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Children's executive function during the COVID-19 pandemic in Argentina: Associations with home literacy, reading, and screen times

Ángel Tabullo [a, b, *], Lorena Canet-Juric [c, d], Valeria Abusamra [e]

[a] Instituto de Ciencias Humanas, Sociales y Ambientales (INCIHUSA), CCT-Mendoza, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Mendoza, Argentina
[b] Pontificia Universidad Católica Argentina, Facultad de Humanidades y Ciencias Económicas (Sede Mendoza), Mendoza, Argentina
[c] Institute of Basic and Applied Psychology and Technology (IPSIBAT), National University of Mar del Plata (UNMDP), Mar del Plata, Argentina
[d] National Scientifc and Technical Research Council (CONICET), Buenos Aires, Argentina
[e] Centro Interdisciplinario de Investigaciones en Psicología Matemática y Experimental "Dr. H. Rimoldi" (CIIPME)- CONICET, Buenos Aires, Argentina

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ABSTRACT

Several studies indicated that the COVID-19 pandemic and the containment measures it required (including social distancing, quarantine and school closure) had a significant impact on children's mental health. The present study aimed to examine executive function difficulties at behavioural level in school children during the COVID-19 lockdown, and to analyze potential associations with home literacy environment, current reading and screen times. Data were collected from mothers of 210 children (9–12 years old) through an online survey. Incidence of EF issues was higher for fourth graders in the flexibility and working memory domains, possibly reflecting developmental differences. Significant increases in children screen times were observed, while most of them did not read for pleasure on a daily basis. Parents' literacy beliefs and children's current leisure reading times were negative predictors of executive function difficulties (with reading times partially mediating literacy beliefs' effects), which increased with videogame times (particularly in 4th graders). Nevertheless, perceived changes on screen or reading times with respect to prepandemic levels were not associated with executive function scores. The results might indicate: 1) opposite effects of literacy and video game times over children's executive functioning; 2) a preference for reading or screen recreational use according to their executive function profiles; or 3) a combination of both. Our findings highlight the relation of home literacy environment, reading and screen times with children's cognitive development, and the importance of following their trajectory during postpandemic times.

1. Introduction

The term "executive functions" (hereinafter, "EF") refers to a set of cognitive processes involved in planning, executing, monitoring and adapting goal-directed behaviors (Miyake & Friedman, 2012). It includes the skills to: manipulate and update contents within working memory, suppress irrelevant information and/or contextually inadequate responses and shift between behaviors, strategies

* Correspondence to: Av. Ruiz Leal s/n, Parque General San Martín, Mendoza, Argentina.
E-mail address: angeljtabullo@gmail.com (Á. Tabullo).

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and cognitive processes to flexibly adapt behavior to situational demands (Lezak et al., 2012). Children's EF can be assessed through cognitive performance-based instruments (such as neuropsychological tests) or behavioral rating scales (either self or heteroreport formats, according to the child's age) (most notably, BRIEF; Gioia et al., 2000). It has been argued that these measures capture different types of information, with the former representing performance efficiency in optimal settings and the latter indicating the frequency of goal achievement in typical settings (Toplak et al., 2013; see also: Soussi et al., 2022). Behavioral scales reflect expected EF patterns in clinical populations, correlate with physiological markers, and predict behavior (Isquith et al., 2013). In addition, both cognitive performance (see Pascual et al., 2019 for a meta-analysis) and behavioral scale (Thorell et al., 2012) measures of EF predict children's academic achievement (see Gerst et al., 2017 for a study combining both assessments), as well as their emotional regulation skills (Li et al., 2020; Rhoades et al., 2009). Moreover, Eisenberg et al. (2019) found that self-report measures of self-regulation (a construct closely related to EF) outperformed experimental task performance in predicting real-life outcomes.

EFs take a long time to emerge, evolve and consolidate, spanning from early childhood to adulthood. Their trajectory is driven by the development and plasticity of the prefrontal cortex and its connections (particularly with the parietal cortex and basal ganglia) (Diamond, 2020). EFs undergo rapid changes from childhood to adolescence, which are considered sensitive plasticity periods (Thompson & Steinbeis, 2020). These trajectories vary between core EF components: while inhibition seems to consolidate between the ages of 5 and 8, working memory reaches adult-level performance around 12, and flexibility reaches peak performances around 15 (Best & Miller, 2010; Jacobsen et al., 2017; Serpell & Esposito, 2016). Studies have frequently examined EF in elementary school children, due to the sensitive developmental stage it encompasses and the EF's relevance to current and future academic achievement (Jacobsen et al., 2017, see Souissi et al., 2022 for a recent review).

It is generally accepted that stress interferes with cognitive functions, and, particularly, with EF (see Shields et al., 2015, 20167for meta-analyses), and it has been shown how environmental stressors, such as early life adverse experiences (Hostinar et al., 2012, Rudd et al., 2021), poverty-related factors (Haft et al., 2017), and natural disasters (Pfefferbaum et al., 2016) can have negative effects on children's EF development. Therefore, EF constitutes a relevant construct to examine when considering the potential impact of the COVID-19 pandemic, and the consequent changes in schooling and daily activities that took place during its first two years, on children. In their efforts to reduce COVID-19 spread, several governments implemented containment measures that included social distancing, school closures and quarantine at home (Canet-Juric et al., 2020; Loades et al., 2020). Confinement alters routine dramatically, leading to social and physical isolation, loneliness, frustration, and boredom; thus, posing a challenge to coping and self-regulation skills (Rodríguez-Rey et al., 2020; Urbina-García, 2021). Lockdown measures in Argentina during 2020 (specially in the state of Buenos Aires,) were the longest and most severe in Latin America (Hale et al., 2021), and in-person schooling activities did not return until August 2022. School closure was effective from March throughout the whole 2020, while recreational, social and cultural outdoor activities for children were also restricted or completely suspended (Canet-Juric et al., 2020). During this period, several studies examined different aspects of the children's behavior, mental health, cognitive and emotional functioning; as well as the changes on their daily routines and their potential impact on them. We briefly review this evidence in the following sections.

2. Children executive functioning during the COVID-19 pandemic

While many studies addressed children's mental health during the pandemic (Andrés et al., 2022; see Bussières et al., 2021, Loades et al., 2020; Theberath et al., 2022 for reviews), only a few focused on EF. These studies (that relied on standard parent report questionnaires) showed a considerable incidence of EF deficits on children's behavioral functioning (Hanno et al., 2022; Lavigne-Cerván, et al.,2021a); Lavigne-Cerván et al., 2021b; Polizzi et al., 2021; Shuai et al., 2021). Some of them found worse EF ratings associated with remote schooling (Hanno et al., 2022), or confinement (Lavigne-Cerván et al., 2021a). Children's anxiety (Lavigne-Cerván, et al., 2021b) and parental distress (Polizzi et al., 2021) were additional predictors of EF issues. Only one study conducted in pre-school children did not find significant differences with pre-pandemic EF levels (Abufhele et al., 2022), but it did observe worse outcomes in language, socioemotional behavior and general development measures. In Argentina, children's EF in the pandemic has not been addressed specifically, but several psychopathology indicators were found to have increased significantly during this period (Andrés et al., 2022). Considering these findings, it would be relevant to examine the incidence of difficulties on different EF domains among Argentinean children. Moreover, it is of interest to analyze the link between these difficulties and the children's daily habits during the pandemic, particularly, their reading frequency and exposure to screen media, as well as other potentially relevant environmental factors, such as their Home Literacy Environment (HLE, Altun, 2022; Korucu, 2020) (see next section for details).

2.1. Children leisure reading during the COVID-19 pandemic

Several studies indicated changes in adults (Salmerón et al., 2020), adolescents and children's reading habits (Clark & Picton, 2020, 2021). Parent-child shared reading (Wheeler & Hill, 2021) and screen-based reading became more frequent (Read et al., 2021). Children's reading frequency and enjoyment also increased throughout the pandemic, motivated by relaxation and emotional regulation (Clark & Picton, 2020, 2021). Considering reading is a cognitively demanding activity that involves vocabulary, metacognitive processes and EF (Butterfuss & Kendeou, 2018; Follmer, 2018), and that leisure reading has been associated with the executive control brain network connectivity in children (Horowitz-Kraus & Hutton, 2018), it would be expected to find associations between reading times and EF during the pandemic. In the same line, another reading-related variable of interest is the Home Literacy Environment (hereinafter, "EF"). HLE can be defined as a set of "experiences, attitudes and materials pertaining to literacy that a child encounters and interacts with at home" (Roberts et al., 2005). HLE can promote children's cognitive development in general (for a review, see: Head-Zauche et al., 2016), and two recent studies suggest that it might be associated with EF skills in preschool children and toddlers (Altun, 2022; Korucu

et al., 2020). Moreover, the literature indicates that the material (e.g. playing and reading materials) and psychosocial (e.g. parenting styles, responsivity, language exposure) factors of home environment might be the crucial proxies of socioeconomic status (SES) effects on children's EF development (see Haft & Hoeft, 2017 for a review), and it has been shown how parent responsivity, companionship and enrichment components of home learning environment mediate the SES association with school-aged (8–12 years-old) children's EF (Sarsour et al., 2011). In this line, HLE may provide a context for parents to encourage their child to listen, pay attention, actively manipulate information and practice self-control – all EF-related skills – during structured, language and literacy-related learning activities (Korucu et al., 2020). This is supported by the fact that family literacy and educational scaffolding in the home environment are significant predictors of EF in 6–14-year-old primary school children (Jasińska et al., 2022). Therefore, it might be possible to find additional contributions of HLE to children's EF during the pandemic besides the potential links with leisure reading. On a related note, a recent study found that mother literacy beliefs were a better predictor of Argentinean toddlers' vocabulary size than shared reading frequency (Medawar et al., 2022), and another indicated that the presence of books and frequency of literacy activities was positively associated with EF skills (Gago-Galvagno, 2020) in infants.

2.2. Children screen times during the pandemic

Since the pandemic drastically reduced the possibility for outdoor activities throughout the globe, it is unsurprising that screen media exposure had increased dramatically among 3–17 year olds and toddlers (for a review, see Bergmann et al., 2022). In the United States, both total screen media exposure and problematic media use (defined as a dependence that interferes with a child's usual functioning) increased among 2–11-year-olds, compared to pre-pandemic levels (Eales et al., 2021). These findings are worrying, considering the American Academy of Pediatrics warning of keeping screen times under two hours a day for children and adolescents (Council of Communications and Media, 2021), and the considerable body of literature indicating detrimental effects of screen times over children's language (for a recent meta-analysis, see Madigan et al., 2020), cognitive development (Hu et al., 2020) and academic achievement (for a recent meta-analysis, see Adelantado-Renau et al., 2019). Problematic media device use (smartphones, tablets) has been associated with worse behavioral EF outcomes on healthy children (Oh et al., 2021), as well as ADHD-diagnosed (Shuai et al., 2021) children during the pandemic. Moreover, it has been observed that longer daily screen times may affect the inhibitory control network development in children by decreasing fronto-striatal connectivity, as well as increasing reward-seeking tendencies that promote impulsive and/or addictive behaviors (Chen et al., 2022).

Converging evidence suggests potentially detrimental effects of screen media exposure on EF throughout development. Longitudinal studies show that TV and video games are predictors of attention problems in middle childhood (Swing et al., 2010). A bidirectional causality has been observed between inattention, impulsiveness and video game use in children (Gentile et al., 2012), and the author proposed that video games might affect self-regulation by favoring more frequent reinforcement and stimulus saliency, as well as displacing activities that are more cognitively demanding (such as homework or reading) or potentially beneficial to cognition (such as sports and physical activity, see for instance: Best, 2010; Veraksa et al., 2021). Moreover, gaming disorders are linked to lower attention, problem-solving and memory skills (Farchakh, et al., 2020), frontostriatal functional alterations and cognitive control deficits (Sugaya et al., 2019) in children. Meanwhile, Internet abuse has been associated with impulsivity, self-regulation and EF deficits in children, adolescents and young adults (Ioannidis et al., 2019; Billieux & Van der Linden, 2012).

On the other hand, it should be noted that evidence regarding video game effects on children is mixed, with some studies pointing to null effects and others indicating positive outcomes on cognitive development, and even EF skills training and improvement (Taylor, 2018, see Fietzer & Chin, 2017; Smirni et al., 2021 for reviews). It has been claimed that potential effects of video games had to be considered in relation to several variables and dimensions, such as content, gaming mechanics, age and (critically) time spent playing (Smirni et al., 2021). Therefore, more data are needed to figure out the potential detrimental effect of different types of screen media on children's EF during the pandemic.

2.3. Present study

There were few studies that examined and described children's EF functioning during the pandemic lock-down (and none in Argentina, one of the countries with the longest lock-down measures). While there's plenty of evidence about the changes on children's screen and reading times during the pandemic, few studies have specifically addressed the potential association of these activities with EF difficulties in this period. In addition, no pandemic study considered the potential contribution of HLE factors as a buffer for EF issues. In order to fill this gap in the literature, the present work had the following objectives: 1) to examine the incidence of EF difficulties among Argentinean school-aged children during the COVID-19 lockdown, 2) to examine children's reading (both leisure and academically motivated) and screen times during the pandemic, a 3) to analyze the potential associations of EF difficulties with HLE, reading and screen times. In this way, we aimed to describe the EF behavioral issues exhibited by Argentinean primary school children during the pandemic, and to identify potential factors from their routine, habits or home environment that might have contributed to increase or ameliorate these issues. It is worth noting that our primary concern was not to show how the pandemic increased the children's EF difficulties or modified their previous EF, but to characterize their current EF functioning and its relevant predictors. Due to lockdown logistic restrictions, data were collected through online surveys. A locally designed and validated behavioral questionnaire was used to assess children's EF functions through parents' reports ("Cuestionario de Funciones Ejecutivas", CuFE - "Executive Functions Questionnaire"; Canet-Juric et al., 2021). Current leisure and study reading times, and TV, internet and video game use frequencies were considered, as well as their perceived changes compared with pre-pandemic times. Moreover, we included specific HLE indicators: number of books at home, parents' attitudes towards reading and shared reading frequency during pre-school. These measures were based on

previous international (d'Apice & von Stumm, 2019) and local (Tabullo & Gago-Galvagno, 2021) studies. We expected to find EF difficulties to decrease with HLE and reading times and to increase with screen exposure.

3. Methodology

3.1. Design and participants

A cross-sectional correlational study was carried out. Our study sample consisted of 210 Argentinean mothers of 9–12-year-old children (108 of them girls, $M = 10.5$, $SD = 0.903$ years), who volunteered to participate on our online survey after being contacted through the children's schools. All their children attended private management schools and were under the remote online teaching modality at the time of data collection, while all the families were undergoing the social distancing phase. The children were either 4th ($n = 47$), 5th ($n = 77$) or 6th ($n = 86$) graders. Most of the children's schools (77%) were categorized as level 3 in the educational opportunities scale (Ferreres et al., 2010) (which indicates a predominantly medium or high SES student population, low absentism, less than 5% of children repeating a grade, no drop-outs and an offer of extracurricular activities). No developmental or learning disorders were reported by the mothers, neither were the children under psychological or psychiatric treatment at the time of the survey. Regarding the parents, 77% of the mothers had either complete or incomplete university level studies (see Table 1 for further details), as well as 61.4% of the parents. The children had an average of 1.18 siblings (SD = 1). None of the children's homes exhibited overcrowding indicators (> 3 people sharing a bedroom), and 80% of the homes had an average of less than two people per bedroom. All the children had access to the internet, TV and computers. In addition, 68.1% of the homes had > 50 book-sized libraries, and 75.7% of the children had their own library (>10 books).

The minimum sample size was estimated with G-power software (Faul et al., 2009). For a multiple linear regression with 14 predictors and a medium effect size ($\alpha = .05$; power =.95; effect size =.15), we calculated an n = 194.

3.2. Instruments

Sociodemographic measures. Close ended questions were used to explore children's gender and age, and parents' and caregivers' educational level, which was classified according to a scale based on the Argentinian education system (Pascual et al., 1993). We chose mother education level as a proxy indicator for SES, considering that it seems to be the SES aspect that is more strongly related to children's language outcomes (Hoff , 2003; Hoff, 2006).

Table 1
Descriptive statistics of study variables.

Variables	M (SD) / %	Minimum	Maximum	n
Sociodemographic data				
Gender				
boys	54%			
girls	46%			
Age (years)	10.05 (0.903)	9	12	210
Mother education				210
Primary	4.8%			
Secondary	18.2%			
University	77%			
Home Literacy				210
Books at Home	3.08 (0.930)	1	4	
Preschool Shared Reading	3.4(1.31)	1	5	
Literacy beliefs	26.1(2.89)	19	30	
Reading Times				
Leisure reading	2.23(1.33)	1	7	
Study reading	3.68 (1.42)	1	7	
Change pre-pandemic	2.8(1.21)	1	5	
Screen Media Times				210
TV	1.91(1.16)	1	7	
Video games	0.18(0.51)	1	7	
Internet	0.15(0.47)	1	7	
Change pre-pandemic	4.31(1.08)	1	5	
Executive function (QEF)				210
Inhibition	2.15(0.718)	1	4	
Flexibility	2.47(0.731)	1	4.7	
Working Memory	2.27(0.665)	1	4.41	

Notes. Descriptive statistics of study variables: sociodemographics data (age, gender, mother education level), home literacy practices and beliefs variables, children's current reading and screen media times (and their perceived change with respect to pre-pandemic times) and Executive Function Questionnaire scores by dimension (inhibition, flexibility and emotional control, and working memory)

HLE measures. Based on previous works (d'Apice & von Stumm, 2019; Tabullo & Gago-Galvagno, 2021), we selected the following variables as indicators of Home Literacy Environment: number of books at home and estimated frequency of shared reading with the child before primary school, and attitude towards literacy. Home library size and shared reading frequency were assessed through 5-item multiple choice questions (*"how many books are there in your home approximately?": less than 10; 10–50; 51–100; more than 100; "How often did you read to your child before primary school, approximately?: less than once a week, once a week, 2–3, 4–5, more than 5 times a week"*). Literacy beliefs was measured through 6 items of the Parent Belief Reading scale (PRBI; DeBaryshe & Binder, 1994) selected from the aforementioned studies (Cronbach's $\alpha = .825$). This scale measures positive affect associated with reading, parents' intentions to elicit children's active verbal participation when reading, whether children acquire moral orientation and world knowledge from books and parents' practical capacity to participate in reading (DeBaryshe,1995). We will also refer to this variable as "reading attitudes" through the text.

Reading and screen times. Our participants reported their children's weekly leisure (defined as reading for non-study purposes) and study reading times, as well as their frequency of TV, internet (for non-study purposes) and video-games use (regardless the device). Responses were made on a 1–7 likert scale (*1. does not do it; 2. a couple days a week; 3. less than 1 h a day; 4. 1–2 h a day; 5. 2–3 h a day; 6. 3–4 h a day; 7. more than 4 h a day*). In addition, they were asked what format their children preferred for leisure and study reading, and the perceived changes in their reading and screen media times with respect to pre-pandemic levels, answering in a 1–5 likert scale (*1. much less than before - 5. much more than before*).

EF Questionnaire. The Executive Functions Questionnaire (EFQ, Canet-Juric et al., 2021) was applied to examine behavioral manifestations of children's EF difficulties. EFQ is a heteroreport questionnaire of 33 items with a Likert format response (1. "*Never*" – 5. "*Always*"), distributed in the following scales: *Working memory* ($\alpha = .91$): examines difficulties for online processing, maintaining and manipulation of information (e.g.: "*finds it difficult to remember long instructions*"), *Inhibition* ($\alpha = .81$): assesses the difficulty to regulate and suppress responses and/or specific behaviors (e.g.: "*interrupts when others are speaking*"), *Flexibility and emotional control* ($\alpha = .81$): assesses difficulties to flexibly adapt behavior to environmental changes and to regulate emotional responses (e.g.: *"finds it difficult to adapt to novel situations"*; *"gets extremely upset when something frustrates or annoys him/her"*). Higher scores indicate more prevalence or frequency of EF issues on children's behavior. The instrument had been validated in a sample of 9–12-year-old school children (M = 11.01, SD = 1.4 years, 53.4% of them girls), attending to 4th, 5th and 6th primary school grades in Buenos Aires state public schools (same state as our participants) before the pandemic. It has shown adequate psychometric properties and significantly predicts children's reading comprehension, math and language academic achievement (Canet-Juric et al., 2021, Canet-Juric et al., 2022). The questionnaire provides normative data (percentiles) to interpret the children's scores qualitatively, according to the following categories: *very good, good, bad and very bad performance (see* Supplementary Table 3 and 4*)*.

3.3. Procedure

Data collection took place between October and November of 2020. The instruments were administered through an online Google forms survey that was distributed to children's parents through local schools. All parents received a document informing them that their participation would be voluntary, anonymous and that they could withdraw from the experiment at any time, without any negative consequences. Contact information of the research group was also provided to clarify doubts that may arise in relation to the care of rights in research contexts. Those who chose to take part followed the survey's link and expressed their consent with a click before moving on the questionnaires. A follow up EF assessment was conducted one year later, but only 22 mothers responded.

This study was performed in accordance with the ethical principles for research with human subjects recommended by the Declaration of Helsinki (World Medical Association, 2013), as well as the ethical guidelines for research with human participants of the American Psychological Association (2010). In addition, this research was conducted following the ethical regulation 5344/99 by the National Scientific and Technical Research Council of Argentina (CONICET) and was approved and supervised by CONICET's committee.

3.4. Data analysis

Statistical analysis were carried out in SPSS v25 and JAMOVI software. EF difficulties were analyzed considering mean scores for each factor and qualitative interpretation (very good, good, bad, very bad) according to normative data (Canet-Juric et al., 2021). Gender and school grade effects were analyzed by a MANOVA, and a repeated measures ANOVA was conducted on the follow up data. Qualitative EF data were analyzed by chi-square tests. Associations between EF and HLE, reading and screen time measures were examined by Pearson and Spearman correlation coefficients.

In order to identify significant predictors of each EF domain scores, separate hierarchical linear regression models were carried out. The first step of the models included sociodemographics (gender, mother education and grade), HLE (literacy beliefs), reading and screen time measures. Literacy beliefs was selected among HLE variables to avoid collinearity issues and reduce multiple comparisons (in the same way, age was considered redundant with respect to grade). The following steps included current reading and screen times interactions with grade, one interaction per step to examine their individual contribution to EF variance. Omnibus ANOVAs were carried out on the model coefficients. Effects of perceived changes on screen and reading times with respect to pre-pandemic levels were examined as additional steps in the models.

Casewise diagnostics were applied to deal with outliers (standardized residuals above 3 or below −3) (Cousineau and Chartier, 2010). Since no outliers were detected, no data was removed from the analysis. Assumptions of normality, homoscedasticity and linearity were verified by inspection of: normal quantile plots of residuals, standardized residuals scatter plots and observed versus predicted val-

ues, respectively. Independence of error assumption was met for all models (1.95 < Durbin-Watson < 2.1). Variance inflation factors indicated that multicollinearity was not a concern in any of the models (1.07 < VIFs < 3.34). Adjusted R squared values and standardized coefficients (with their corresponding confidence intervals) are reported. To correct for multiple comparisons, we applied the Benjamini-Hochberg False Discovery Rate method to Omnibus ANOVA results (Benjaimini & Hochberg, 1995) with an alpha level = .05. While still conservative, this method yields more statistical power than the Bonferroni adjustment. FDR-corrected p-values are reported in the results.

To further test and verify the regression analysis effects, we ran a path analysis on all EF measures using the PATHj module (a JAMOVI implementation of the R lavaan package) (Galluci & Jentschke, 2021). We excluded mother education (which was not the primary focus of our study) and synthesized reading times in a single variable to minimize the number of parameters. With a total of 23 free parameters, the 5:1 sample size-free parameter ratio recommended by Bentler and Chou (1987) is satisfied. (with N = 210 we are close to a 9:1 ratio) The model included gender, grade, videogame times (and their interaction), literacy beliefs and a reading times composite (calculated as the sum of both reading frequencies) as predictors (see Fig. 1). Direct and indirect effects (mediated by reading times) of literacy beliefs over EF-WM measures were included. Model fit was determined by the following indexes: chi-square, comparative index (CFI), Tucker-Lewis index (TLI), mean square error of approximation (RMSEA) and root mean square residual (SRMR) (Xia & Yang, 2019). Given the continuous nature of outcome variables, the Maximum Likelihood method was applied for parameter estimation (Shi & Maydeou-Olivares, 2019). A bootstrapping procedure with 10,000 samples was used to produce 95% bias-corrected confidence intervals.

4. Results

4.1. Descriptive statistics of HLE, reading and screen times and EF difficulties

A complete summary of descriptive statistics can be found in Table 1. See supplementary materials (Tables 1 and 2) for a detailed description of children's reading and screen times.

4.2. EF difficulties

Mean scores of EF difficulties can be found on Table 1. According to the MANOVA, only the effect of sex was significant (Wilk's $\lambda = 0.936$, $F(3189) = 4.277$, $p = 0.006$, $\mu^2_p = 0064$). Girls exhibited lower EF difficulties in working memory and inhibition (F's > 0.035, p's < 0.003, $\mu^2_p < 0047$).

According to EFQ norms, better functioning scores (good and very good) were more frequent in the inhibition domain (74.8%), while approximately half the children exhibited worse (regular and bad) cognitive flexibility (49.5%) and working memory (42,8%) ($\chi 2\ (6) = 18.8$, $p = 0.005$) (see supplementary Table 3 for a detailed description by grade). Significant differences between grades were observed for flexibility ($\chi 2\ (6) = 18.8$, $p = 0.005$) and working memory scores ($\chi^2\ (6) = 13.3$, $p = 0.038$). In both domains, fourth graders had the highest proportion of "bad" scores (38.3% and 23.9%, respectively) while sixth graders had the lowest (10.6% and 9.3%) (see supp. Table 3). Finally, a follow-up assessment conducted on a sub-sample (n = 22) one year later did not find significant changes on any EF function, in any of the grades (F's < 1.403, p's > 0.270).

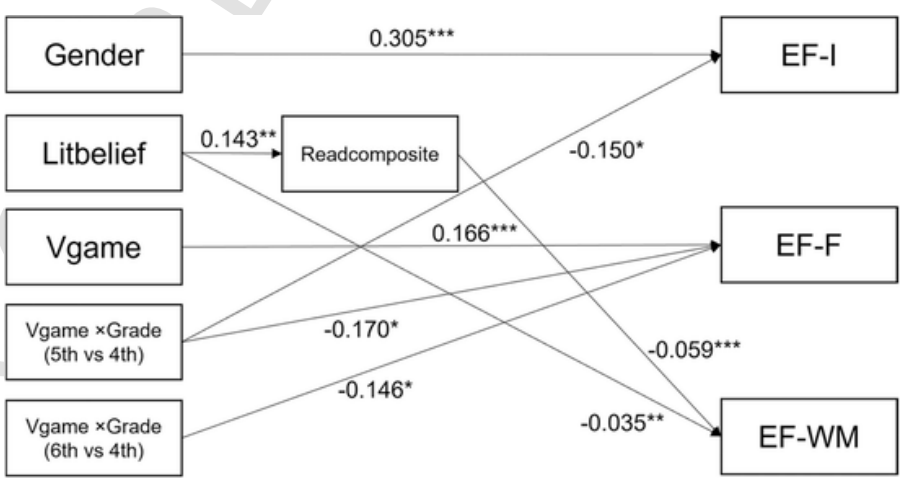

Fig. 1. Diagram of significant coefficients in the path analysis model. Gender, grade (not shown), literacy beliefs, video game times and video game times × grade interactions were included as exogenous predictors, reading composite was added as a mediator of literacy belief effects and EF measures were entered as endogenous outcome variables. Covariances among EFs are considered but not shown. EF-I: Executive function Inhibition scores; EF-F: Executive function Flexibility scores; EF-WM: Executive function working memory scores; litbelief: literacy beliefs; vgame: video game times; readcomposite: reading times composite score. *p < .05, * *p < .01, * p < .001.

Table 2
Linear regression analysis coefficients for EF measures.

						95% Confidence Interval	
Predictor	Estimate	SE	t	p	Stand. Estimate	Lower	Upper
EF-I: Step 2							
Grade							
(5 – 4)	0.378	0.356	0.851	0.389	0.009	-0.360	0.377
(6 – 4)	0.304	0.335	0.907	0.366	-0.160	-0.544	0.225
Gender	**0.310**	**0.105**	**2.95**	**0.040**	**0.438**	**0.145**	**0.730**
mother ed	**0.099**	**0.039**	**2.509**	**0.043**	**0.177**	**0.038**	**0.316**
litbelief	-0.022	0.019	-1.171	0.347	-0.090	-0.241	0.062
internet	0.035	0.029	1.224	0.444	0.095	-0.058	0.248
vgame	0.070	0.059	1.192	0.392	0.183	-0.120	0.487
TV	0.021	0.030	0.697	0.541	0.048	-0.089	0.185
Lread	0.018	0.041	0.443	0.658	0.034	-0.118	0.186
Sread	-0.034	0.035	-0.994	0.403	-0.069	-0.207	0.068
VideoG ×grade:							
(5 – 4)	**-0.225**	**0.074**	**-3.03**	**0.003**	**-0.589**	**-0.973**	**-0.206**
(6 – 4)	-0.096	0.070	-1.37	0.172	-0.252	-0.615	0.111
EF-F: Step 2							
Grade							
(5 – 4)	0.661	0.368	2.613	0.097	-0.114	-0.235	1.687
(6 – 4)	0.391	0.346	1.133	0.259	-0.478	-0.290	1.073
Gender	0.125	0.109	1.153	0.418	0.172	-0.089	0.340
mother ed	-0.008	0.041	-0.185	0.948	-0.013	-0.087	0.072
litbelief	-0.027	0.020	-1.382	0.338	-0.107	-0.065	0.012
internet	0.060	0.030	2.025	0.110	0.158	0.002	0.119
vgame	**0.172**	**0.061**	**2.839**	**0.035**	**0.440**	**0.052**	**0.291**
TV	-0.003	0.031	-0.082	0.934	-0.006	-0.064	0.059
Lread	0.016	0.042	0.387	0.874	0.030	-0.067	0.100
Sread	-0.030	0.036	-0.837	0.577	-0.059	-0.101	0.041
VideoG ×grade:							
(5 – 4)	**-0.241**	**0.077**	**-3.144**	**0.002**	**-0.616**	**-0.392**	**-0.090**
(6 – 4)	**-0.170**	**0.072**	**-2.354**	**0.02**	**-0.436**	**-0.313**	**-0.028**
EF WM: Step 2							
Grade							
(5 – 4)	0.634	0.318	1.992	* 0.048	-0.082	-0.438	0.275
(6 – 4)	0.088	0.300	0.293	0.770	-0.409	-0.780	-0.037
Gender	0.167	0.094	1.775	0.117	0.255	-0.028	0.539
mother ed	0.061	0.035	1.746	0.107	0.120	-0.016	0.255
litbelief	**-0.045**	**0.017**	**-2.641**	**0.045**	**-0.196**	**-0.342**	-0.050
internet	0.094	0.053	1.784	0.161	0.266	-0.028	0.561
vgame	0.024	0.027	0.911	0.137	0.061	-0.072	0.194
TV	0.038	0.026	1.472	0.364	0.111	-0.038	0.259
Lread	-0.080	0.031	-2.583	0.455	-0.175	-0.308	-0.041
Sread	**-0.024**	**0.036**	**-0.668**	**0.045**	**-0.050**	**-0.196**	**0.097**
VideoG ×grade:							
(5 – 4)	-0.158	0.066	-2.390	* 0.018	-0.451	-0.823	-0.079
(6 – 4)	-0.082	0.063	-1.303	0.194	-0.233	-0.585	0.120

Notes. EF-I: Executive function Inhibition scores; EF-F: Executive function Flexibility scores; EF-WM: Executive function working memory scores; Mother ed: mother education; litbelief: literacy beliefs; TV: tv times; vgame: video game times; internet: internet times; Lread: leisure reading times; Sread: study reading times. Significant effects have been highlighted in bold. *Omnibus ANOVA was not significant.

4.3. Associations between EF difficulties, HLE, reading and screen times

Significant associations were found between EF scores, HLE, screen exposure and reading habits (see Supplementary Table 5). Cognitive flexibility difficulties decreased with parent reading attitudes and leisure reading times, while working memory issues decreased with age, reading attitudes, shared reading before school, and study as well as leisure reading times ($-.141 < r < -.285$, p's $< .05$). In addition, HLE variables (literacy beliefs, number of books at home, shared reading) covaried significantly with each other (r's $> .418$, p's $< .001$). Regarding the children's screen use and reading habits, both leisure and study reading times ($r = .171$, p $< .05$) and internet and video game (but no TV) times ($r = .265$, $p < .05$) were significantly associated. On the other hand, both video game and internet use were inversely associated with leisure (but not study) reading times (r's $< -.167$, p's $< .05$). More positive parent reading attitudes were associated with more frequent children leisure reading ($r = .308$, $p < .001$), and less frequent video game and internet use (r's $< -.149$, p's $< .05$). Finally, perceived increases in children reading times and screen use during the pandemic were inversely correlated ($r = -.265$, $p < .001$).

Table 3
Path analysis of EF measures: coefficients.

95% Confidence Intervals								
Outcome	Predictor	Estimate	SE	Lower	Upper	β	z	p
EF-F	Vgame	0.166	0.051	0.066	0.265	0.434	3.263	0.001
EF-F	Grade (5 vs 4)	0.727	0.318	0.103	1.351	0.496	1.731	0.184
EF-F	Grade (6 vs 4)	0.461	0.296	-0.119	1.041	0.318	1.558	0.119
EF-F	Vgame × grade (5 vs 4)	-0.170	0.066	-0.300	-0.041	-0.574	-2.578	0.010
EF-F	Vgame × grade (6 vs 4)	-0.146	0.062	-0.268	-0.025	-0.494	-2.359	0.018
EF-WM	litbelief	-0.035	0.014	-0.062	-0.009	-0.157	-2.586	0.010
EF-WM	gender	0.164	0.079	0.009	0.320	0.129	2.070	0.038
EF-WM	readcomposite	-0.059	0.018	-0.094	-0.024	-0.194	-3.273	0.001
EF-I	videog	0.039	0.050	-0.058	0.136	0.104	0.786	0.432
EF-I	gender	0.305	0.091	0.127	0.482	0.217	3.359	< .001
EF-I	Grade (5 vs 4)	0.700	0.310	0.091	1.308	0.486	1.432	0.125
EF-I	Grade (6 vs 4)	0.355	0.290	-0.214	0.924	0.250	1.223	0.221
EF-I	Vgame × grade (5 vs 4)	-0.150	0.064	-0.277	-0.024	-0.516	-2.331	0.020
EF-I	Vgame × grade (6 vs 4)	-0.072	0.061	-0.191	0.047	-0.248	-1.182	0.237
readcomposite	litbelief	0.143	0.052	0.041	0.245	0.193	2.739	0.006
EF-WM	Litbelief □ readcomposite	-0.008	0.004	-0.016	-0.001	-0.038	-2.101	0.036

Notes. EF-I: Executive function Inhibition scores; EF-F: Executive function Flexibility scores; EF-WM: Executive function working memory scores; Mother ed: mother education; litbelief: literacy beliefs; TV: tv times; vgame: video game times; internet: internet times; readcomposite: reading times composite score. Significant effects have been highlighted in bold.

4.4. HLE, reading and screen times predictors of EF difficulties

We examined HLE, reading and screen times predictors of EF difficulties scores by a series of hierarchical linear regression models, fit for each EF subscale (see methods: data analysis section). The first step of the model included demographic, HLE, reading and screen time variables, while the interactions of reading and screen times with grade were included in subsequent additional steps (step 2: *videogame times* × *grade,* step 3: *internet times* × *grade,* step 4: *leisure reading times* × *grade,* step 5: *study reading times* × *grade*). Table 2 provides a complete list of regression coefficients for the highest step that turned out significant (i.e. that significantly increased R^2 with respecto to previous models).

EF-I scores. The second model accounted for 9.39% of the variance ($F(12,184 = 2.69$, $p = .002$). The inclusion of video game times × grade interaction significantly increased the explained variance ($\Delta R^2 = .04$, p = .009), while the rest of the interactions (internet, leisure and study reading times × grade) did not (F's < 1.98, p's > .142). Inhibition difficulties increased with mother education ($\beta = .177$, $p = .043$), and were higher among boys ($\beta = .437$, $p = .040$). Omnibus ANOVA tests showed that the interaction between video game times and grade was significant ($F(2184) = 4.82$, $p = .045$) (See Table 2) (FDR-corrected p-values are reported). Video game times were more positively associated with EF-I scores in fourth than in fifth graders ($\beta = -.589$, $p = .003$). No other significant effects were found.

EF-F scores. The second model accounted for 9% of the variance ($F(12,182 = 2.6$, $p = .003$), the inclusion of video game times × grade interaction contributed to increase explained variance ($\Delta R^2 = .047$, p = .007) while the rest of the interactions did not (F's < 1.83, p's > .162). Cognitive flexibility issues increased with video game times ($\beta = .440$, $p = .035$), while no other significant main effects were observed (p's > .097). The Omnibus ANOVA tests indicated a significant video game × grade interaction ($F(2184) = 5.07$, $p = .035$) (see Table 2) (FDR-corrected p-values are reported). Video game times were more positively associated with EF-F scores in fourth than in fifth ($\beta = -.616$, $p = .002$), and sixth graders ($\beta = -.436$, $p = .02$). No other interactions or effects turned out significant.

EF-WM scores. The second model accounted for a total of 15.2% of the variance ($F(12,183) = 3.92$, $p < .001$). The inclusion of video game times × grade interaction significantly increased fit ($\Delta R^2 = .025$, $p = .034$), while the rest of the interactions did not (F's > 3.03; p's < .051). However, the video game times × grade effect was not significant after FDR correction (p = .102). Working memory difficulties decreased with literacy beliefs ($\beta = -.195$, $p = .045$) and study reading times ($\beta = -.170$, $p = .045$) (See Table 2) (FDR-corrected p-values are reported). No other interactions or effects turned out significant.

Effects of change in reading and screen times. An additional model including changes in reading times and changes in screen times factor did not contribute to improving fit in any of the EF scores analyses ($\Delta R^2 < .0198$, p's > .123).

Path analysis of EF predictors. The model fitted our data well (χ^2 (10) = 15.6, $p = .0116$; CFI = 0.960; TLI = 0.916; RMSEA = 0.047, SRMR = 0.045). The effects were significant for all outcome variables: EF-I ($R^2 = .069$, Wald χ^2 (6) = 19.91, $p = .003$), EF-F ($R^2 = .058$, Wald χ^2 (5) = 15.21, p = .010), EF-WM ($R^2 = .097$, Wald χ^2 (3) = 29.9, $p < .001$); reading times ($R^2 = .037$, Wald χ^2 (1) = 7.26, $p = 0.007$) (see Fig. 1). EF-I scores were higher for boys ($\beta = .217$, $p = .001$) and were more associated with video game times in 4th (vs 5th) graders ($\beta = -.516$, $p = .021$). EF-F scores increased with video game times ($\beta = .434$, $p < .001$), and were more associated with video game times in 4th than in 5th ($\beta = -.574$, $p = .005$) and 6th ($\beta = -.494$, $p = .016$) graders. EF-W scores were higher for boys ($\beta = .129$, $p = .040$) and decreased with literacy beliefs ($\beta = -.157$, $p = .008$) and reading composite scores ($\beta = -.194$, $p = .001$). Finally, an indirect effect was observed for literacy beliefs on EF-WEM scores, mediated through reading times ($\beta = -.038$, $p = .03$) (see Supplementary Table 7 for details).

5. Discussion

This study has been the first to examine school-aged children's EF functioning during the COVID-19 lockdown in Argentina, and its potential association with HLE, reading and screen times. Around half our sample exhibited higher EF issues (i.e.: higher proportion of regular or bad scores) in the cognitive flexibility / emotional control (49.5%) and working memory domains (42.8%). More prominent increases were observed for screen times, which were also inversely related to reading. The exploratory analysis indicated that HLE variables and reading times were associated with lower EF difficulties (flexibility and WM). Regression analyses indicated that videogames were significant predictors of flexibility and inhibition issues (particularly in fourth graders) while mother literacy beliefs and reading times were associated with fewer WM problems in general. These findings are discussed in detail in the following paragraphs.

6. Children's EF difficulties during COVID-19 lockdown

Given the potential impact of COVID-19 and the concomitant lock-down measures as stressors and considering the known effects of diverse stressors (such as adverse life experiences, trauma or even natural disasters) on executive functions, it was relevant to examine the current incidence of EF difficulties among children during the pandemic and consider its potential predictors. We found more issues in the cognitive flexibility/emotional regulation and working memory dimensions among our sample, while better scores for inhibition were observed. In addition, the incidence of flexibility and working memory issues was higher among fourth graders (and lowest in sixth graders). Many studies point to age as one of the strongest predictors of EF performance in primary school (Arán Filippetti, 2011; Jacobsen et al., 2017; Segundo-Marcos et al., 2022) This pattern resembles the observed developmental trajectories of EF components in experimental tasks: since inhibition, working memory and flexibility seem to follow a developmental order, it is not surprising to find worse behavioral outcomes for the latter among the youngest children, for whom EFs might be less consolidated (Best & Miller, 2010; Jacobsen et al., 2017, Serpell & Esposito, 2016; Soussini et al., 2022). This might also be consistent with the fact that fourth graders exhibited the largest effects of screen times on EF issues (see "Associations between EF difficulties and screen times" section), although further replications on larger samples would be needed to interpret this result. In addition, we observed lower incidence of inhibition and working memory issues among girls. The original EF questionnaire study (Canet-Juric et al., 2021) and other works (e.g.: Jacobsen et al., 2017) did not find such gender effects, while other suggest that these effects do exist, but decrease along the school years (Klenberg et al., 2001; Villaseñor et al., 2009). In general, little support for EF gender differences has been found in the literature (Grissom & Reyes, 2019), therefore this effect should be interpreted with caution until replication.

Parents' reports of children's EF issues during the COVID-lockdown are consistent with several pandemic studies indicating an increase in perceived behavioral indicators of EF deficits in children. From a sample of confined Spanish children, between 30% (BRIEF-2 scale) and 35% (BDEFS-CA scale) exhibited low EF functioning scores, which were considerable worse to those from a pre-pandemic unconfined sample (Lavigne-Cervan+ et al., 2021a). Another study from the same group (Lavigne-Cerván et al., 2021b) coincided in finding that children's EF difficulties were best explained by state anxiety scores. In addition, different studies showed that the incidence of EF difficulties was significantly associated with the school learning format during the pandemic, with the worse outcomes observed for remote vs in-person schooling (Lavigne-Cerván et al., 2021b; Hanno et al., 2022). Another line of evidence showed that parental distress was an additional predictor of children's behavioral EF outcomes (Polizzi et al., 2021). All these results are congruent with a previous study that showed increased psychopathology indicators (anxiety, depression, impulsivity, inattention, aggression) and lesser positive affect on a large sample of Argentinean children and adolescents (Andrés et al., 2022), that was more prominent within the 9–11 age range and in those children under total confinement (as opposed to those under social distancing conditions). This study also showed a link between parents and children's mental health. Overall, the aforementioned studies coincide in indicating that the pandemic and confinement-related distress have taken a toll on the children's self-regulating capabilities, a process that could be buffered or intensified by their parents' psychological wellbeing and their home's emotional climate. Our study indicates a high incidence of working memory and flexibility issues perceived by the children's parents, therefore our findings can also be interpreted as compatible with (but not evidence of) this interpretation, even though we did not compare different lock-down or schooling conditions and our design was cross-sectional and correlational. While we cannot directly attribute the EF difficulties observed in our sample to pandemic-related stressors or remote schooling, previous evidence suggests that they might at least be significant contributing factors. In addition, we found additional HLE, reading and screen time variables that might have influenced EF functioning during the lock-down period (see the sections below). It is worth noting that our study was conducted on a sample of mostly high socioeconomic level homes (most parents had completed university education), therefore it is quite possible that EF problems in children had been worse in those homes more vulnerable to social and environmental stressors during the pandemic. On the other hand, cognitive flexibility and working memory issues tended to increase with mother education within our sample. This rather counterintuitive finding might be indicating that more highly educated mothers were more aware of and/or exigent with their children's behavior, leading to worse perceived behavior ratings. Finally, we should point out that our follow-up assessment one year later did not show evidence of changes in EF ratings with respect to the lockdown period, suggesting that cognitive flexibility and working memory issues may have persisted (although the extremely low sample size limits the significance of this particular finding). On the other hand, this second assessment took place only three months after the return to in person schooling in Argentina (August 2021).

6.1. Children reading and screen times during COVID-19 lockdown

Most parents perceived large increases in their children's recreational screen times, while only one third of the sample reported the same for leisure reading. We observed higher reading frequencies in approximately one-third of our sample, a similar proportion as a previous large-scale study in the UK (Clark & Picton, 2020, 2021). These studies pointed out that coping and emotional regulation were two of the more frequent reasons for reading among children. Nevertheless, we also found a perceived decrease in the reading frequency of one-third of our sample, and almost 17% of them did not read for pleasure at all. This might be in part due to the increase on screen times, since they were both inversely correlated. This large increment (reported by around 60% of the parents) is consistent with the higher screen times observed during the pandemic among school-aged children in several countries, particularly during lockdown measures (Eales et al., 2021; Werling et al., 2021; see Bergmann et al., 2022 for a review). One of these studies (Eales et al., 2021) found that problematic media use increased particularly for school-aged children, associated with factors such as: family stress, schools-closure and the limitations of lockdown measures as well as parental behaviors and attitudes towards screen media. While we did not assess problematic use specifically, this interpretation can be extended to our sample, since 1) children in Argentina endured a prolonged lockdown without possibility of outdoor activities, favoring more sedentary forms of entertainment 2) exhibited increased distress indicators (Andrés et al., 2022), which may have prompted turning to screen devices as a coping mechanism.

6.2. Associations between EF difficulties, HLE and reading times

Our exploratory correlation analysis showed that several HLE variables (literacy beliefs, preschool shared reading) and leisure reading times were negatively associated with cognitive flexibility and working memory issues. Moreover, regression and path analyses indicated that more frequent reading times were seen in children with fewer working memory issues. The latter also decreased with better parents' reading attitudes. More interestingly, literacy beliefs effects were partially mediated by children's reading times. Two non-mutually exclusive interpretations can be put forward to explain this pattern: 1) reading-stimulating home environments and current reading practices promote EF development, acting as a protective factor against behavioral EF issues and possibly buffering the impact of the pandemic and lockdown-related stress, 2) those children with more working memory difficulties will be less prone to engage in cognitively demanding activities such as leisure reading, favoring more passive or quickly rewarding forms of entertainment, like screen media. While we cannot infer causality due to the correlational nature of our data, several lines of evidence indicate a positive impact of HLE and reading practices on children's cognitive development in general (d'Apice & von Stumm, 2019; for a review, see: Head-Zauche et al., 2016) and EF in particular. Recent studies found significant associations between HLE variables and EF skills in preschool (Altun, 2022; Korucu et al., 2020), and primary school (Jasińska et al., 2022) children. It has been proposed that HLE may provide a context for parents to encourage their child to listen, pay attention, actively manipulate information and practice self-control – all EF-related skills – during structured, language and literacy-related learning activities (Korucu et al., 2020). During storybook reading, parents may prompt their children to remember details or actively predict possible outcomes for the narrative and characters (Bernier et al., 2010), thus scaffolding the children's meaning-creation processes. It might also be the case that the "literacy beliefs" construct covaries and acts as a proxy for other language-related behaviors and variables (conversations with the child, quantity or quality of linguistic stimulation) that might contribute to childrens' cognitive development through linguistic stimulation (d'Apice & von Stumm, 2019). Furthermore, reading comprehension actively engages EF (Nouwens et al., 2021; see Follmer, 2018 for a meta-analysis and Butterfuss & Kendeou, 2018 for a review), and working memory has been found a robust predictor of children's comprehension performance (Peng et al., 2017). It is thus expected that better EF functioning scores (WM in particular) are associated with more frequent reading times. Quite in fact, two studies conducted on Argentinean children applying the same behavioral questionnaire showed that working memory issues were negatively associated with narrative and expository text comprehension (Canet-Juric et al., 2021; Canet-Juric et al., 2022). Lastly, a neuroimaging study (Kraus & Hutton, 2017) found that more frequent leisure reading was associated with a stronger connectivity between visual and cognitive control regions in school-aged children, a result that was interpreted as an indicator of EF engagement during reading. Summing it up, our results could be interpreted as evidence of a positive impact of HLE and reading practices on EF, which might act as a buffer on EF functioning at a behavioral level (for instance, in the face of potential stressors such as the pandemic lockdown). Furthermore, part (but not all) of the effects of mothers' literacy beliefs on children's working memory was explained by their positive influence over the children's reading practices, which in turn was associated with fewer EF issues. It should be noted that we did not observe significant effects of the perceived changes in reading times (compared with pre-pandemic times) on EF issues, which might be indicating a more stable long-term effect of HLE and reading practices on executive functioning.

6.3. Associations between EF difficulties and screen times

Longer video game times were associated with more behavioral issues in inhibitory control and flexibility, particularly among fourth graders. As was the case with reading-related variables, two compatible explanations can be put forward. Screen media use might have contributed to behavioral EF problems by favoring more passive or instantly gratifying mental activities, while competing with more focused and cognitively demanding activities (such as reading, as we did observe in our sample). Conversely, children exhibiting more distractibility, impulsivity, or self-regulation problems might have been more attracted to screen media (Gentile et al., 2012). However, unlike the literacy environment and practices, screen media is a much more heterogeneous construct, and the evidence of its impact on cognitive development is more diverse, mixed and even contradictory.

Our findings are congruent with previous evidence suggesting a detrimental effect of screen exposure on self-regulation and EF skills (Chen et al., 2022, Gentile et al., 2012, Swing et al., 2010). While we did not consider problematic use indicators in our study,

our results are also consistent with the EF deficits observed in gaming abuse or addiction research (Farchakh et al., 2020; Sugaya et al., 2019). A theoretical model of problematic internet use has pointed out the importance of stressful events as potential triggers; as well the contribution of coping styles and impaired executive functions (particularly, inhibitory control) in the maintenance of these behaviors (Brand et al., 2016). We did not find evidence of internet effects, but it could be argued that pandemic-related stressors might have a similar effect on video games use, intensifying their link with EF difficulties. Even when we lack direct measures of stress for our sample, a previous study did find increased stress-related symptomatology among a similar sample of Argentinean children (Andrés et al., 2022).

On the other hand, it should be noted that the evidence regarding video game effects on children is not so clear, since positive EF outcomes have also been found (see Fietzer & Chin, 2017; Smirni et al., 2021 for reviews). It is likely that these effects ultimately depend upon factors such as age, game type and, most importantly, total play times (Smirni et al., 2021). Within our sample, EF effects of video game times were more prominent among fourth graders, even though their proportion of high video game times was relatively similar to the rest of the groups (4th: 57.45%, 5th: 59.74%, 6th: 41.38%). This might suggest that younger school children exhibit higher susceptibility for gaming effects on their EFs (possibly because some components are relatively under-developed), but this possibility should be verified and further examined on larger samples.

To sum, longer video game times were associated with worse EF behavioral ratings (inhibition and flexibility). It should be noted that the parents' perceived increase (compared with pre-pandemic times) was not a significant predictor of EF. Therefore, our findings can be interpreted as video games being: 1) detrimental to EF in children, 2) a preferred source of entertainment (or even a coping mechanism) for those children with more EF issues or 3) a synergic combination of the former (see Gentile et al., 2012). Finally, it is also worth noting that we did not observe significant detrimental effects of TV on EF within our sample, unlike previous studies (Nathanson et al., 2014; Lillard et al., 2015; Swing et al., 2010). This might be explained by the fact that high TV times (more than 3 h a day) were much less frequent in our sample (11.4%) than high video game (27.1%) or internet times (22.9%); respectively). Furthermore, it is quite possible that streaming has replaced traditional TV among our children. Neither did we find significant effects of internet times on children's EF. Since previous evidence has linked problematic internet use to EF difficulties within this age range (Oh et al., 2021), this might suggest that abuse indicators are more sensible to examine web surfing and social media effects on EF than plain screen times.

6.4. Limitations and future directions

We should point out the following limitations in the present study. First, the relatively low sample size, combined with potential selection bias (since participants were volunteers recruited from social networks) and the fact that our sample was composed mostly by high NSE participants (parents who completed university), might reduce the generalizability of our findings. In addition to selection bias, social desirability might have influenced the mothers' responses in the reading, screen times and EF questionnaires. While this might have affected our measures, we did not find evidence of ceiling or floor effects, and we were still able to observe high screen times and lower reading times. Future studies should focus on the aftermath of the pandemic in more socially vulnerable populations. The correlational nature of our findings does not allow us to draw conclusions about causality. In addition, a larger scale follow up would have provided more empirical ground to comment on the trajectory of the EF issues one year after the lockdown measures. On a related note, we did not have access to within-subject pre-pandemic EF assessments for our sample (but we did have pre-pandemic normative data of the EF questionnaire), and we did not specifically ask parents to compare current behavior with pre-lockdown functioning. Therefore, we cannot claim that the incidence of EF issues observed in our sample is due to the pandemic or the lockdown measure. On the other hand, several studies suggest that this might have been the case indeed, as they found that confinement and remote schooling were associated with worse behavioral EF scores in children (Lavigne-Cerván,et al.,2021b); Hanno et al., 2022). There are possible limitations in use of an online parental heteroreport scale to assess EF instead of direct cognitive performance tests might be questioned, even though it was the only available assessment instrument due the lockdown measure. However, these measures can be used to make predictions about the manifestations of EF on children's daily behavior (Gioia et al., 2017), and they have been shown to provide a useful complement to performance tests (Gerst et al., 2017). Moreover, Eisenberg et al. (2019) compared the predictive power of heteroreport surveys and experimental tasks, and found that while surveys modestly and heterogeneously predict real-world outcomes, tasks largely do not. In particular, EF questionnaires are robust predictors of children's academic achievement in math or reading skills (Canet-Juric et al., 2021; Canet-Juric et al., 2022, Gerst et al., 2017). Still, future studies might benefit from including performance-based measures. On a related note, we relied on parents' report of reading and screen times instead of more direct and objective measures of children's activities (such as total and application screen times statistics generated by smartphones), which might be more accurate and should be considered in future studies. Finally, we did not consider other potentially relevant variables in our study, such as parenting style or stress, psychopathology indicators (such as anxiety or depression tests) or children personality traits.

6.5. Summary

We were able to identify high EF functioning difficulties in the domains of cognitive flexibility (and emotional regulation) and working memory in around half our sample during the COVID-19 lockdown, in accordance with other studies of children behavior in the pandemic. Fourth graders exhibited the highest proportion of low scores in these EFs, which might be reflecting developmental differences with the older children. In addition, we observed larger increases of screen media than reading times, while most children did not read for leisure on a daily basis. We found that both parents' literacy beliefs and children's reading times were associated with fewer EF issues (particularly in the working memory domain). In addition, reading times partially mediated this effect from literacy

beliefs. Conversely, video game times were positive predictors of inhibition and flexibility problems, especially among younger children. Since we cannot infer causality, our results could be explained as: 1) effects of reading and screen media over EF functioning, 2) a preference for reading or screens, according to the children's EF profile or 3) a combination of both. At any rate, our findings are compatible with previous literature that highlights the toll of the pandemic and the lockdown on the children's cognitive and emotional self-regulation skills. Considering the relevance of behavioral EF to academic achievement and children's psychological wellbeing, we recommend (in line with Andrés et al., 2022) that parents and public institutions be mindful of the current trajectory of children behavior and recreational habits, to preserve their mental health during the transition to the post-pandemic normality.

Compliance with Ethical Standards

none.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the CONICET research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Author contribution

All authors contributed to study design, data collection, manuscript writing and reviewing. Ángel Tabullo carried out the statistical analysis.

Uncited references

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Declaration of Competing Interest

All authors declare that they have no conflict of interest.

Data Availability

Data will be made available on request.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.cogdev.2023.101378.

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