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Effectiveness of an Executive Functions Parental Program in ADHD Children

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Abstract

Attention/Deficit Hyperactivity Disorder (ADHD) is one of the most prevalent disorders in the child population. Evidence suggests that children with this disorder usually present impairments in executive functions (EF). This study aims to evaluate the effects of a home-based intervention applied by parents (Flii, A Space Adventure) on the EF of Brazilian children with ADHD. Sixteen children with ADHD aged 7 to 12 participated in this study. A battery of neuropsychological tests and questionnaires was applied as assessment. Afterwards, children' received Flii programa applied at home by the parents. A relevant improvement in visuospatial working memory in the Flii group after the intervention (T2) compared to the control group. The results of the intragroup analyzes suggest that the intervention group had gains in processing speed, cognitive flexibility, verbal and visuospatial working memory. These results suggest that Flii was effective in promoting some changes in the children' executive functioning.
Keywords: attention/deficit hyperactivity disorder (ADHD), intervention, executive function, effectiveness

Resumo

Efetividade de um programa em funções executivas aplicado por pais em crianças com TDAH. O Transtorno de Déficit de Atenção/Hiperatividade (TDAH) é um dos transtornos mais prevalentes na população infantil. Evidências sugerem que crianças com esse transtorno geralmente apresentam prejuízos nas funções executivas (FE). Este estudo tem como objetivo avaliar os efeitos de uma intervenção em FE aplicada pelos pais de crianças brasileiras com TDAH. Dezesseis crianças com TDAH de 7 a 12 anos participaram deste estudo. Na avaliação foi aplicada bateria de testes neuropsicológicos e questionários. Em seguida, as crianças receberam o programa Flii aplicado em casa pelos pais. Observou-se uma melhora relevante na memória de trabalho visuoespacial no grupo Flii após a intervenção (T2) em comparação ao grupo controle. Os resultados das análises intragrupos sugerem que o grupo intervenção obteve ganhos em velocidade de processamento, flexibilidade cognitiva, memória de trabalho verbal e visuoespacial. Esses resultados sugerem que o Flii foi eficaz em promover algumas mudanças no funcionamento executivo das crianças.
Palavras-chave: transtorno de deficit de atenção/hiperatividade (TDAH), intervenção, funções executivas, efetividade

Resumen

Efectividad de un programa en funciones ejecutivas aplicado por padres a niños con TDAH. El Trastorno por Déficit de Atención e Hiperactividad (TDAH) es uno de los trastornos más prevalentes en la población infantil. La evidencia sugiere que los niños con este trastorno suelen presentar deficiencias en las funciones ejecutivas (FE). Este estudio tiene como objetivo evaluar los efectos de una intervención en FE aplicada en casa por padres de niños brasileños con TDAH. Dieciséis niños de 7 a 12 años participaron en este estudio. Fuera aplicada una batería de pruebas y cuestionarios neuropsicológicos. Fuera observada una mejora en la memoria de trabajo visoespacial en el grupo Flii después de la intervención (T2) en comparación con el grupo control. Los resultados de los análisis intragrupo sugieren que el grupo de intervención obtuvo ganancias en la velocidad de procesamiento, flexibilidad cognitiva, memoria de trabajo verbal y visoespacial. Estos resultados proponen que Flii fue eficaz para promover algunos cambios en el funcionamiento ejecutivo de los niños.
Palavras clave: trastorno por déficit de atención e hiperactividad (TDAH), intervención, funciones ejecutivas, efetividad

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Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most prevalent mental health conditions among children and adolescents (Polanczyk et al., 2015). Characterized by persistent symptoms of inattention, hyperactivity, and/or impulsivity, ADHD can cause substantial impairments throughout life (American Psychiatric Association [APA], 2013).

Studies suggest that young children with ADHD experience difficulties with attention, working memory, cognitive flexibility, behavioral inhibition, and self-regulation (Barkley, 2015; Tamm & Nakonezny, 2015). This executive functioning deficit contributes to critical outcomes in both academic and social functioning for ADHD children (Tamm & Nakonezny, 2015).

Executive functions (EF) is an umbrella term defined as a series of mental processes necessary for situations that require concentration and attention, such as making important decisions and solving problems (Diamond, 2013). They enable humans to carry out planned, sequenced, and effective actions and are essential for physical and mental health, academic success, as well as social and cognitive development (Diamond, 2013). The model proposed by Miyake et al. (2000, reviewed by Diamond, 2013) emphasizes three core EF: inhibitory control, working memory, and cognitive flexibility. From these main processes, more complex EF are generated, such as reasoning, problem-solving, and planning (Diamond, 2013).

EF deficits are considered a core feature within ADHD, but recent evidence indicates that children with ADHD have heterogeneous behavioral and neuropsychological profiles. This heterogeneity appears to generate different subtypes of EF presentations, which strengthens the idea that children with ADHD may be divided into three or more subgroups based on EF profiles (Kofler et al., 2019). Nonetheless, these impairments often harm social, familial, and academic contexts of ADHD individuals (Barkley, 2015).

Interventions based on EF training improve the cognitive, academic, and social functioning of both typical (Diamond, 2013; Diamond & Ling, 2016; Dias & Seabra, 2017) and ADHD children (Veloso et al., 2020). Indeed, cognitive training appears to be an effective intervention for children and adolescents with ADHD and it can be a complementary treatment option for this disorder (Veloso et al., 2020). Consequently, the number of interventions that promote EF in these individuals has grown over the past years (Cortese et al., 2015; Veloso et al. 2020).

Although some interventions have been implemented, their effects on individuals with ADHD have varied. While certain studies have demonstrated significant improvement in the executive functions of children with ADHD post-intervention (Cortese et al., 2015; Tamm & Nakonezny, 2015), other research has found no substantial enhancement in their post-intervention abilities (Rapport et al., 2013; van Dongen-Boomsma et al., 2014).

Despite limited research on parental programs aimed at developing executive functions, studies have demonstrated the efficacy of programs involving parental involvement in enhancing executive functioning in children with ADHD (Shuai et al., 2017; Tamm & Nakonezny, 2015). They can cause significant effects on ADHD symptoms (Shafiee-Kandjani et al., 2017) and may be useful in generalizing the learned skills, as demonstrated in the Shuai et al. (2017) study. Moreover, combining parent involvement and home setting seems to intensify intervention outcomes (Shuai et al., 2017; Tamm & Nakonezny, 2015).

Therefore, this study aims to evaluate the effects of Flii, A Space Adventure in the EFs of Brazilian ADHD children aged 7 to 12. The primary aim of this study is to evaluate the impact of the Flii program on multiple cognitive domains, specifically intelligence, attention, inhibitory control, cognitive flexibility, and working memory, among children diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD). The research hypothesis posits that the Flii program, a parent-administered home-based intervention, can significantly enhance the executive functioning of children with ADHD.

Method

Study Design

This empirical study utilized a longitudinal and comparative design, whereby the intervention group (IG) was assessed prior to and after the intervention, and then again in a 3-month follow-up. The control group (CG) was evaluated prior to and following the intervention, but did not receive the intervention during this period. Owing to inherent limitations in the study design, it was not feasible to examine the control group during the 3-month follow-up assessment.

Participants

Sixteen ADHD children aged 7 to 12 participated in this study. Most of them were male (94.4%) and attended a private school (77.8%). The majority of the families were supported by mothers (56.6%). Parents' level of education and family economic information are presented in Table 1.

Table 1 . *Flii Group (IG) and Control Group (CG) Sociodemographic Data*

	Flii Group			Control Group		
	Md	*M*	*SD*	Md	*M*	*SD*
Age						
Pre-test (years)	9.50	9.10	1.969	8.50	8.88	1.959
Sex	N	%		N	%	
Male	10	100%		7	87.5%	
Female	0	0%		1	12.5%	
School Type	N			N		
Public	2	20%		2	25%	
Private	8	80%		6	75%	
Medication use (T1)	N			N		
Yes	7	70%		4	50%	
No	3	30%		4	50%	
Medication use (T2)	N			N		
Yes	7	70%		4	50%	
No	3	30%		4	50%	
Medication use (T3)	N			N		
Yes	6	60%		—	—	
No	4	40%		—	—	
Economic Class	N			N		
A	1	10%		0	0%	
B	5	50%		2	25%	
C	4	40%		5	62.5%	
D - E	0	0%		1	12.5%	
Family Income (U$D)	N			N		
<=189,47	0	0%		1	12.5%	
460,27- 812,18	4	40%		5	62.5%	
1.484,86 - 2.968,97	5	50%		2	25%	
>=6.723,96	1	10%		0	0%	
Mother's Schooling	N			N		
Did not answer	0	0%		0	0%	
Illiterate/Unfinished elementary and middle school	0	0%		0	0%	
Unfinished high school	0	0%		0	0%	
Finished high school	3	30%		4	50%	
Finished undergraduation	4	40%		2	25%	
Finished graduation	3	30%		2	25%	
Father's Schooling	N			N		
Did not answer	0	0%		1	12.5%	
Illiterate/Unfinished elementary and middle school	0	0%		0	0%	
Unfinished high school	0	0%		1	12.5%	
Finished high school	6	60%		5	62.5%	
Finished undergraduation	3	30%		1	12.5%	
Finished graduation	1	10%		0	0%	
Householder	N			N		
Mother	5	50%		5	62.5%	
Father	5	50%		3	37.5%	

In this study, a total of 16 children were recruited and randomly assigned to either the Intervention Group (IG) or the Control Group (CG). The IG comprised eight children, while the CG comprised six children. Additionally, two children were initially part of the CG but later underwent the intervention. These two children participated in the CG while on the intervention's waiting list but later joined the IG and were included in the data analyses. The evaluation conducted at T2 included data from both the IG and the two children who underwent the intervention after initially being part of the CG. Data analyses for both groups are presented in Table 1.

Assessment Instruments

Socio-Demographic Questionnaire

A sociodemographic questionnaire was developed to be used in the research with the objective of obtaining relevant information about the participants. This questionnaire collected data of the participating parents' age, gender, current work situation, education level, as well as their children's age, gender, education, and school type (private or public).

ABEP Questionnaire

This questionnaire measures the participants' SES according to the Brazilian Association of Market Research Companies 2018 classification. The SES is obtained based on the number of assets or services that the participant has at home. It also records the education level of the household head. Each answer awards a number of points and a final score is recorded, resulting in a socioeconomic class classification: A, B, C, D, and E (Associação Brasileira de Empresas de Pesquisa [ABEP], 2018), being A the highest level.

Additionally, Table 2 presents the other instruments utilized in the program and the aspects evaluated by them.

Table 2. *Instruments Utilized on Program and Cognitive Function Assessed*

Instruments	Evaluation aspects	Concept	Author	Description
Five Digit Test	Inhibitory Control	Capacity of cognitive control over behaviors and interferences (Diamond, 2013).	Sedó, 2007	This test consists of 4 steps: reading, counting, choosing and alternating. In the choosing stage, the respondent is required to have inhibitory control ability to count the numbers presented instead of the automatic reading response. In the alternation stage, the respondent must exercise his ability to alternate and respond to stimuli following two rules simultaneously, counting and reading.
	Cognitive Flexibility	Ability to make thinking flexible, change perspectives, consider different alternatives for the resolution of a given situation (Diamond, 2013).		
Trail Making Test	Cognitive Flexibility	Ability to make thinking flexible, change perspectives, consider different alternatives for the resolution of a given situation (Diamond, 2013).	Partington & Leiter, 1949	This test consists of two parts, TMT-A and TMT-B. Initially, in TMT-A the participant must connect with a pencil the letters in alphabetical order from A to M and numbers from 1 to 12 in less than 60 seconds. In TMT-B, the participant is proposed to connect letters and numbers, alternating between them.
WISC-IV	Working Memory and short-term memory (Auditory-verbal)	It refers to the ability to retain and manipulate auditory verbal information in the mind, during the absence of perceptual stimuli (Diamond, 2013)	Wechsler, 2003, 2013	First, the respondent must memorize and repeat some sequences of digits in the same order. Second, the participant needs to memorize the sequences by evoking them in backward order. In Letter-Number Sequencing, the respondent is asked to memorize and organize letters and numbers in random order.
Corsi Block-Tapping Test	Working memory and short-term memory (Visuospatial)	It refers to the ability to retain and manipulate visuospatial information in the mind, during the absence of perceptual stimuli (Diamond, 2013)	Corsi, 1973	Test for short-term memory and visuospatial working memory. It involves a series of blocks with gradually increasing span to be played, first in forward order and secondly in backward order.

continue...

Table 2. Continuation

Instruments	Evaluation aspects	Concept	Author	Description
WASI				
	Estimated IQ	Represents general cognitive functioning and refers to Total IQ based on the score obtained in the verbal IQ and performance IQ subtests of the WASI scale (Wagner et al., 2014).	Heck et al., 2009	In this work, the Vocabulary and Matrix Reasoning subtests of the scale were used. The Vocabulary subtest is measuring crystallized intelligence and general intelligence. The Matrix Reasoning is a measure of non-verbal fluid reasoning and general intellectual ability.
TAVIS-IV				
	Sustained Attention	Refers to voluntary modulation and directing to a stimulus, required when there is a need to maintain attentional focus on a task for a long period of time (Langner & Eickhoff, 2013)	Duchesne & Mattos, 1997	Computerized instrument that measures selective, alternating, and sustained attention on three different tasks. In this study, only the sustained attention task was applied. In the task, the participant must detect the target stimulus that appears on the screen at random intervals.

Note. WASI - Wechsler Abbreviated Scale of Intelligence; WISC-IV - Wechsler Intelligence Scale for Children; TAVIS-IV - Visual Attention Test.

Intervention

The Flii Program was built with the objective of developing children's EF through activities required in their daily routine. Flii is the name of the character created to provide an identifiable figure for children aged 7 to 12 years old. It was built into four modules of six different tasks each. The modules address the following cognitive functions: Organization and Planning; Attention, Cognitive Flexibility, and Inhibitory Control; Working Memory and Emotional Regulation. The program is applied by parents to carry out tasks in their children's daily routine. Tasks were briefly described in Table 3. They were trained by psychologists and psychology students to monitor each activity with the children. Two different tasks are applied weekly by parents at home or at other non-clinical contexts. In order to promote the child's engagement, Flii was built from a plot of a character who is lost in space and needs the child to do activities to help him return home. When the child is able to carry out the week's activities, he gets a game sticker to put on his album.

Flii was theoretically grounded by a systematic review that was previously conducted by Bitencourt. After developing Flii, a space adventure, a group of psychology researchers evaluated the content of this intervention tool. The psychometric properties related to content validity were found to be adequate, with a high content validity index (CVI = 0.92) (Bitencourt, 2021).

Table 3. *Flii Tasks*

Module 1	Module 2	Module 3	Module 4
Assembling your Flii Tidying up your room Preparing your backpack Organizing homework Preparing a snack Learning how to shop	Switching the rule between color and figure Switching the rule between figure and category Different color game Stop, pay attention, think and answer Guess what? Problem judge	Remembering the words Remembering and gathering foods Remembering daily activities Remembering daily activities Forming words Back and forth Arranging objects	What is the emotion? Recognizing emotions Thinking about emotion Expressing emotions Table of emotions Expressing emotions with help of the family

Procedures

This study was approved by the Research Ethics Committee of the Federal University of Bahia (CAAE number 19515718.6.0000.5686 - Opinion Number: 4.192.831). Parents/legal guardians who agreed to be part of the study signed the Informed Consent Form before answering the questionnaires. Parents were informed that the children would participate in three assessments, one before the intervention, one after it, and 3 months after finishing the intervention. They would also participate in the assessment by answering questionnaires. The assessment lasted an average of 2 hours with each family.

Regarding the intervention program, parents were informed that they should go to the Office at the Federal University of Bahia once a week for 3 months to receive the material and instructions for the activities that would be carried out during the week. A team member was responsible for monitoring the intervention and was available to assist each family during the whole process.

Data Analysis

The data were analyzed by SPSS Statistics 25.0 for Windows (Statistical Package for Social Sciences). The database preparation started from the input process, with missing data analysis and checking the sample distribution with Kolmogorov-Smirnov and Shapiro-Wilk Tests. Both tests indicated a non-normal distribution of the sample, leading to the use of a non-parametric test to proceed with the analysis. Descriptive statistics for analysis of frequency, median, mean and standard deviation scoring were done. Intergroup analyses were performed using non-parametric statistical tests, namely the Mann-Whitney U test, to compare the Intervention Group (IG) and Control Group (CG) at two time points: before intervention (T1) and after intervention (T2).

To evaluate the Flii group, a Friedman Test was conducted to compare three analysis times: before intervention (T1), after intervention (T2), and a 3-month follow-up (T3). On the other hand, the Wilcoxon test was employed to compare the control group's performance at two time points: before intervention (T1) and 3 months after T1 (T2). The control group was not assessed in a follow-up evaluation. The effect size measure, d Cohen, was used to compare the means of the groups at each time point (before, after intervention, and follow-up).

Results

Intergroup Analysis

The comparison (Mann-Whitney U Test) between the Flii (IG) and control group (CG) before intervention (T1) showed no significant differences ($p > 0.05$) in WASI, FDT, Digit subtest, Letter-Number Sequencing, the Corsi Block-Tapping Test, TAVIS-IV, and TMT.

Regarding the comparison (Mann-Whitney U Test) between Flii (IG) and the control group (CG) after the intervention period (T2) no statistically significant differences in estimated IQ, inhibitory control, cognitive flexibility, processing speed, verbal short-term memory, verbal working memory and visual short-term memory were observed. However, the analysis shows a significant difference ($p = 0.04$, $d = 1.068$) between the Flii (IG) ($M = 0.35$, SD = 0.93) and the control group (CG) ($M = -0.50$, SD = 0.59) in the backward order of the Corsi Block-Tapping Test after intervention (Table 4).

The Corsi Block-Tapping task was large ($d = 1.068$) according to the Cohen Test (d) reference. This finding suggests a relevant improvement in visuospatial working memory in the Flii group after intervention (T2) compared to the control group.

Intragroup Analysis

The Friedman test was run to compare the differences before intervention (T1), after intervention (T2), and 3-month follow-up (T3) in the Flii group. The Wilcoxon Test was run to compare the group control performance before intervention (T1) and 3 months after T1 (T2). The control group was not submitted to a follow-up assessment.

Intelligence: Estimated IQ-WASI

The results showed no significant difference in estimated QI (WASI - matrix reasoning and vocabulary subtests) before and after intervention in the intervention (IG) and the control (CG) groups.

Processing Speed, Inhibitory Control, and Cognitive Flexibility: FDT

There were no significant differences in FDT in the Flii group's response in time performance before and after the intervention in reading, choice, inhibition and flexibility domains. However, there were differences in counting the time ($p = 0.003$) between T1 ($M = 67.20$, $SD = 41.50$) and T2 ($M = 54.80$, $SD = 29.48$) with a moderate effect size ($d = -0.344$), and between T1 ($M = 67.20$, $SD = 41.50$) and the follow-up (T3) ($M = 47.30$, $SD = 19.72$) with a large effect size ($d = -0.613$). Concerning shifting time ($p = 0.025$), there were differences between T1 ($M = 119.40$, $SD = 68.90$) and T3 ($M = 90.50$, $SD = 45.79$), with a moderate effect size ($d = -0.49$).

Regarding the control group, there was one significant difference in the choosing task ($T = 4.00$, $p = 0.05$) in T1 ($M = 85.92$, $SD = 40.77$) and after the 3-month waiting intervention (T2) ($M = 69.59$, $SD = 21.14$), with a large effect size (*d* = -0.503). The comparative analysis between IG and CG are presented in Table 4 and shows a decrease in counting response (processing speed) time and in alternate (cognitive flexibility/alternating attention) in IG. In the CG, there was also a decrease in choosing time (inhibitory control/selective attention), but the IG analysis also shows a decrease in this task performance.

Table 4. *Outcome of Friedman test (intervention group) and Wilcoxon test (control group) for Task Performance*

	IG										CG						
	T1		T2		T3						T1		T2				
Measure	M	SD	M	SD	M	SD	X^2	p	d^a	d^b	M	SD	M	SD	T	p	d^a
WASI																	
Estimated IQ	98.50	14.80	99.80	13.95	98.20	18.25	0.60	-	-	-	87.75	6.27	90.37	16.03	22.00	-	-
FDT (Five Digit Test)																	
Reading	41.00	19.79	44.89	17.58	37.60	15.27	1.897				34.70	11.26	31.80	9.46	14.00	-	-
Counting	67.20**	41.50**	54.80**	29.48**	47.30**	19.72**	11.74**	0.003	0.344	0.613	58.11	33.84	53.20	29.80	8.50	-	-
Choice	109.50	80.33	93.02	66.77	75.10	41.19	5.600	-	-	-	85.92*	40.77*	69.59*	21.14*	4.00*	0.05	0.503
Shifting	119.40*	68.90*	98.62	55.52	90.50*	45.79*	7.400*	0.025	-	-0.49	92.09	48.31	88.89	41.28	16.00	-	-
Inhibition	64.75	63.83	47.14	57.39	37.50	27.94	4.200	-	-	-	51.22	35.94	37.84	15.86	6.00	-	-
Flexibility	74.61	58.50	53.78	45.27	52.90	34.46	5.600	-	-	-	57.38	42.74	57.09	37.47	15.00	-	-
Digit Span																	
Forward Order	6.00	1.63	6.20	2.39	6.20	1.93	0.069	-	-	-	5.62	1.84	6.25	2.43	22.00	-	-
Backward Order	4.80*	2.25*	6.00*	1.82*	5.80	1.87	7.092*	0.029	0.586	-	5.25	1.83	5.12	2.10	4.00	-	-
Letter-Number Sequencing																	
Total Score	11.20*	5.99*	14.20*	6.71*	13.80**	6.44**	11.8**	0.003	0.472	0.418	9.25*	5.52*	12.37*	5.55*	36.00*	0.012	0.564
Corsi Block Tapping																	
Forward Order	6.8	2.61	7.10	1.85	7.10	2.02	0.364	-	-	-	5.87	2.58	7.12	2.58	19.00	-	-
Backward Order	5.10*	2.72*	7.20*	2.82*	6.10	1.91	6.061	0.048	0.758	-	4.62	2.87	4.87	2.90	13.50	-	-
TAVIS-IV																	
Reaction time	0.85	0.38	0.91	0.44	0.91	0.37	0.364	-	-	-	1.21	0.74	0.87	0.38	6.00	-	-
Hits	41.20	8.02	44.80	11.86	48.50	12.17	0.663	-	-	-	40.12	6.933	44.62	12.03	14.00	-	-
Commission Error	9.50	22.03	5.80	13.21	5.80	9.28	2.000	-	-	-	12.62	20.86	3.62	2.77	13.50	-	-
Omission Error	3.00	0.48	1.80	2.57	0.70	1.33	2.154	-	-	-	2.00	2.39	0.62	1.40	1.50	-	-
Trail Making Test (TMT)																	
Part A	20.10	2.61	21.60	4.37	21.00	3.85	1.900	-	-	-	20.62	6.86	20.25	6.96	6.00	-	-
Part B	9.00	7.14	12.60	5.96	11.90	6.55	1400	-	-	-	10.25	8.50	10.38	9.57	8.00	-	-

Note. [a]effect size between pre (T1) and post-intervention (T2); [b]effect size between pre-intervention (T1) and follow-up (T3) (After 3 months).

Auditory-Verbal and Visuospatial Working Memory: Digits (BO), Corsi Block-Tapping Test (BO) and Letter-Number Sequencing

The results about auditory-verbal and visuospatial working memory analysis are shown in Table 4. The Friedman Test showed that there was a significant difference in the Flii group in the Digit's Backward Order (BO) (*p* = 0.029) between T1 (*M* = 4.80, *SD* = 2.25) and T2 (*M* = 6.00, *SD* = 1.82), with a large effect size (*d* = 0.586). Regarding the Corsi Block-Tapping backward order (BO) the analysis showed a statistically significant difference (X(2)2= 6.061, *p* = 0.04) between T1 (*M* = 5.10, *SD* = 2.72) and T2 (*M* = 7.20, *SD* = 2.82), with a large effect size (*d* = 0.758). In the Letter-Number Sequencing test, significant differences were presented by the Flii group (*p* = 0.003) between T1 (*M* = 11.20, *SD* = 5.99) and T2

(*M* = 14.20, *SD* = 6.71) with a moderate effect size (*d* = 0.472), and also between T1 (*M* = 11.20, *SD* = 5.99) and T3 (*M* = 13.80, *SD* = 6.44), with a moderate effect size (*d* = 0.418). The control group also showed a significant difference ($p = 0.012$, $d = 0.564$) between T1 (*M* = 9.25, *SD* = 5.52) and T2 (*M* = 12.37, *SD* = 5.55) with a large effect size.

These results are presented in Table 4 and indicate that children in the Flii group showed a better performance in the Digit test backward order and the Corsi Block-Tapping task backward order after the intervention. Regarding Sequence of Numbers and Letters both groups increased the scores.

Verbal and Visuospatial Short Term Memory: Digit Test (FO) and Corsi Block-Tapping Test (FO)

The Corsi Block-Tapping test forward order (FO) and the Digit test forward order (FO) did not show a significant difference over the time in both groups. These results suggest there were no significant differences in the auditory-verbal and visuospatial short-term memory in the intervention and the control groups (Table 4).

Sustained Attention: TAVIS-IV - Task 3

The TAVIS-IV task 3 (sustained attention) showed no significant differences between the reaction time before and after the intervention, for either group (Table 4). Regarding the number of correct answers, commission errors and omission errors, no significant differences were found in the intervention and the control groups.

Processing Speed and Cognitive Flexibility: Trail-Making Test (TMT)

No statistically significant difference was found in TMT part A and part B over the time in the intervention and the control groups. These results suggest there were no differences in the processing speed and the cognitive flexibility assessed by this test.

Effects of the Flii program

Significant differences ($p < 0.05$) between the control (CG) and the intervention (IG) groups after the Flii program in the pre-test (T1), the post-test (T2) and the follow-up (T3) were found on statistical analysis. These results were summarized in Table 5 and showed more statistically significant differences in the intervention group (IG), which presented a better performance in executive functioning.

Concerning auditory-verbal and visuospatial WM there was an increase in the number of correct answers in the Digit test and the Corsi Block-Tapping task backward order. In the Letter-Number Sequencing subtest, referring to auditory-verbal WM as well, the control group also showed a significant difference. Regarding processing speed assessed by FDT the Flii group showed differences after the intervention in the Counting task and the control group showed differences in the Choosing task. About cognitive flexibility assessed by the Shifting task in FDT, there was also a difference in the intervention group.

Table 5. *Flii Program Effects — Summarized Results*

Measures	Flii Group (IG)			Control Group (CG)		
	Significant Differences	Tendency	Effect Size	Significant Differences	Tendency	Effect Size
Intelligence						
Estimated IQ -WASI	No	No alteration	-	No	No alteration	-
Working Memory						
Visual (Corsi BO)	Yes	Increased	**0.758**	No	No alteration	-
Verbal (Digits BO)	Yes	Increased	0.586	No	No alteration	-
Letter-Number Sequencing	Yes	Increased	0.472	Yes	Increased	0.564
Inhibitory Control						
FDT Inhibition Time	No	No alteration		No	No alteration	-
FDT Choosing Time	No	No alteration	-	Yes	Faster	**- 0.503**
Cognitive Flexibility						
FDT Switch Time	No	No alteration	-	No	No alteration	-
TMT Part B	No	No alteration	-	No	No alteration	-
FDT Shifting Time	Yes	Faster	**-0.49**	No	No alteration	-
Processing speed						
FDT Reading Time	No	No alteration	-	No	No alteration	-
FDT Counting time	Yes	Faster	**-0.613**	No	No alteration	-
TMT Part A	No	No alteration	-	No	No alteration	-

continue...

Table 5. Continuation

Measures	Flii Group (IG)			Control Group (CG)		
	Significant Differences	Tendency	Effect Size	Significant Differences	Tendency	Effect Size
Short Term Memory						
Visual (Corsi FO)	No	No alteration	-	No	No alteration	-
Verbal (Digits FO)	No	No alteration	-	No	No alteration	-
Sustained Attention						
TAVIS Reaction Time	No	No alteration	-	No	No alteration	-
TAVIS Hits	No	No alteration	-	No	No alteration	-
TAVIS Error	No	No alteration	-	No	No alteration	-

Discussion

Cognitive training studies diverge about their efficacy in promoting EF development in ADHD children, but recent evidence suggests that significant results can be found especially if these intervention programs are designed to meet a child's everyday situations. However, little is known about the effects of ecological home-based EF programs for ADHD children in Brazil. To address this gap, the goal of this study was to evaluate the effects of *Flii*, *A Space Adventure*, an EF home-based program applied by parents, in ADHD children's executive functions.

The first statistical analysis showed a significant difference in visuospatial WM between the experimental and the control groups after the intervention. However, no statistically significant differences were found in other functions by this analysis. Improvements in visuospatial WM after training are reported in the literature (Dovis et al., 2015; van Dongen-Boomsma et al., 2014). WM training seems to be superiorly effective in visuospatial WM among children with ADHD (van der Donk et al., 2016). The reason why this happens remains unclear, but there are some hypotheses, such as the additional effects of medication on this ability during training, level of impairment before intervention that creates more space to improve those skills, the characteristics of the intervention tasks, which may tap into the domain of visuospatial WM more frequently, and so on (van der Donk et al., 2016). Therefore, it is possible that some of these aspects contributed to this result, since the Flii tasks were designed to meet children's everyday tasks, such as card and arranging games, which may direct more the visuospatial WM, and since 70% of the intervention group were using medication during the pre and post-intervention assessments.

Moreover, both visuospatial and verbal WM improved in the intervention children after training in the intragroup analysis. WM improvements can be explained by the development and multi-component characteristics of the WM. Firstly, studies suggest a substantial increase in this ability from childhood until puberty and early adulthood (Cowan, 2016; Swason, 2017). Secondly, executive components like the central executive underlie WM's theoretical framework, playing an important role in cognitive functioning (Baddeley, 2000; Baddeley & Hitch, 1974). Finally, the EFs, including WM, work in an integrative way in which one's improvement can impact another (Malloy-Diniz et al., 2014). Therefore, it is possible that our sample's age range and *Flii*'s training of multiple EFs may have contributed to this outcome in children's WM.

Also, both groups improved their verbal WM on one objective measure over time, in the Letter-Number Sequencing Subtest. This WISC subtest not only assesses verbal WM, but also measures attention span, short-term auditory recall, processing speed, and sequencing abilities. Verbal WM is greatly impacted by development and there is a substantial increase in this ability from childhood until puberty and early adulthood (Cowan, 2016; Swason, 2017). Moreover, recent evidence suggests that poorer verbal WM performance in ADHD is age-related, with younger children with ADHD showing greater difficulties (Ramos et al., 2019). Along with the control group's inhibition performance, it is possible to suggest that children in this group presented this cognitive outcome due to developmental processes rather than a training effect.

Regarding short-term memory, no significant differences were found. Such results may indicate that cognitive training for executive functions, diverse and unfocused, has no specific effect on short-term memory. The Rapport et al. (2013) meta-analysis points out that improvements of moderate magnitude are found in short-term memory when trained alone. However, both short-term memory and inhibition processes would not benefit from the facilitative intervention training (FIT) program (i.e., cognitive training), that is, we should not expect them to increase in multifocal training like the Flii program.

The results show no significant differences in children's inhibition after training in both objective measures. This finding corroborates the Cortese et al. (2015) meta-analysis result of no effects on inhibitory control on the reviewed cognitive training studies. Even though most of the work addressed in this review did not specifically target inhibition, the result of our study can indicate that a multiple EFs training design might not favor the improvement of this ability in ADHD children as well. Studies of specific EFs training, like inhibitory control, may benefit children's ability to inhibit automatic processes more precisely. For instance, in the Jones et al. (2020) study, an inhibition-targeted training significantly improved ADHD children's inhibitory control. Therefore, future studies should address if specific targeted training may have a larger impact on children's inhibition when compared to programs targeting multiple EFs. Even though this outcome was observed in the IG, there was an improvement tendency on the choosing task scores in both groups, with the CG showing a significant difference. This result may be due to developmental processes, since inhibition abilities develop largely in early childhood and have a gradual improvement throughout life (Memisevic & Biscevic, 2018).

Additionally, the Flii children's shifting improved after intervention. This result is consistent with previous studies of cognitive training (Tamm et al., 2015). Furthermore, since the effects were maintained, it might favor the development of ADHD children's attentional and executive skills over time. This is important because shifting allows people to alternate from one situation, task, or aspect of a problem to another as the circumstances demand, having a great impact on how one tolerates change and makes transitions (Tamm et al., 2015). However, there were no significant differences in children's measures of cognitive flexibility (CF). This especially concerns children with ADHD because studies suggest that they present deficits in this ability (Capovilla et al., 2007). Improvements on ADHD children's CF could contribute to their adaptive process in different contexts such as improving learning and social relationships. However, since gains in shifting were observed, it is possible that the program benefited CF somehow, since these terms are overlapping and shifting can be seen as a lower level of CF (Dajani & Uddin, 2015).

There was a significant difference in one objective assessment of processing speed between before and after the program, as well as between the before and the 3-month-follow-up. This indicates that our sample improved the processing speed over time, and the results were maintained even 3 months after the program was finished. Low levels of processing speed are frequently associated with inattention symptoms in ADHD children (Barkley, 2014), thus improvements in this function could favor attentional processes. A recent study suggests that baseline processing speed predicts behavioral treatment outcomes in ADHD children with predominantly inattentive subtype and is associated with a greater symptom improvement (Adalio et al., 2018). Thus, this cognitive gain possibly contributed to both functional outcomes and the other gains achieved in this present study. Such improvement could also be noticed from parents' reports of a decrease in inattention symptoms, attentional and thought problems, showing this complementary relationship among children's executive, attentional and behavioral aspects.

Also, children's estimated IQ showed no significant improvements after the program. Even though intelligence is related to EF (Diamond, 2013), studies diverge on the far-transfer effect of cognitive training programs on this cognitive ability, because while some report this outcome in participants after training, others show no improvement in intelligence, setting a limitation in the neuropsychological field (Melby-Lervåg et al., 2016). The present study indicates that Flii intervention was not able to promote this far-transfer effect in ADHD children's intellectual abilities, corroborating with studies that suggest that the training of EF causes no effect on intelligence (Melby-Lervåg et al., 2016).

A broad analysis of the results makes it possible to consider some hypotheses for the gains found. The improvement in attention, auditory-verbal and visuospatial working memory, cognitive flexibility, processing speed are related to executive functions in the child's global functioning. Executive functions (EFs) have been linked to numerous developmental outcomes and are a stronger predictor of cognitive functioning than IQ (Diamond, 2013). Enhancing EFs can positively impact a child's behavior, ultimately leading to an improved quality of life (Diamond, 2013).

Flii's proposal as an intervention program for EF is also to increase children's autonomy in daily routine activities. In this program, parents teach their children more adaptive strategies to deal with daily routine activities through self-monitoring. Hence, the potential for a joint modality of intervention is observed, where cognitive training and parental monitoring are present throughout the entire process. As a result, an improvement in executive functioning is obtained.

Conclusion

This study has some strengths, such as the fact that it tested the effectiveness of an intervention program for executive functions in a group of ADHD children. Deficits in executive functioning in children with ADHD have been evidenced in the literature (Barkley, 2002, 2008). Proposing alternatives to mitigate this negative effect is extremely important for the quality of life of children with this disorder. Another positive aspect of this study is the use of an intervention modality with active parental participation, involving children's daily activities. Such interventions have benefits for both children and parents (Coates et al., 2014). In addition, training using implicit executive functioning tasks can be even more beneficial for children of atypical development, being more enjoyable and easier to apply when involved in the child's everyday activities (Takacs & Kassai, 2019). This can open possibilities for new studies with proposals for ecological interventions, which may be less costly.

This study has some limitations. First, weekly contact between researchers and parents may be insufficient to keep parents active and involved in the program. Secondly, we did not use a blinded design to address participants' assessments before, after the program, and in the 3-month-follow-up, which can have had an effect on our results and has been reported as an important methodological concern to be aware of (Cortese et al., 2015; Rapport et al., 2013). Third, our sample size was probably insufficient to capture more statistically significant analyzes. Moreover, we did not differentiate in our analyses the ADHD subtypes, which seems to be an important aspect regarding EF impairments. Also, our neuropsychological assessment lacked instruments with more ecological validity. Therefore, the next studies should consider these methodological aspects to address these questions.

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