ARTIGO ORIGINAL

Artigo recebido: 23/2/2023
Aprovado: 15/6/2023

Executive functions and mental health in students during COVID-19 pandemic

Funções executivas e saúde mental em estudantes durante a pandemia de COVID-19

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DOI: 10.51207/2179-4057.20230014

Summary

Executive functions (EF) are a set of higher-order cognitive processes that regulate thoughts, emotions, and actions. Adequate EF are required to deal with unexpected changes in daily routines, such as those that occurred because of the COVID-19 pandemic and maintain healthy emotional and behavioral regulation. This study analyzed the EF and mental health of grade 3 to 5 schoolchildren (8-9 years old) before and during the COVID-19 pandemic in Brazil and sought to identify any variations and correlations between these two factors. Parents of students completed the Strengths and Difficulties Questionnaire (SDQ) for emotional and behavioral screening, and the Inventory of Difficulties in Executive Functions, Regulation, and Delay Aversion for children (IFERA-I) to evaluate EF. The Wilcoxon test for paired samples was used to compare the differences between the variables before and during the pandemic and revealed problems in EF (inhibitory control: Z=-1.967; p=0.049; working memory: Z=-2.476; p=0.013; regulation: Z=-2.521; p=0.012) and in respect of the emotional symptoms' subscale of the SDQ (Z=-2.392; p=0.17). Using Spearman's correlation, significant associations were observed between worse mental health in children and greater problems with EF. There was a statistically significant positive correlation between the emotional symptoms scale in the SDQ and problems with cognitive flexibility (ρ=0.600; p=0.002) and delay aversion (ρ=0.398; p=0.054) identifies by the IFERA-I. Our results highlight the need for the implementation of appropriate public policies that enable schools to stimulate the development of EF abilities to protect the mental health of children.

Keywords: Executive Functions. Mental Health. Behavior. Childhood. COVID-19.

Resumo

Funções executivas (FE) são um conjunto de processos cognitivos de ordem superior que regulam pensamentos, emoções e ações. As FE adequadas são necessárias para lidar com mudanças inesperadas nas rotinas diárias, como as que ocorreram devido à pandemia de COVID-19 e manter uma regulação emocional e comportamental saudável. Este estudo analisou as FE e a saúde mental de escolares do 3º ao 5º ano (8-9 anos) antes e durante a pandemia de COVID-19 no Brasil e buscou identificar variações e correlações entre esses dois fatores. Os pais dos alunos preencheram o Questionário de Forças e Dificuldades (SDQ) para triagem emocional e comportamental, e o Inventário de Dificuldades em Funções Executivas, Regulação e Aversão ao Atraso para crianças (IFERA-I) para avaliar as FE. O teste de Wilcoxon para amostras pareadas foi usado para comparar as diferenças entre as variáveis antes e durante a pandemia e revelou problemas nas FE (controle inibitório: Z=-1,967; p=0,049; memória de trabalho: Z=-2,476; p=0,013; regulação: Z=-2,521; p=0,012) e quanto à subescala de sintomas emocionais do SDQ (Z=-2,392; p=0,17). Usando a correlação de Spearman, foram observadas associações significativas entre pior saúde mental em crianças e maiores problemas com FE. Houve correlação positiva estatisticamente significativa entre a escala de sintomas emocionais do SDQ e os problemas de flexibilidade cognitiva (ρ=0,600; p=0,002) e aversão ao atraso (ρ=0,398; p=0,054) identificados pelo IFERA-I. Nossos resultados destacam a necessidade da implementação de políticas públicas adequadas que permitam às escolas estimular o desenvolvimento de habilidades de FE para proteger a saúde mental das crianças.

Unitermos: Funções Executivas. Saúde Mental. Comportamento. Infância. COVID-19.

Trabalho realizado no Programa de Programa de Pós-Graduação em Distúrbios do Desenvolvimento - Universidade Presbiteriana Mackenzie, São Paulo, SP, Brasil.

Conflito de interesses: Os autores declaram não haver.

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Introduction

Executive functions (EF) control goal-oriented behavior by controlling and regulating thoughts, emotions, and actions (Dias & Malloy-Diniz, 2020; Seabra et al., 2014). EF allow individuals to achieve their goals through the voluntary control of stimuli (internal and external), organization and planning to meet their daily demands (Blair, 2017; Chan et al., 2008; Diamond, 2013; Zelazo et al., 2013). Therefore, EF are fundamental to organizing behavior in the face of environmental demands (Diamond, 2013) and play a fundamental role in solving problems and making decisions flexibly and creatively (Diamond & Ling, 2019; Miyake & Friedman, 2012; Weintraub et al., 2013; Zelazo & Carlson, 2012). The present study uses the hypothetical componential model of Diamond (2013) and the empirical model of Miyake et al. (2000) as its theoretical background. These models presuppose the existence of basic components of EF (inhibitory control, working memory, and cognitive flexibility) with relatively independent constituent abilities, despite the interrelationships between them (Dias & Malloy-Diniz, 2020; Seabra et al., 2014).

The number of studies about EF has increased in recent decades, and their findings have in general supported the idea that there is a need to adequately stimulate the development of these functions to achieve success in different areas of life. In childhood in particular, higher levels of EF is associated with efficient learning and favorable school performance, as well as the development of social and emotional skills (Cardoso & Fonseca, 2016; Dawson & Guare, 2010; Dias & Seabra, 2013; Meltzer, 2010). EF and the mental health of schoolchildren have an intrinsic relationship with academic performance. The better the development of EF and socio-emotional skills, the better the performance in an academic context tends to be (Ahmed et al., 2019; Korucu et al., 2022; Mattar et al., 2020; Robson et al., 2020; Smithers et al., 2018). This is especially true for the students in their first school years, as their development of cognitive and socio-emotional skills during this period contributes to their progression throughout their school years (Ribner et al., 2017).

The COVID-19 pandemic and the implications for Brazilian education

The COVID-19 pandemic directly affected schools around the world, including in Brazil (Engzell et al., 2021; Pericàs et al., 2020; Sousa & Carvalho, 2020). The closing of schools to prevent the spread of the virus affected 48 million students and 2 million Brazilian teachers in a sudden but necessary way. Schools, both public or private, faced many obstacles when trying to maintain the quality of education in online classes or remote teaching (Gonçalves et al., 2020; Sociedade Brasileira de Pediatria, 2021).

Students from public schools tended to be more harmed by remote teaching because of the greater socio-economic vulnerability in this group, who had less access to the internet and a lack of devices such as computers, cell phones, and tablets, which resulted in digital exclusion and, consequently, school exclusion (Todos Pela Educação, 2021). Although it was necessary to suspend school activities during the pandemic to ensure the health and safety of students and teachers, this action deprived students of the cognitive stimulation associated with attending school, causing impairment to their development (Dawson, 2021; Kuhfeld et al., 2020).

The main challenges faced by these Brazilian students and their families, highlighted in a report published by the civil society organization *Todos pela Educação* (2021) were: 1) a lack of access to technology to be able to follow classes remotely; 2) some families being unable to help their children with remote learning due to lack of knowledge of the subjects being taught; 3) "particular problems with students just starting school who could not work autonomously and required close supervision; 4) obstacles and difficulties faced by teachers in implementing classes and choosing the best models for distance learning. In a survey carried out by Instituto Península (2020) with 7,734 teachers in the months of April and May 2020, 83% declared they were unprepared for classes delivered by remote teaching, 88% said they had never taught virtual classes and 55% had no kind of training to use the online tools. Social isolation and being deprived

of face-to-face education impacted the children's education and, therefore, their cognitive, emotional, and social development.

Recent studies have begun to show the effects of this period on children, revealing impairments in EF development (He et al., 2021; Hendry et al., 2022; Lavigne-Cerván et al., 2021; Nichols, 2022) and impaired mental health (Bilar et at., 2022; Donida et al., 2021; Linhares & Enumo, 2020; da Silva Moreira & Passig da Silva, 2020; Wang et al., 2020). The objective of this research was, therefore, to assess the mental health/behavior problems and the EF abilities of school children from the 3rd to the 5th year of elementary school before and during the pandemic and compare any changes or associations between these variables.

Methods

Participants

Students from an elementary public school in the city of São Paulo were taking part in a project that was assessing emotional, behavioral, and cognitive variables when the pandemic began. So, 24 participants were followed up during the pandemic. This article analyzes data from these 24 3rd to 5th grades students before and after the pandemic. Table 1 shows the number of participants per school year and their age.

Instruments

The Inventory of Difficulties in Executive Functions, Regulation, and Delay Aversion - Children's Version (IFERA-I): identifies difficulties in the EF of children and adolescents between 3 and 14 years old based on responses from parents and teachers and has been shown to have adequate accuracy and validity for Brazilian children (Trevisan, 2014). It assesses the child's difficulty on five scales, with a total of 28 items: inhibitory control, working memory, cognitive flexibility, delay aversion, and state regulation. For each item in the inventory, the respondent must mark one of the following responses: (1) never; (2) rarely; (3) sometimes; (4) often or (5) always. The higher the score, the greater the number of EF problems.

The Strengths and Difficulties Questionnaire (SDQ): used to screen behavior and mental health problems in individuals aged 4 to 16 years. The scale was initially developed by Goodman (1997) and has been validated for use in Brazil (Saur & Loureiro, 2012; Stivanin et al., 2008). The instrument covers five areas: emotional symptoms (ES), conduct problems (CP), hyperactivity/inattention (HIP), peer relationship problems (PRP), and prosocial behavior (PB). Each one of the 25 questions is a three-level Likert scale (Not True=0, Somewhat True=1, or Certainly True=2). The scores on each scale correspond to the sum of the scores on each item. The higher the score on the Es, CP, HIP, and PRP subscales, the greater the difficulties in these behaviors. In the PB subscale, the higher the score, the greater the capacity for prosocial behavior.

Table 1

Participants per school year and age

school year	N	Percentage	Age means (SD)
3º	9	37.5	8.0 (0.0)
4º	6	25.0	9.0 (0.0)
5º	9	37.5	9.9 (0.3)
Total	24	100.0	

Note: SD = Standard Deviation.

Source: survey data.

Procedure

The research was approved by the Mackenzie Presbyterian University Ethics Committee (08745119.2.0000.0084). The parents completed the two instruments used in this study before the pandemic (February and March 2020) and during the pandemic (October and November 2020 - via telephone due to social isolation). It should be noted that from March until the date of the second collection, schools maintained remote teaching.

Data analysis

Descriptive analyses were conducted with the results given as mean and standard deviation, followed by a Spearman correlation between the results

of the two instruments, and the Wilcoxon test for paired samples to compare the differences between the variables before and during the pandemic. SPSS v.21, (IBM Corp., Armonk, NY, USA, 2021) was used for the analyses. Non-parametric analyses were conducted due to the data distribution not being normal.

Results

Comparison of the results of the IFERA-I and SDQ scales before and during the pandemic

Table 2 shows a descriptive analysis of the results. Comparing the before and during the pandemic responses from IFERA-I, an increase in the averages can be seen in all inventory areas as shown by positive values of median difference ([results during pandemic] - ([results before pandemic]). That is, in descriptive terms, there was an increase in students' EF problems.

Table 3 shows the results of the analysis comparing the students' mental health indicators before and during the pandemic based on the results of the SDQ. There was in increase in scores in respect of "emotional symptoms" and "peer problems", reflecting an increase in difficulties in these areas.

Table 2

Description of descriptive statistics and results of the Wilcoxon Test in paired samples for the IFERA-I applied before and during the pandemic

	IC		WM		FL		DA		SR		Total	
	Before	During	Before	During	Before	During	Before	During	Before	During	Before	During
Minimum	1	1.33	1	1.17	1	1	1	1.6	1	1.5	1.07	1.32
Maximum	4.33	3.83	3.33	4.5	3.4	3.6	4.6	5	4.17	4.33	3.78	3.36
Median	2.34	2.76	1.96	2.41	2	2.38	2.68	3.03	2.41	2.98	2.27	2.71
Standard deviation	0.9	0.62	0.66	0.7	0.64	0.76	0.94	0.86	0.82	0.72	0.69	0.48
Median difference	0.42		0.45		0.38		0.35		0.57		0.44	
Z	-1.967		-2.476		-1.917		-1.317		-2.521		-2.600	
Sig.	0.049		0.013		0.055		0.188		0.012		0.009	

Note: Sig. = Significance; IC = Inhibitory Control; WM= Working Memory; FL = Flexibility; DA = Delay Aversion; SR = State Regulation.
Source: survey data.

Table 3

Description of descriptive statistics and Wilcoxon test results in paired samples for the SDQ applied before and during the pandemic

	Emotional symptoms		Conduct problems		Hyperactivity/ inattention		Peer relationships problem		Prosocial behavior	
	Before	During	Before	During	Before	During	Before	During	Before	During
Minimum	0	0	0	0	0	0	0	0	3	6
Maximum	6	8	6	5	9	6	5	6	10	10
Median	3.16	4.54	2.41	1.87	4.08	3.62	1.37	2.29	8.62	8.87
Median difference	1.38		-0.54		-0.46		0.92		0.25	
Standard deviation	1.8	2.32	1.74	1.36	2.56	1.66	1.27	2.05	1.68	1.22
Z	-2.391		-1.575		-0.971		-1.703		-0.737	
Sig.	0.017		0.115		0.331		0.089		0.461	

Source: survey data.

Spearman's correlation analysis of the results of the IFERA-I and SDQ scales before and during the pandemic

Tables 4 and 5 show the results of the correlation analysis between the IFERA-I and SDQ results before and during the pandemic respectively. Before the pandemic, the IFERA-I regulation scale had more significant correlations with SDQ scales, mainly in respect of conduct problems, hyperactivity/inattention, and peer relationships problems.

Table 4

Spearman correlations of responses to the IFERA-I and SDQ inventories by parent respondents before the pandemic (n=24)

BEFORE COVID PANDEMIC Emotional symptoms Conduct problems			SDQ				
			Hyperactivity inattention	Peer relationships problem	Prosocial behavior		
IFERA-I	IC	ρ	0.203	0.327	0.512*	0.154	-0.321
		Sig.	0.341	0.119	0.011	0.473	0.126
	WM	ρ	0.343	0.421*	0.469*	0.347	-0.252
		Sig.	0.101	0.041	0.021	0.097	0.234
	FL	ρ	0.296	0.344	0.326	0.288	-0.142
		Sig.	0.159	0.099	0.120	0.173	0.507
	DA	ρ	0.428*	0.336	0.279	0.385	-0.355
		Sig.	0.037	0.108	0.187	0.063	0.089
	RG	ρ	0.294	0.612**	0.504*	0.429*	-0.316
		Sig.	0.164	0.001	0.012	0.036	0.133
	TOTAL	ρ	0.348	0.529**	0.501*	0.353	-0.376
		Sig.	0.095	0.008	0.013	0.091	0.070

Note: ρ = Spearman coefficient; Sig. = Significance; IC = Inhibitory Control; WM= Working Memory; FL = Flexibility; DA = Delay Aversion; SR = State Regulation.

Source: survey data.

Table 5

Spearman correlations of IFERA-I and SDQ inventory responses by parent respondents during the pandemic (n=24)

DURING COVID PANDEMIC Emotional symptoms Conduct problems			SDQ				
			Hyperactivity inattention	Peer relationships problem	Prosocial behavior		
IFERA-I	IC	ρ	0.287	0.331	0.385	0.035	-0.190
		Sig.	0.174	0.114	0.063	0.870	0.375
	WM	ρ	0.234	0.435*	0.530**	0.212	-0.298
		Sig.	0.271	0.034	0.008	0.320	0.157
	FL	ρ	0.600**	0.183	0.462*	0.420*	-0.184
		Sig.	0.002	0.393	0.023	0.041	0.389
	DA	ρ	0.398	0.051	0.169	0.112	-0.070
		Sig.	0.054	0.814	0.431	0.603	0.744
	RG	ρ	0.077	-0.030	-0.042	0.133	0.142
		Sig.	0.722	0.889	0.844	0.536	0.510
	TOTAL	ρ	0.410*	0.109	0.420*	0.218	-0.130
		Sig.	0.046	0.614	0.041	0.306	0.545

Note: ρ = Spearman coefficient; Sig. = Significance; IC = Inhibitory Control; WM= Working Memory; FL = Flexibility; DA = Delay Aversion; SR = State Regulation.

Source: survey data.

During the pandemic, the SDQ scales (emotional symptoms, hyperactivity inattention, and peer relationships problem) correlated significantly with the IFERA-I flexibility scale, which may indicate that the parents perceived their children to have greater difficulties with problem-solving.

During the pandemic, some associations between EF and mental health can be observed. Working memory showed a significant correlation with conduct problems (p=0.034) and hyperactivity/impulsivity (p=0.008). Cognitive flexibility correlated significantly with emotional symptoms (p=0.002), hyperactivity/impulsivity (p=0.023), and peer relationship problems (p=0.041). Total IFERA-I scores correlated with emotional symptoms (p=0.046) and hyperactivity (p=0.041). The main difference observed in the correlations between the results of the SDQ and IFERA before and during the pandemic was an increased number of significative correlations with the emotional symptoms scale from the SDQ.

Discussion

The results corroborate previous findings that reported losses in student development during the pandemic and remote teaching period (REF). When comparing EF and mental health indicators before and during the pandemic, it is possible to observe an increase in problems, especially emotional symptoms, possibly related to social isolation and the closure of schools.

Fonseca et al. (2020) found that the lack of face-to-face classes prevented students from socializing and led to an increase in emotional problems and problems with peer relationships, while the lack of proper professional monitoring related to learning increased student dependence and reduced their autonomy. This can affect the students' ability to make the decisions necessary to increase their development, and consequently present greater risks in respect of the impairment of the development of their executive, social and emotional functions (Bilar et at., 2022; Donida et al., 2021; Hendry et al., 2022; Nichols, 2022) which can directly affect their academic performance. Given this evidence in respect of the impairment of children's cognitive functions and mental health, those responsible for schools should be made aware of the need to evaluate students in return to face-to-face activities and develop appropriate targeted interventions (Linhares & Enumo, 2020). This should not only be limited to academic skills but should also consider social and emotional skills.

The results of this study, which indicated an increase in executive difficulties during the pandemic, reinforce the need to stimulate EF as an intervention strategy. Given the correlation with mental health, these strategies can also influence emotional abilities, providing better conditions for students and, thus, promoting their development in a broader way that includes cognitive, social, and emotional aspects (Linhares & Enumo, 2020). This research revealed a strong association between the children's ability to have new perspectives on problem-solving, measured as cognitive flexibility, and emotional problems. It is our hypothesis that that the stimulation of executive skills has a direct effect on the student's learning and their social and emotional skills. It should be noted that the pandemic had some negative effects on the students' learning, even before remote teaching began, due to the economic impact of the pandemic increasing the students' socioeconomic vulnerability and impairing their socio-emotional skills.

These difficulties increased during the remote teaching period and became even more complex, especially as the teachers did not always have the skills or experience required to implement effective strategies during this period in respect of this different type of teaching or those targeting the health and psychological care of the students. These types of measures are essential to guarantee the provision of effective teaching as well as equity in education (Azevedo et al., 2020; Baron et al., 2020; Brooks et al., 2020; Christoffel et al., 2020; Golberstein et al., 2020; Grewenig et al., 2021; Loades et al., 2020; Newlove-Delgado et al., 2021; Pereda & Diaz-Faes, 2020).

Considerations

The difficulties observed during the pandemic can generate long-term damage to student

development, and schools will need to take measures to help in this scenario, such as those suggested in the study by Oliveira et al. (2020), who highlighted interventions in EF and mental health. Each student should be assessed so that their level can be established, and the teaching program can be resumed from an appropriate point. It is essential to use robust, scientifically based interventions, which need to be based on pedagogical proposals, including structured teaching, adequate literacy methods, the use of homework as a teaching strategy, reading programs and strategies to reduce student absences.

For students who have difficulties, it is important to use small-groups and follow-up programs. The use of structured interventional programs (such as those presented by Bodrova & Leong, 2007; Cardoso & Fonseca, 2016; Carvalho, 2017; Dias & Seabra, 2013; León, 2018; Rosário et al., 2007) focusing on EF and socio-emotional skills can make a difference to the students' experiences and contribute directly to their development. Therefore, public policies that produce such actions are very important as they enable schools to employ appropriate strategies that can help to mitigate the negative effects of the pandemic on students.

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