted from ANEP-DGEIP (2021a, 2021b, 2022, 2023)

sizes (from 24.43 children per class in 2018 to 23.64 in 2021 and 21.19 in 2022), as well as increases in birth control and decreases in teenage pregnancy.

The Present Study

Drawing on census-like data from nearly all kindergarteners in Uruguay, this study aims to document how school readiness scores among kindergarten children (age 5 classrooms) evolved from before (2018–2019), during (2020–2021), and three years after the onset of the pandemic (2022), when mitigation measures were lifted. Secondarily, we aim to investigate if changes in developmental scores differed across the school's SES.

Method

Participants and Procedure

This study uses data from 160,877 children (49% girls) that took part in the nationwide School Readiness-Child Development Inventory (INDI) assessments conducted in 2018, 2019, 2020, 2021, and 2022. The assessments were carried out in public preschools in Uruguay in kindergarten classrooms, with children around 5 years old (*M*age = 69.2 months; *SD* = 4.4). In 2018 and 2019 around 90% of children were evaluated. In 2020, response rates for INDI dropped as attendance was optional during the second semester and many children were absent regularly (impeding the administration of the assessment) or no longer attending; in 2021 they improved substantially, but still, disruptions prevented administering the INDI to children in some centers. Only in 2022 they were similar to the pre-pandemic situation (see Table 2 for details). Demographic and developmental data was analyzed as part of a technical and policy agreement with national educational authorities (CODICEN) and datasets analyzed were fully anonymized and treated according to data protection regulations and thus, are not publicly available. Assessments were conducted during three weeks in the last semester of the school year (September to December) and were completed by the teacher responsible for the class. Teachers receive annual training on the developmental assessment used in this study and can access automatic reports about their students' developmental profiles after completing the assessment (Vásquez-Echeverría et al., 2022).

There were little variations in socio-demographic characteristics across the years. There was no statistical difference in sex. There were small age-in-months differences which can be explained by differences in the months that assessments were carried out. The traditional assessment period before the pandemic began in late October/November. In 2020, INDI was administered in late November, in 2021 in late September, and in 2022 in November. Small, but statistically significant differences in the sample size by socioeconomic quintiles were observed each year. These differences are mainly due to the increase in cases with missing data in SES categorization (see supplementary material S1). For this reason, and to avoid missing values that may bias results, the SES variable will be incorporated into the analysis as "NA" category. Information about ethnicity is not available.

Table 2 Number of evaluations and coverage

	n	% of enrollment
2018	34,220	89.90%
2019	35,980	92.83%
2020	22,650	57.83%
2021	34,355	87.39%
2022	33,672	91.49%

Measures

School Readiness

Child development before school entry was assessed using the *School Readiness—Child Development Inventory (INDI),* a norm-referenced, teacher-reported assessment. Teachers are invited to respond to 52 items using a 6-point Likert scale (1 = never; 6 = always). INDI has four developmental domains, some of which include subscales (Vásquez-Echeverría et al., 2022): (a) Cognitive development (subscales: Language, Logical-mathematical skills, Self-projection, and Executive functioning); (b) Motor development; (c) Socio-emotional development (subscales: Internalizing, Externalizing and Prosocial behaviors); and (d) Attitudes towards learning. Supplementary Material S2 details the number of items, possible score range, and a sample item for each INDI dimension and subscale. The version of INDI used in this study was designed for Uruguayan children aged 49 to 79 months (age 4 and age 5 classrooms). Test–retest (*r* range 0.80—0.90), inter-rater (ICC range 0.71—0.95), and internal consistency (α range 0.73—0.93) indicate adequate to excellent reliability (Vásquez-Echeverría, 2022).

Sociodemographics

Children's age in months, sex, and school SES quintile (1 = lowest, 5 = highest) were extracted from National Administration of Education (CODICEN-ANEP) administrative datasets and used as covariates in analyses. The school SES is classified according to the distribution of an

index calculated from a survey on the socioeconomic and cultural characteristics of families of children attending each school (e.g., parental education, access to social protection services) and that is updated every 5 years (ANEP-DGEIP, 2021a).

Data Analysis

Capitalizing on available pre-pandemic (2018, 2019) pandemic (2020, 2021) and post-pandemic (2022) administrative datasets, this study adopted a cross-sectional strategy to analyze trends in developmental scores for cohorts of kindergarten classrooms. Within this analytical design, we assume that there are similar levels of school readiness prior to the pandemic, and any differences that are observed from before to during or after the health emergency declaration would be attributed to the pandemic context or its long-lasting effects (i.e., *with and without comparison*; Khandker et al., 2009).

Using related datasets, Gonzalez et al. (2022), handled possible selection bias due to lower coverage in 2020 between exposed and non-exposed cohorts through panel data. Using a difference-in-differences approach, impact estimation was performed by comparing a COVID cohort with a control cohort, and thus measuring the change in the expected trend given by the control cohort against the COVID cohort. Herein we use a simple difference approach that compares pre and post-pandemic levels. Differences in estimates correspond to both pre-existing differences between cohorts and/or the impact of the pandemic. Gonzalez et al. (2022) found that lower-performing children were more likely to drop out, but the bias was small and did not appear to affect average scores. In the following years (2021 and 2022) the coverage of assessed children improved, resulting in lower attrition bias that was comparable to pre-pandemic years. A mixed effects model is used to estimate the variations of a child development indicator across years. This model combines fixed effects, which capture general trends across all years, while controlling for covariates such as age in months during assessment, class size, socioeconomic status of the center, and random effects, to account for the inherent variability stemming from the clustering of observations within each class. The model is structured as follows:

$$Level1 - y_{ij} = \alpha_{0j} + \beta Year_{ij} + \alpha_1 X_{ij} + e_{ij}$$

$$Level2 - \alpha_{0j} = \alpha_{00} + \mu_{0j}$$

i varies from 1 to n, with n representing the total number of children.

j varies from 1 to g, signifying the number of classes or groups.

y is the standardized score for developmental variables for each child i in class j.

Year indicates the year of the INDI assessment.

X represents control variables, including age in months, class size, and school SES quintile.

The coefficient of interest, β, reflects the difference (gains/losses) relative to the reference year (2018).

α_{0j} captures variations in the intercept between different groups, encompassing random effects at the class-level.

α_{00} represents the grand mean.

e and μ denotes the corresponding error terms.

First, we present the results for the null model only including random intercept. In a second, model we included the time (year) as a fixed effect. Lastly, in the third step we added all covariates as fixed effects. Null hypothesis significance testing was adjusted using the Bonferroni correction. Model fit was compared using the AIC and BIC, expecting a reduction as model complexity increased, and RMSE to assess the models' predictive accuracy. Adjusted R^2 will be used as an effect size estimation and more complex models should increase explained variance. Using this model's estimated marginal means (i.e., least squares means) we made the contrasts by year (p-value adjusted by Tukey's method). We show estimates for the differences in scores for cohorts of consecutive years to analyze change in shorter time periods and between the 2022 and 2019 cohorts, to compare the latest available INDI scores with the pre-pandemic situation.

To investigate potential heterogeneous effects based on socioeconomic levels, an analysis of variance is conducted for both the *period* and *quintile* factors. In this scenario, the *period* variable labels years 2018 and 2019 as pre-pandemic, 2020 and 2021 as pandemic, and 2022 values as post-pandemic. For this analysis, a mixed-effects model is employed again. This model incorporates fixed effects for the period and quintile variables, including their interaction, while also accounting for class size and age covariates, and random effects at the group level.

We followed Ferguson´s (2009) criteria to interpret correlational standardized estimates as small (0.20), moderate (0.50), and strong (0.80) effect sizes; and for squared association indices 0.04 as small, 0.25 as moderate and 0.64 as strong effects. We used R packages lme4 (Bates et al., 2015) and emmeans (Lenth et al., 2023) to analyze data and this study was not pre-registered.

Results

Descriptive statistics for INDI scores are presented in Supplementary Material S3. The estimated results of the model are shown in Table 3. According to the variance components

Table 3 Results of Mixed Models with Random Class-Level Intercept and Fixed Effects by Socioeconomic Level, Age, and Class Size

	Language	Logical-Math	Self-projection	Executive functioning	Prosocial	Internalizing	Externalizing	Cognitive dev	Motor dev	Attitudes t/ learning
Null model										
ICC	0,24	0,19	0,31	0,27	0,36	0,28	0,19	0,22	0,29	0,25
R^2	0,24	0,19	0,31	0,27	0,36	0,28	0,19	0,22	0,29	0,25
	437,962,7	445,072,6	428,733	438,351,6	423,869,4	443,339,2	462,405,8	430,629,6	433,537,1	446,019,6
	437,992,7	445,102,6	428,763,1	438,381,7	423,899,5	443,369,3	462,436	430,659,6	433,567,2	446,049,7
RMSE	0,85	0,88	0,81	0,83	0,78	0,83	0,88	0,86	0,83	0,84
Year Fixed Effect model										
ICC	0,23	0,17	0,3	0,27	0,36	0,28	0,17	0,21	0,27	0,25
R2	0,24	0,19	0,31	0,27	0,36	0,28	0,19	0,22	0,29	0,25
AIC	437,538,2	444,596,2	428,531,2	438,178,3	423,861,1	443,346,3	461,994,4	430,262,5	433,220,8	445,978,8
BIC	437,608,27	444,666,28	428,601,37	438,248,48	423,931,41	443,416,63	462,064,71	430,332,4	433,290,94	446,049,08
RMSE	0,85	0,88	0,81	0,83	0,78	0,83	0,88	0,86	0,83	0,84
Year (Intercept)	0,13 (0,012)***	0,08 (0,011)***	0,07 (0,014)***	-0,15 (0,013)***	-0,02 (0,015)	0,01 (0,013)	0,13 (0,011)***	0,07 (0,012)***	0,08 (0,013)***	-0,04 (0,013)*
2019	-0,01 (0,018)	0 (0,016)	0,04 (0,02)	0,18 (0,019)***	0,02 (0,021)	-0,02 (0,019)	-0,04 (0,016)	0,03 (0,017)	0,02 (0,019)	0,06 (0,018)**
2020	-0,19 (0,019)***	-0,14 (0,017)***	-0,12 (0,021)***	0,23 (0,02)***	0,06 (0,023)*	0,02 (0,02)	-0,31 (0,017)***	-0,12 (0,019)***	-0,16 (0,02)***	0,03 (0,02)
2021	-0,3 (0,018)***	-0,27 (0,016)***	-0,21 (0,02)***	0,13 (0,019)***	-0,03 (0,021)	0,04 (0,019)	-0,21 (0,016)***	-0,24 (0,017)***	-0,27 (0,019)***	-0,02 (0,018)
2022	-0,02 (0,018)	0,04 (0,016)*	0,03 (0,02)	0,24 (0,019)***	0,09 (0,021)***	-0,05 (0,019)*	-0,13 (0,016)***	0,05 (0,017)*	-0,01 (0,019)	0,12 (0,018)***
Mixed effects										
ICC	0,22	0,16	0,31	0,27	0,36	0,28	0,17	0,2	0,28	0,25
R^2	0,28	0,22	0,34	0,28	0,37	0,28	0,19	0,26	0,32	0,28
AIC	428,969,8	435,727,3	421,154,7	436,182	421,921,5	441,783,9	461,554,3	421,324,7	426,334,3	439,551,9
BIC	429,109,99	435,867,39	421,294,98	436,322,38	422,062,06	441,924,45	461,694,93	421,464,55	426,474,58	439,692,41
RMSE	0,83	0,86	0,79	0,83	0,77	0,83	0,88	0,84	0,81	0,83
Year (Intercept)	-3,72 (0,049)***	-4,05 (0,05)***	-3,39 (0,049)***	-1,94 (0,05)***	-1,66 (0,049)***	1,49 (0,05)***	0,02 (0,051)	-4,04 (0,05)***	-3,44 (0,049)***	-3,48 (0,049)***
2019	0,03 (0,017)	0,03 (0,015)	0,06 (0,019)**	0,19 (0,019)***	0,03 (0,021)	-0,03 (0,019)	-0,04 (0,016)	0,07 (0,016)***	0,05 (0,019)	0,09 (0,018)***
2020	-0,17 (0,018)***	-0,13 (0,016)***	-0,11 (0,021)***	0,24 (0,02)***	0,07 (0,022)***	0,02 (0,02)	-0,31 (0,017)***	-0,1 (0,018)***	-0,15 (0,02)***	0,04 (0,019)
2021	-0,16 (0,017)***	-0,12 (0,015)***	-0,08 (0,019)***	0,19 (0,019)***	0,02 (0,021)	-0,01 (0,019)	-0,2 (0,016)***	-0,1 (0,016)***	-0,15 (0,019)***	0,1 (0,018)***
2022	0,0032 (0,017)	0,08 (0,015)***	0,05 (0,019)	0,25 (0,019)***	0,1 (0,021)***	-0,07 (0,019)***	-0,13 (0,016)***	0,08 (0,016)***	0,02 (0,019)	0,15 (0,018)***
School SES										

Table 3 (continued)

	Language	Logical-Math	Self-projection	Executive functioning	Prosocial	Internalizing	Externalizing	Cognitive dev	Motor dev	Attitudes t/ learning
Q2	0,13 (0,018)***	0,12 (0,016)***	0,11 (0,021)***	0,06 (0,02)	0,07 (0,023)**	-0,07 (0,021)***	-0,08 (0,017)***	0,13 (0,018)***	0,08 (0,021)***	0,09 (0,02)***
Q3	0,21 (0,019)***	0,22 (0,016)***	0,19 (0,021)***	0,09 (0,02)***	0,12 (0,023)***	-0,1 (0,021)***	-0,08 (0,017)***	0,21 (0,018)***	0,11 (0,021)***	0,14 (0,02)***
Q4	0,27 (0,018)***	0,3 (0,016)***	0,23 (0,021)***	0,13 (0,02)***	0,18 (0,023)***	-0,14 (0,02)***	-0,13 (0,017)***	0,28 (0,018)***	0,15 (0,02)***	0,17 (0,02)***
Q5	0,38 (0,018)***	0,48 (0,016)***	0,32 (0,02)***	0,19 (0,02)***	0,23 (0,022)***	-0,21 (0,02)***	-0,19 (0,017)***	0,42 (0,017)***	0,21 (0,02)***	0,28 (0,019)***
Q NA	0,12 (0,032)***	0,14 (0,028)***	0,13 (0,037)**	0,04 (0,036)	0,09 (0,04)	-0,1 (0,036)	-0,11 (0,029)***	0,13 (0,031)***	0,07 (0,036)	0,12 (0,034)***
Age (months)	0,05 (0,001)***	0,06 (0,001)***	0,05 (0,001)***	0,02 (0,001)***	0,02 (0,001)***	-0,02 (0,001)***	0,003 (0,001)***	0,06 (0,001)***	0,05 (0,001)***	0,05 (0,001)***
Class size	-0,01 (0,001)***	-0,01 (0,001)***	-0,01 (0,001)***	-0,0018 (0,001)	-0,0024 (0,001)**	0,0003 (0,001)	0,0003 (0,001)	-0,01 (0,001)***	-0,001 (0,001)	-0,002 (0,001)**
Children (*n*)	164,797	164,066	166,563	167,117	169,056	169,430	170,276	160,791	165,997	168,858
Groups (*n*)	9449	9419	9436	9435	9481	9493	9513	9305	9446	9471

Note: * < 0.05; ** < 0.01; *** < 0.001. R^2 refers to the conditional R^2. Reference category for School SES Quintile: Q1 (most disadvantaged). Q = School SES Quintile. Dev = development

of the model, random effects explain between 18 and 36% of the variability, depending on the dimension, and increases when fixed effects are included, especially in the cognitive and motor areas.

For the pre-pandemic period (2019–2018), developmental scores increased in a statistically significant manner in most indicators, but with small effect sizes. During the pandemic, (2020 and 2021) scores show a statistically significant decrease with moderate effect size differences in cognitive and motor development, as well as attitudes towards learning but with smaller effects. Concerning subscales, lower scores were found in language, logical-mathematical, self-projection, while improvements were found in externalizing behaviors. In 2022, we found significant improvements in most developmental domains assessed.

After having adjusted for confounding factors (as covariates) we observed a positive and significant effect of the school socioeconomic context and age-in-months, as well as the heterogeneous effect of class size, which has a negative significant association with cognitive development, prosocial behavior and attitudes towards learning.

To visually represent the results of the regression analyses, we plotted the predicted means for each year in Fig. 1. We observe that cognitive and motor development evolved favorably until 2019 and then deteriorated during the first year of the pandemic, specifically for language, logical-mathematical skills, and self-projection subscales. There was a very small rebound in attitudes toward learning in 2021 (the second year of the pandemic) compared to 2020. In addition, children showed fewer externalizing problems in 2021 than in 2020. In 2022 (post-pandemic) we observed a recovery of losses, with similar levels of school readiness scores compared to the pre-pandemic situation.

In Table 4 we present the contrasts of the means, for these analyses of consecutive years. Moreover, comparing scores in 2022 to prepandemic scores (2019) and we found very small or no differences, suggesting that scores returned to prepandemic levels. Scores that in 2022 were statistically significantly higher than in 2019, were logical-mathematical, executive functioning, prosocial behaviors, and attitudes toward learning, while externalizing behaviors score was statistically significantly lower, in all cases with very small effect sizes.

Supplementary Material S4.1 presents the results of the analysis of variances using as factors period and socioeconomic status of the schools. We found a main effect of SES (higher SES shows higher scores) and a main effect of period for all scores (during the pandemic developmental levels worsened for all dimensions, except externalizing, and similar scores are observed before and after the sanitary emergency). No interactions between SES x Period were observed. To exemplify, Fig. 2 depicts ANOVA results for Cognitive and Motors scores (see Supplementary S4.2 for other dimensions and subscales).

Discussion

To investigate the effects of the COVID-19 pandemic on early childhood development, we documented changes in school readiness from before (2018, 2019) during (2020, 2021) and after the national health emergency declaration ended (2022) among children in Uruguay attending public kindergartens. Overall, we found that scores showed a small-to-moderate deterioration in 2020, compared to the pre-pandemic period, which remained at similar levels in 2021, and finally a recovery to pre-pandemic levels in 2022.

Concerning the health emergency years (2020–2021) sustained learning losses among preschoolers converge with forecasts of researchers in education (Bailey et al., 2021), and we provided empirical evidence for the claim. In 2021 in Uruguay, there were some socio-economic improvements in comparison to 2020 (e.g., social mobility, economic GDP, employment rates), but there were still major disruptions to the school calendar. As these socioeconomic improvements and disruptions would both impact child development (Bacher-Hicks & Goodman, 2021), this mix could explain in part why we observed small changes in levels of school

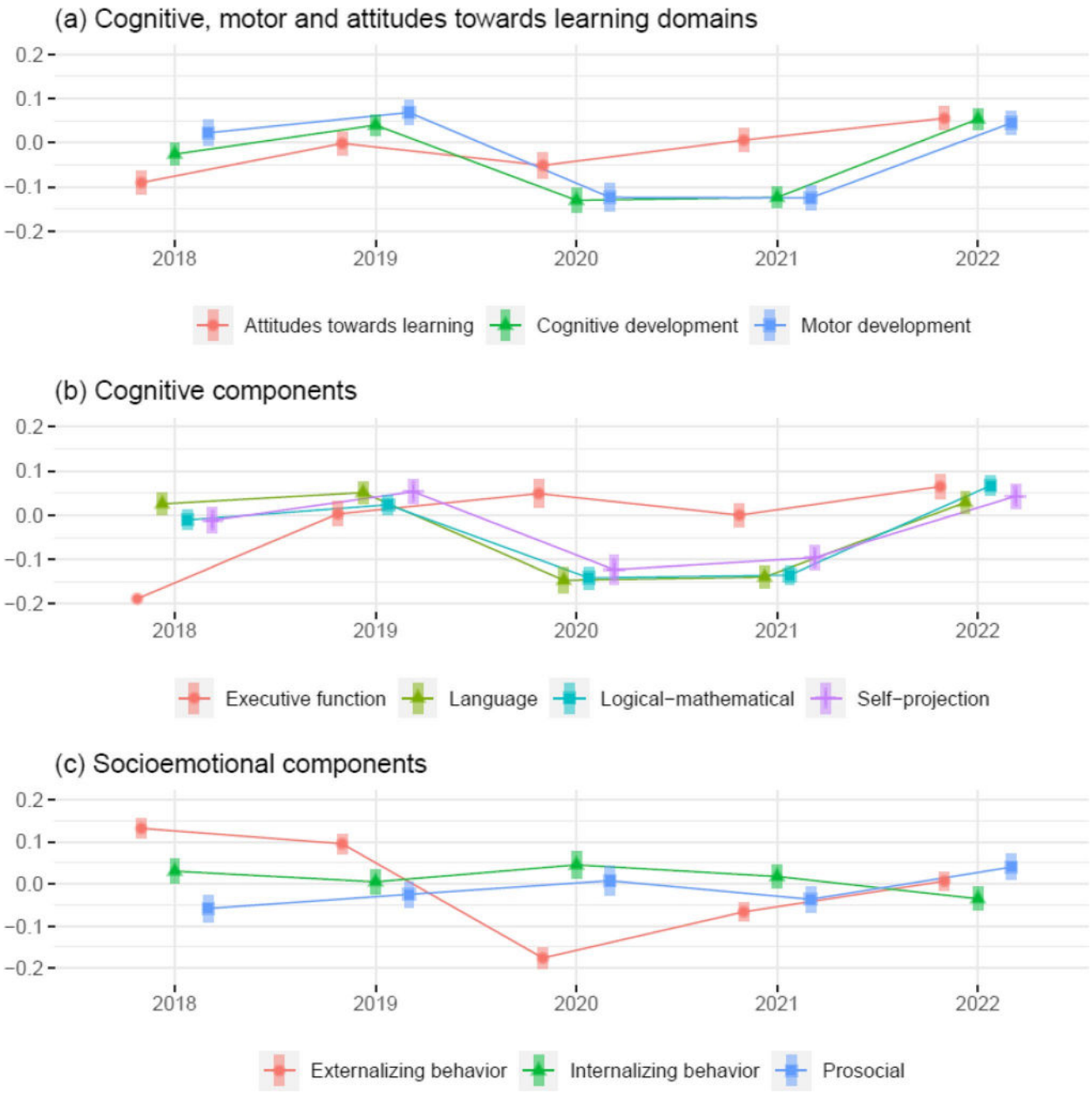

Fig. 1 Mixed-Model marginal mean estimates across years for INDI dimensions and components

readiness compared to 2020. School entry is a critical time in early child development as school readiness influences children's later performance in academic settings (Duncan et al., 2007) which highlights the critical nature of these losses for these cohorts of children.

We found that most components of cognitive development, namely language, logical-mathematical skills, and self-projection, declined from 2019 to 2020 or 2021 with small to medium effect sizes, as did motor development. More specifically, we found that levels were stable from 2018 to 2019, dropped in 2020, and then stayed low in 2021. Motor development was similar, with scores rising from 2018 to 2019, declining with the pandemic in 2020, and remaining low in 2021. Losses in motor, cognitive development and learning converge with multiple studies carried out among school-age children (Hammerstein et al., 2021, Betthäuser, 2023). In 2020, there was a slight decline in attitudes towards learning, but they rebounded to pre-pandemic levels in 2021, underscoring the importance of in-person classes in fostering creative and motivational processes. This resurgence may be attributed to the influential role of peer interactions, as highlighted by Vygotsky's (1977) theoretical model. Internalizing and prosocial behaviors generally remained stable over the four years suggesting a marginal impact of the pandemic. This diverges from a study that found increased internalizing problems among preschoolers in the United States during lockdown (Glynn et al., 2021) and samples from other ages (Kauhanen, 2022). However, in Uruguay, there was never a government-imposed lockdown, which might have influenced children's internalizing behaviors directly or indirectly (e.g., via parental stress). On the other hand, the lack of change in prosocial behaviors from before to during the pandemic was also observed among school-age children in China (Liu et al., 2021), which enhances the generalizability of these findings. Lastly, we observed that externalizing problems followed a different pattern: a stable level from 2018 to 2019, less externalizing problems in 2020, and then a rise in externalizing behaviors in 2021 when in-person classes tended to resume to normality. In fact, the only effect above the 0.10 threshold in our data was the higher levels of externalizing behaviors observed in the 2021–2020 comparison. This could be because the educational setting in 2021 entailed fewer restrictions in social distancing and more in-person attendance compared to 2020, which would have contributed to a rise in peer interactions. Increased externalizing behaviors in childhood have also been reported in studies conducted during home lockdowns (Glynn et al., 2021).

In 2022 the COVID-19 crisis was declared over in Uruguay. We found that school readiness scores had returned to pre-pandemic levels by the end of the year, and this recovery was mostly homogeneous across socioeconomic levels of schools. This could be explained by several factors. First,

Table 4 Comparison of the marginal means for each cohort predicted by the mixed-effects model

contrast	Language	Logical-Mathematical	Self-projection	Executive functioning	Prosocial	Internalizing	Externalizing	Cognitive development	Motor development	Attitudes t/ learning
2019—2018	0,03 (0,017)	0,03 (0,015)	0,06 (0,019)**	0,19 (0,019)***	0,03 (0,021)	-0,03 (0,019)	-0,04 (0,016)	0,07 (0,016)***	0,05 (0,019)	0,09 (0,018)***
2020—2019	-0,2 (0,018)***	-0,16 (0,016)***	-0,18 (0,021)***	0,05 (0,02)	0,03 (0,022)	0,04 (0,02)	-0,27 (0,017)***	-0,17 (0,018)***	-0,19 (0,02)***	-0,05 (0,019)
2021—2020	0,01 (0,018)	0,01 (0,016)	0,03 (0,021)	-0,05 (0,02)	-0,04 (0,022)	-0,03 (0,02)	0,11 (0,017)***	0,01 (0,018)	0 (0,02)	0,06 (0,019)*
2022—2021	0,17 (0,017)***	0,2 (0,015)***	0,14 (0,019)***	0,06 (0,018)**	0,08 (0,021)**	-0,05 (0,019)	0,07 (0,016)***	0,18 (0,016)***	0,17 (0,019)***	0,05 (0,018)
2022—2019	-0,02 (0,017)	0,04 (0,015)*	-0,01 (0,019)	0,06 (0,018)**	0,06 (0,021)*	-0,04 (0,019)	-0,09 (0,016)***	0,01 (0,016)	-0,02 (0,019)	0,06 (0,018)*

Note: p-valor * < 0.05; ** < 0.01; *** < 0.001

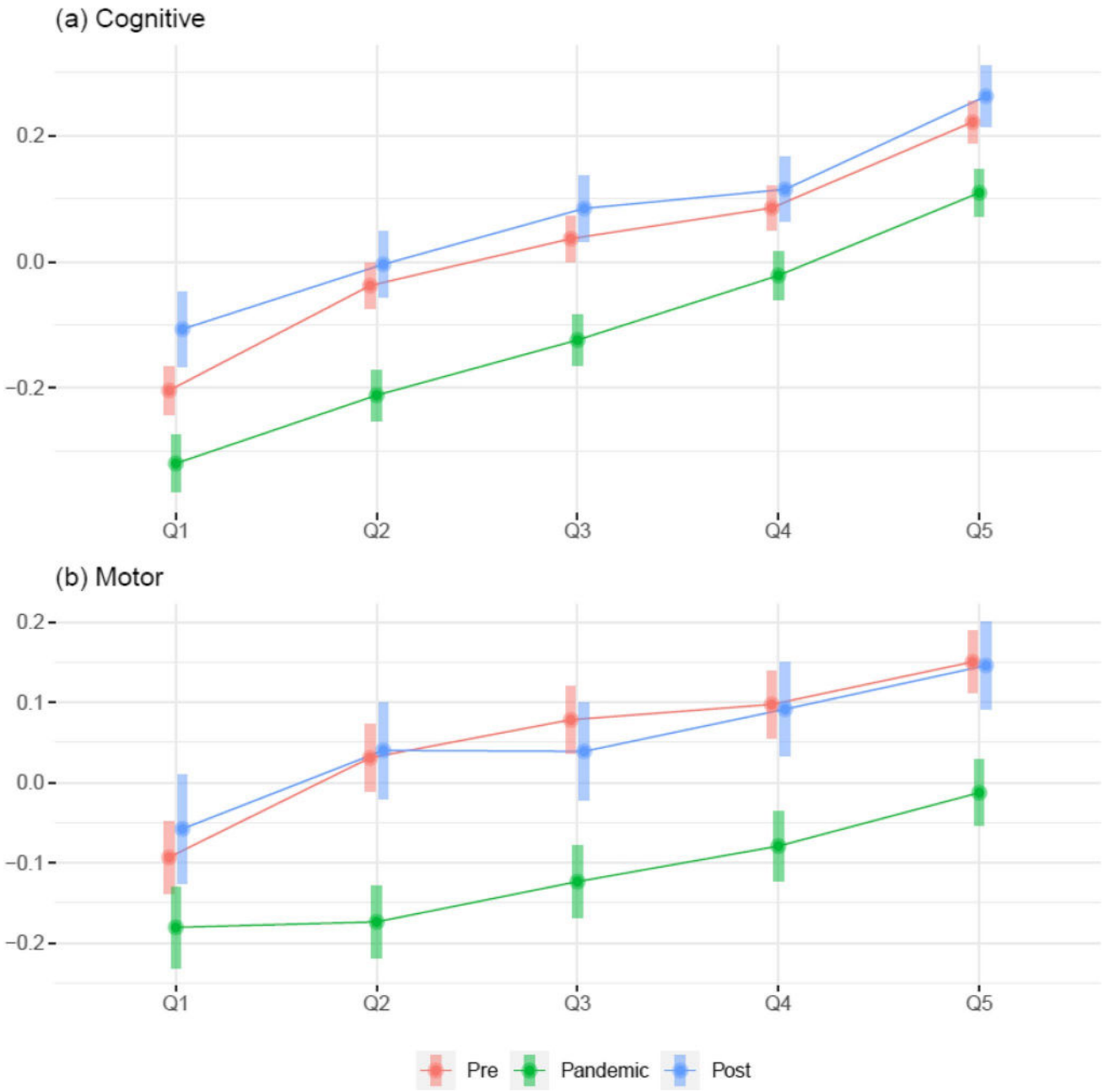

Fig. 2 ANOVA estimated means for (a) cognitive (b) and motor dimensions by school SES quintiles

the school year in 2022 was not disrupted by the pandemic. Second, the 2022 kindergarten cohort was in preschool during the pandemic in 2020 during Age 3 (not compulsory in Uruguay) and in 2021 while in Age 4 classrooms. Overall, they only lost approximately 30 days of compulsory preschooling. In other words, school attendance for the 2022 cohort was quite similar to the pre-pandemic era, and main differences may arise from Age 3 classroom when attendance is not compulsory and lower also in the pre-pandemic situation. In this vein, some scholars have claimed for the study of the characterization of the effects of the pandemic on child development from a historical perspective, as the onset of the pandemic may interfere specifically with other socioeconomic processes and in particular periods that may be more or less sensitive for developmental outcomes (National Academies of Sciences, Engineering, and Medicine, 2023). Third, the economic growth in 2022 conduced to a higher GDP than in 2018 to 2021. Fourth, the quality of education could have improved in 2022. Class sizes were lower because of substantial drops in fertility rates and lower

numbers of newcomming immigrants. Teachers were offered new programs and recommendations (e.g. courses, *dossiers*) to help compensate for the negative impact of the pandemic, based on INDI results. Similarly, the use of INDI reports has progressively become more popular in assisting instruction and intervention. In sum, some technical recommendations concerning the recovery of child development after the COVID-19 crisis were implemented timely in Uruguay (Holla, 2023). Parenting and home environment may also be improving as evidenced by lower rates of teen pregnancy and declining numbers of children born in poverty.

Interestingly, we found that executive functioning appeared unaffected across years. This goes against the findings of a cohort study carried out in the United States among 7-year-olds that showed that pandemic-related school closures were associated with deteriorated executive functioning (Hanno et al., 2022). These differences could be attributed to contextual factors such as the absence of lockdown in Uruguay. Methodological or statistical differences could also explain divergent findings. For instance, in Uruguay, Gonzalez et al. (2022) used a differences-in-differences approach and found statistically significant, though very small, declines in executive functioning from before to one year into the pandemic. Furthermore, in the case of preschool-aged children, attention and regulation may be more easily stimulated in a home environment compared to other cognitive processes.

We drew on the strengths of large datasets of preschoolers conducted before (2018, 2019) during (2020, 2021), and after the health emergency declaration in Uruguay (2022) to document changes over time. Data was collected in person using a psychometrically validated and comprehensive teacher report of developmental markers in school readiness (Vásquez-Echeverría et al., 2022). Our study expanded on the findings of Gonzalez et al. (2022) by applying a different estimation technique, and added novelty by including new data from the pandemic in 2021 and after the pandemic in 2022. However, several limitations should be considered. Results were based solely on teachers' reports that do not allow to disentangle specific method effects. Furthermore, answers may have been biased during the pandemic because teachers were likely under increased stress and could have had lower expectations for their students. A measurement invariance analysis could be performed in a future study to analyze if there are any underlying changes in response processes. Lower response rates in 2020 provoked a slight bias of excluding lower-performing children, which could lead to an underestimation of differences in comparisons that use scores from that year. SES information about the schools varied in missingness, and that may bias results. The cross-sectional design limits the possibility to infer causality and does not inform us about the long-lasting effects of learning losses within any specific cohort. The multifaceted nature of the impact of the pandemic on society does not allow us to conclude that any one aspect was responsible for the differences observed (Bacher-Hicks & Goodman, 2021). For instance, reduced peer interactions due to school closures may be limiting children's skills for learning naturally from others, especially peers (Vigotsky, 1977), but also reduced income in many families may limit the resources devoted to parenting and access to learning materials. Further studies would be necessary to generalize our observations to other regions and age groups. Since social and health-related preventive measures varied considerably across countries and years, our results may not replicate in other contexts. We found that school readiness scores in kindergarten returned to pre-pandemic levels in 2022, but had the pandemic not occurred, eventually scores for this cohort could be higher than in pre-pandemic levels. Finally, our study was not able to investigate if those who were in kindergarten during the pandemic experienced enduring difficulties in the aftermath of the pandemic.

Conclusion

A growing body of literature highlights the pandemic's negative influence on children's development and learning (Goudeau et al., 2021; Hammerstein et al., 2021), but no studies have estimated if any recovery is occurring. We found that developmental losses prevailed long after the onset of the pandemic (in 2021), but recovery took place in most domains by late 2022, more than two and a half years later. Further systematic assessments of child development would be important to better understand how the COVID-19 pandemic could affect children in the years to come, if recovery is effectively taking place, or if the detrimental effects of the COVID-19 context are more pervasive in some cohorts than others. For instance, it would be important to conduct longitudinal studies to estimate if children who were in age 5 classrooms during the pandemic experienced negative effects later on in development, in second or third grade for example. Our results can inform education and health policy-makers about under which conditions post-pandemic recovery is taking place. Also, our findings may imply that Uruguayan efforts to avoid full lockdown (keep schools open, possibility to visit relatives, go to green spaces, etc.), were a protective factor in mitigating the negative developmental effects of the pandemic among 3-year-old children in 2020. Still, our study was not designed to test this hypothesis in particular. As such, we suggest that policymakers direct additional resources and support to children and families to follow up pandemic kindergarten and pre-k cohorts in the upcoming years. In the future (e.g. new pandemic scenarios), our results could inform policymakers in analyzing the pro-cons tradeoffs of using full lockdowns as a preventive

measure. Lastly, researchers interested in the pandemic's influence on early child development can build on our study and focus on the consequences of the COVID-19 era on school readiness and learning trajectories specifically.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11121-024-01716-4.

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Declarations

Ethical Approval This study does not require specific IRB approval. The use of de-identified INDI administrative datasets for research is specified in the agreement between the University of the Republic and the National Administration of Education. All ethical procedures of confidentiality, anonymity, and file protection were followed regarding the analyses of administrative datasets.

Conflicts of Interest None

Informed Consent Not applicable

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