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EF Train: Development of an Executive Function Training Program for Preschool and School-aged Children with ADHD

Terpsichori Korpa*, Christos Skaloumbakas, Matthaios Katsounas, Pinelopi Papadopoulou, Fotini Lytra, Stavroula Karagianni

Aglaia Kyriakou Children's Hospital, Athens, Greece

Panagiota Pervanidou

National and Kapodistrian University of Athens, Greece

Abstract

Executive functions are involved in the manifestation of ADHD symptoms. These functions have been proven to predict academic achievement and performance promoting school readiness and social functioning, thus training programs are essential. The current study focused on the development of an executive function training program "EF Train" and assessed its effect on the enhancement of three core executive functions, i.e. working memory, inhibitory control and sustained attention. A group of 52 children with ADHD ranging from 4 to 7 years of age were assigned to either a training group who performed 20 sessions of the executive function training program or a control group that received no training. The assessment of executive function improvement was carried out before, immediately after and three months after the completion of the "EF Train". Data analysis revealed that the training program led to significant improvements of the core executive functions, as well as diminished ADHD symptoms. The findings indicate that executive function programs may assist on the attenuation of ADHD symptomatology providing additional non-invasive approaches for executive function improvement.
Key words: Keywords: ADHD, executive functions, EF Train, children.

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Novelty and Significance

What is already known about the topic?

- Deficits in executive functioning predicts poor academic performance and occupational functioning.
- Evidence indicate that core ADHD symptoms are associated with deficits in executive functions.
- Training of executive functions may alleviate ADHD symptomatology.

What this paper adds?

- EF Train enhanced executive functioning using non-invasive measures.
- EF Train reduced ADHD symptomatology and the beneficial effects transferred to children's behavior in school and family context.

Regulation of behavioral and cognitive deficiencies associated with ADHD in children and adults has been a matter with increasingly high interest in recent years. Much discussion has been in press about the optimal ways of treating ADHD symptomatology with research suggesting that pharmacotherapeutic and behavioral approaches being the most effective (Molina *et alia*, 2009). However, novel non-invasive approaches are equally important as they offer patients additional means to cope with their symptoms and improve their children's overall daily functioning, especially if children are of preschool or early school age and the parents are reluctant to have their children try medication (Adler & Nierenberg, 2010).

* Correspondence: T Korpa, ADHD/LD Unit, Department of Child and Adolescent Psychiatry, "Aglaia Kyriakou" Children's Hospital: Thivon & Levadeias, 11527, Athens, Greece. Email: terpsikorpa@med.uoa.gr

Research has shown that ADHD symptoms are associated with deficits in core executive functions, such as working memory, cognitive flexibility, inhibitory control and sustained attention (Barkley, 1997; Gibson *et alia*, 2011; Sergeant, Geurts, & Oosterlaan, 2002; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). A generally approved notion regarding the role of executive functions is that they comprise a set of interrelated high order cognitive abilities that control goal directed behavior (Diamond, 2013; Enríquez Geppert, Huster, & Herrmann, 2013). These cognitive abilities are of great importance as they assist children in holding and managing information in mind, modifying their behavior in response to new incoming information as well as clearing any possible conflict due to various sources of stimulation when response is needed. Consequently, executive functions have been proven to function as predictors of academic achievement and performance (Clark, Pritchard, & Woodward, 2010; Miller & Hinshaw, 2010), while at the same time, they promote school readiness and adaptive social functioning (Welsh, Nix, Blair, Bierman, & Nelson, 2010). The paramount importance of executive functions in directing behavior underscores the significance of methods that may improve them, particularly in cases where they are found to be deficient.

Executive function training can be classified in two distinct categories, strategy and process-based. Strategy-based training encompasses interventions that promote training of specific tasks, such as mnemonic techniques in memory training studies (Karbach & Unger, 2014). However, this type of cognitive training may result in limited transfer, with no improvements in other cognitive abilities except for the specific task (Rebok, Carlson, & Langbaum, 2007). Thus, the executive function training program used in this study was designed as a process-based intervention. This type of training design targets a wider range of cognitive operations and has proven to be more efficient in longer transfer effects (Kray & Ferdinand, 2013; Titz & Karbach, 2014). We selected three executive functions as targets for our intervention: working memory, inhibitory control and sustained attention, as deficits in these functions have been implicated in the manifestation of ADHD symptoms (Rapport *et alia*, 2008; Elosua, Del Olmo, & Contreras, 2017).

Recent notions of working memory suggest that it is a dynamic system of great value in situations where a person has to actively maintain attention and adapt according to specific goals and information processing (Shipstead, Hicks, & Engle, 2012), which is why inattention of children with ADHD is particularly associated with deficits in this executive function (Diamond, 2013). Recent findings from preschool and early school stage children showed that training of visual and auditory working memory not only improves this executive function, but also promotes near and far transfer effects (Dahlin, Nyberg, Bäckman, & Neely, 2008; Shipstead *et alia*, 2012).

Inhibitory control is a necessary executive function that is required when impulsive thoughts and behaviors need to be regulated and has been found to function deficiently in ADHD population (Pliszka, Liotti, & Woldorff, 2000; Rahmi & Wimbarti, 2018). Children with ADHD experience deficits in suppressing cognitive, emotional and behavioral responses, which might lead to academic difficulties and social problems (Diamantopoulou, Henricsson, & Rydell, 2005; Loe & Feldman, 2008; Coutinho, Reis, da Silva, Miranda, & Malloy-Dinniz, 2017). According to Barkley (1997), impairments in inhibitory control are crucial as it is responsible for suppressing unwanted behavior, delaying the final answer as well as changing it in case it progresses to an unsatisfactory response, and inhibiting a probable distraction in order for a person to alter the strategy until the wanted outcome. Research has shown that inhibitory control develops rapidly during preschool and early school years (Best & Miller, 2010; Kray, Karbach, & Blaye, 2012), suggesting that transferability effects can be achieved through the individual's lifespan (Liu, Zhu, Ziegler, & Shi, 2015; Zhao, Chen, & Maes, 2018).

Similarly, another form of control is sustained attention, where the individual has to remain focused on the given task and situation over time, inhibiting any possible interference from environmental stimuli (Tajik-Parvinchi, Bahons, & Schachar, 2014). Deficits in sustained attention may affect performance as it deteriorates more rapidly over time, resulting in a difficulty maintaining the focus to specific sources of information needed in the private and academic setting (Tucha *et alia*, 2008; Tucha *et alia*, 2017). Research regarding the transferability of this executive function is scarce, as only few studies have showed that trained sustained attention benefits can be transferred in different tasks (Bigorra, Garolera, Guijarro, & Hervás, 2016).

The aim of this study was to develop an executive function (EF) training intervention that targets multiple executive functions and optimizes their efficiency, while achieving a transfer of its positive effects not only in tasks of similar nature, but also in observable behaviors that are associated with the EF in investigation. Recent studies utilizing parent rated instruments has shown that executive function skills may be enhanced and transferred while mediating symptoms of inattention, impulsivity and hyperactivity (Beck, Hanson, Puffenberger, Benninger, & Benninger, 2010). It was expected that children that received the intervention program would have less ADHD symptoms, or ADHD symptoms of less intensity as perceived by their parents and teachers, when compared to children of the control group. Specifically, it was hypothesized that children of the intervention group would have lower scores than controls on parent and teacher rated instruments assessing the core symptoms of ADHD immediately after and three-months after the completion of the executive function training intervention. Additionally, it was hypothesized that children that had received the intervention would show greater gains in tasks measuring working memory, inhibitory control and sustained attention as compared to the control group, immediately after the treatment and at three-months post treatment.

Method

Participants

The sample consisted of 52 children diagnosed with ADHD and was divided in two groups, the intervention and the control group. Children of the sample ranged from 4 to 7 years of age, where the mean age (*M*) of the intervention group was 5.72 (*SD*= 1.06) and the *M* of the controls was 5.65 (*SD*= 1.07). The intervention group consisted of 29 participants (55.8% of the sample) of which 17 were boys, and the control group consisted of 23 participants (44.2% of the sample) of which 10 were girls. Families of children with ADHD were recruited through invitation in the Attention Deficits and Learning Disabilities Unit in Athens Children's Hospital Aglaia Kyriakou after completing the initial screening procedure as part of the typical services provided by the hospital.

Measures

Parenting Stress Index-Short Form (PSI-SF; Abidin, 1995). This is a parent rated instrument that measures various aspects of parenting stress through a total of 36 items. Except for the Total Score, this questionnaire measures three subscales of parenting stress, namely Parental Distress, Parent-Child Dysfunctional Interaction, and Difficult Child, on a 5 point Likert Scale (0= Strongly Agree to 4= Strongly Disagree). The strong psychometric properties of PSI-SF are presented through its internal reliability with Cronbach's α >.87 (Abidin, 1995).

Strengths and Difficulties Questionnaire (SDQ; Goodman, 2001). This is a parent rated behavioral questionnaire that places emphasis on measuring strengths as well as difficulties of children through a total of 25 items. The SDQ consists of 5 subscales investigating children's attributes regarding Emotional Symptoms, Conduct Problems, Hyperactivity/ Inattention, Peer Relationship Problems, and Prosocial Behavior. This instrument uses a three-point Likert system ranging from 0 as "not true" to 2 as "certainly true". SDQ has been standardized for use in Greek population with good psychometric properties Cronbach's $\alpha > 0.70$ (Giannakopoulos *et alia*, 2013).

Children's Behavior Questionnaire-Short Form (CBQ-SF; de la Osa, Granero, Penelo, Domènech, & Ezpeleta, 2014). This is a parent and teacher rated instrument that measures several dimensions of temperament issues. The CBQ-SF has been developed by extracting 94 items from the CBQ forming three distinct factors labeled as Negative Affectivity, Surgency Extraversion and Effortful Control. These factors are designated to measure 15 dimensions of temperament which are described as Activity Level, Anger/Frustration, Approach, Attentional Focusing, Discomfort, Falling Reactivity and Soothability, Fear, High Intensity Pleasure, Impulsivity, Inhibitory Control, Low Intensity Pleasure, Perceptual Sensitivity, Sadness, Shyness, Smilling and Laughter of children. The items are rated on a Likert scale ranging from 0 (extremely untrue of your child) to 5 (extremely true for your child) along with a "not applicable" response option when parents and teachers are unable to describe the corresponding behavior. The parent rated version of CBQ–SF has shown an internal consistency for the 15 primary subscales of .48 to .79 Cronbach's α, while the teachers version were satisfactory α >.60 (Teglasi *et alia*, 2015).

Child Behavior Checklist (CBCL)-Teacher Report Form (TRF; Achenbach & Rescorla, 2001). The CBCL (parent rated) and TRF (teacher rated) are behavior and emotion assessment questionnaires that consist of 113 items and assess internalizing and externalizing problems. These instruments are empirically designed to measure six DSM-oriented subscales, such as Affective Problems, Anxiety Problems, Somatic Problems, Attention Deficit/Hyperactivity Problems, Oppositional Defiant Problems, and Conduct Problems. Parents and teachers are asked to report on a three-point scale the degree of each behavior over the past six months, which is described accordingly by items on the questionnaires (0= not true, 1= somewhat or sometimes true, and 2= very true or often true). Raw scores of the scale are extracted and converted to *T*-scores according to child's age and gender, where borderline clinical range is considered between 65 and 69 and clinical range corresponds to *T*-scores above 70. The CBCL and TRF are instruments of strong psychometric properties and has been standardized for use in Greek population with test–retest coefficients ranging from .78 to .88 and Cronbach's α ranging from .75 to .84 (Rousos *et alia*, 1999; Achenbach & Rescorla, 2001).

ADHD Rating Scale-IV (ADHD-RS-IV; DuPaul *et alia*, 1998; Greek version, Kalantzi-Azizi, Aggeli, & Efstathiou, 2012). This is a parent and teacher rated instrument that assesses the symptomatology of Attention Deficit Hyperactivity Disorder in children through 18 items. A scale of 4 points ranging from 0 to 3, which range from never to very often, is used in order to investigate the DSM-IV based items measuring the degree of Inattention and Hyperactivity/Impulsivity symptoms over the past 6 months. Completion of the answer sheet requires the raw scores of each of the subscales to be converted in percentile scores in order to measure the ADHD symptomatology according to age and gender. The scores of ADHD-RS-IV Greek version have been found to be internally consisted with Cronbach's α coefficient for teacher's scale being above .96 and for the parent's scale being above .85 (Kalantzi-Azizi *et alia*, 2012).

Tower Task (Simos, Mouzaki, & Sideridis, 2007a). This is a neurocognitive assessment tool developed as part of the *Executive Functions Assessment Battery* and it was designed for measuring working memory and the ability of problem solving. Similar to the *Tower of Hanoi*, the design consists of a wooden flat board, three vertical wooden pegs with even spaces between them and three wooden cylinders of same size and different color (green, blue, orange). The Tower Task requires from the participants to rearrange the cylinders from a fixed starting point to the suggested goal position in a specific number of moves. This test consists of 10 tasks of ascending difficulty, where the total score derives from correct responses and abidance by the rules, which allow participants to only move one cylinder at a time, place the cylinder on the peg and not on any other surface, respond to the suggested time and set of moves. The Tower Task has an internal consistency of .78 Cronbach's α.

Task of Selective Visual Attention (TSVA; Simos, Mouzaki & Sideridis, 2007b). As part of Attention and Focus Assessment Battery instrument, TSVA measures selective and sustained attention. This pen and paper task illustrates on a single sheet of paper an array of images of well known objects arranged in X lines of X images per line and the child is asked to only cancel out a specific image which appears a few times dispersed in the array under time restrictions amidst several distractors. The total score is derived by counting the cancellation errors and the test has been standardized for use in Greek population with good psychometric qualities (Cronbach's α >.63).

Task of Selective Auditory Attention (TSAA; Simos, Mouzaki, & Sideridis, 2007b). This is an instrument developed to add in the Attention and Focus Assessment Battery a neurocognitive tool that measures sustained attention and impulse control. It assesses the ability of the participant to successfully sustain attention on the target-stimulus, which is heard randomly through a series of distractor words. This instrument measures the state of participants' vigilance and the sustained attention through the auditory path, while impulse control is necessary to avoid possible errors. Firstly, the participant is presented with a sheet of paper illustrating four different kinds of fruit. The participant is instructed to respond (point at stimulus) only when the stimulus-word is heard (i.e. pear). However, in order to measure impulse control, instructions clarify that when fruit A is presented, the participant has to point at fruit B and vice versa, while fruit C is pointed as is and fruit D needs not to be pointed even if heard. The TSAA produces a total of omission (missing the target) and a total of commission (pointing the wrong target) errors and Cronbach's α coefficient was found to be satisfactory (>.72).

Raven's Colored Progressive Matrices (CPM; Raven *et alia*, 1998). This is a non-verbal measure that assesses participants' ability to reason by analogy and to evaluate differences. The CPM consists of three 12-item sets, which progressively increase the level of difficulty with set A being the easiest, set Ab of moderate difficulty and set B presenting the most challenging items. In addition, the difficulty increases through the items of each set individually, while vivid colors of the items attract participants' attention. Each item consists of an incomplete pattern and during assessment the participant is required to fill the missing part selecting the correct option from below the matrix by pointing or noting the corresponding number. After completion of the task raw scores are extracted and converted to percentiles based on normative data of various groups. Raven's CPM test retest reliability was found with a coefficient of r >.90.

Parenting Stress Index-Short Form (PSI-SF; Abidin, 1995). This is a parent rated instrument that measures various aspects of parenting stress through a total of 36 items. Except for the Total Score, this questionnaire measures three subscales of parenting stress, namely Parental Distress, Parent-Child Dysfunctional Interaction, and Difficult Child, on a 5 point Likert Scale (0= Strongly Agree to 4= Strongly Disagree). The strong psychometric properties of PSI-SF are presented through its internal reliability with Cronbach's α >.87 (Abidin, 1995).

Executive Function Training Program

The ADHD intervention program used in the present study is called "EF Train", which was developed under the scope of training specific components of executive function and attention as it is possible to encounter instances of selective impairment (Loose, Kaufmann, Auer, & Lange, 2000; Sturm & Willmes, 1991). Participants of the intervention group received a total of 20 sessions (twice per week) of the training program, with each session running for approximately 45 minutes. EF Train was designed with the purpose of enhancing the executive functions of preschool and early-stage primary school children through 8 separate tasks that need 5 minutes each to be completed. The tasks are Card Sorting, Visual Go no Go, Stroop, Auditory Go no Go-Words, Flanker Fish, Match/no Match, Flanker and, Auditory Go no Go-Sounds.

The *Card Sorting* task presents a series of 60 cards depicting members of different families with specific characteristics. The child is required to classify the cards in two or more piles depending on specific criteria (i.e., wears glasses, is old, boy or girl, etcetera) until the end of the task. The card sorting task measures false classifications and time of task completion, while training visual sustained attention and processing speed.

The *Visual Go no Go* task uses the same deck of cards as the Card Sorting Task, while the child is presented with one card at a time and is required to promptly point if the target characteristic appears. The target characteristic is randomly set by the trainer and during this 5 minute task the child is allowed to respond only if the corresponding card appears while avoiding distractors. The Visual Go no Go task measures omission and commission errors and enhances visual sustained attention, inhibitory control and working memory.

Stroop tasks consisted of three different sheets of paper that contain 20 opposed pairs of stimuli in a set sequence. The pairs of stimuli in this task are images of day-night, rock-knife, and the numbers 1-2. When a stimulus appears, it is required by the child to orally express the opposing corresponding stimulus. The trainer assesses time of completion, omission and commission errors, while executive functions trained by this task are auditory sustained attention, inhibitory control and working memory.

Auditory Go no Go-Words is a task that contains 20 arrays of stimuli that represent different animals and colors. The trainer sets the target stimulus out and the child is required to respond every time that it is orally presented by the trainer, while avoiding distractors. This task trains auditory sustained attention, inhibitory control and working memory through the elimination of omission and commission errors.

Flanker Fish is a card based task, which depict a series of fish in a single row. This task uses 60 cards, which contains 5 fish each and are classified in four different categories, fish pointing right, four fish pointing left and the middle one points right, fish pointing left, four fish pointing right while the middle one points left. Executive functions trained through this task are visual sustained attention and processing speed.

Flanker task is constituted of 60 cards, which are classified in 6 different categories based on the represented stimuli. Each card contains three stimuli in different order, which depict images of a blue star, a smiley face, a green dot, a downwards pointing blue arrow, an upwards pointing yellow arrow, and a heart. The child is presented with one card at a time and it is required to point when the target stimulus appears in the place that has been set by the trainer (left, middle, right). After the completion of the task, trainer evaluates the omission and commission errors, which determine the visual sustained attention and inhibitory control ability of the child.

Auditory Go no Go-Sounds is a task that contains 10 arrays of 10 different animal sounds, such as dog, cat, bird, rooster, donkey, pig, cow, sheep, horse and frog. These sounds are randomly presented and the child is required to respond every time the target stimulus appears. The arrays are divided in two categories of 5 single and 10 double auditory presented animal sounds. During the first category the target stimulus appears four times, while the second category presents 6 times the target stimulus in 1 second intervals. This task trains auditory sustained attention, inhibitory control and working memory and is rated through omission and commission errors.

Procedure

Participating families were referred to the study by contacting the AD/LD Unit in P&A Kyriakou" Children's Hospital in order to arrange a typical assessment for their children. Initially, participants provided information regarding their children's developmental and health record and after the standard screening procedure, families that met the criteria for the study were informed about the intervention program. Informed consent was obtained from families interested in participating in this study prior to the administration of any measurement or assessment tools.

During the standard evaluation, all children included in the sample were assessed for the presence of any psychiatric disorders. This procedure was conducted by the scientific team of the ADHD/LD Unit, using the standard clinical psychiatric interview, CBCL and ADHD-RS-IV. In addition, parents were invited to provide their responses regarding various aspects of their children's emotional and behavioral problems by completing the PSI-SF, SDQ and CBQ-SF questionnaires while the teachers were asked to complete the teacher's version of CBQ- SF. The questionnaires were provided and the responses were collected by the scientific team of the ADHD/LD Unit. Following the administration of these instruments, the diagnoses were reviewed by the specialists at a diagnostic meeting. Children with ADHD, who were diagnosed with any comorbid disorder or received ADHD medication, were excluded from the study.

Subsequently, the sample was classified into two groups, an intervention and a control group. The first stage of this study was the assessment of both groups prior to the intervention by collecting data from all the ADHD and Behavioral, as well as the Executive Function assessment measures. After the initial assessment each child in the intervention group attended meetings with the expert administering the EF Train program for 2 months with two sessions per week. The second stage of this study was the assessment of both groups following completion of the training program. The final stage of the study was a follow-up assessment of both groups three months after the completion of the training program by the intervention group. With regard to the children of the sample, inclusion criteria for this study, which was performed in 2018, 4 to 7 years of age and a diagnosis of ADHD.

Results

The study sample consisted of 52 children, of which 21 were diagnosed with the Inattentive subtype of ADHD and 30 were diagnosed with the Combined subtype of ADHD. The two study groups were similar in terms of age, SES, sex and ADHD subtype (Table 1).

Parenting stress levels and general difficulties of children were examined at pre-test, post-test and follow up between the control and intervention group (Table 2). The majority of PSI subscales did not show any significant interaction between the two groups. However, higher scores were found in the parental distress subscale, where significantly lower scores were presented by the intervention group compared to the controls. In addition, significant interactions were found in the total SDQ and

Table 1. Participants' characteristics in the two study groups.

		Control		Intervention Group		*p*
		M	*SD*	*M*	*SD*	
Age		5.65	1.07	5.72	1.06	.81*
Socioeconomic Status		55.7	7.36	51.79	8.58	.08*
		n	%	*n*	%	*p*
Sex	Boys	13	56.52	17	58.62	.87**
	Girls	10	43.48	12	41.38	
ADHD Subtype	Inattentive	9	39.13	13	44.83	.68**
	Combined	14	60.87	16	55.17	

Notes: *= *T*-Test; **= Pearson's Chi–Square Test.

Table 2. Means and Standard Deviations for parenting stress and general difficulties at pre-test, post-test and follow-up between control and intervention groups.

	Measures	Control			Intervention			Group x Intervention Time	
		Pre *M* *(SD)*	Post *M* *(SD)*	FU *M* *(SD)*	Pre *M* *(SD)*	Post *M* *(SD)*	FU *M* *(SD)*	*F*	η_{ϱ}^{2}
PSI - SF	Parental Distress	44.52 (7.95)	43.74 (7.56)	43.3 (7.58)	44.76 (5.44)	46.17 (6.25)	41.03 (7.14)	4.68*	.09
	PCDI	44.91 (4.26)	45.30 (5.7)	45.57 (5.05)	47.52 (4.24)	41.31 (6.64)	46.93 (4.54)	.43	.01
	Difficult Child	45.96 (5.36)	45.87 (6.06)	45.91 (5.49)	42.97 (9.02)	42.66 (8.45)	44.48 (6.01)	.76	.02
	Total	135.30 (12.85)	134.61 (16.28)	134.78 (14.96)	135.48 (11.83)	135.72 (12.76)	132.17 (8.31)	1.49	.03
SDQ	Emotional Symptoms	6.52 (2.15)	5.30 (1.99)	5.61 (1.94)	6.76 (1.92)	3.21 (1.44)	4.28 (2.03)	5.61**	.09
	Conduct Problems	6.26 (2.15)	4.43 (1.97)	4.74 (2.38)	6.14 (2.19)	2.38 (1.24)	3.66 (1.52)	3.37*	.06
	Hyperactivity	6.04 (2.09)	6.96 (1.36)	7.17 (1.49)	6.48 (1.92)	4.38 (1.99)	5.01 (2.28)	9.37**	.16
	Peer Problems	6.70 (1.89)	5.04 (2.27)	6.52 (2.39)	6.38 (2.03)	2.38 (1.18)	4.17 (1.77)	5.99**	.11
	Prosocial Behaviour	6.30 (2.21)	5.91 (1.51)	6.43 (1.65)	5.97 (2.08)	3.38 (1.66)	5.83 (1.95)	4.44*	.08
	Total	25.52 (4.09)	21.74 (3.29)	24.04 (4.77)	25.76 (4.15)	12.34 (2.92)	17.10 (3.91)	21.91**	.31

Notes: *= p <.05; **= p <.01.

its subscales between the control and the intervention group. Specifically, parents of children of the intervention group scored significantly lower than the controls showing a high effect size in hyperactivity, emotional and peer problems.

Table 3 presents the results of a series of mixed model ANOVAs for parent-rated temperament issues before and after the executive function training program between the control and the intervention groups. Scores on CBQ-SF did not show significant differences between the two groups on the majority of the temperament dimensions except for the specific subscales relative to ADHD symptomatology. The analysis regarding scores on the Impulsivity subscale revealed a main effect of group, $F(1, 50)= 17.16$, $p= .001$, a main effect of intervention time, $F(2, 100)= 39.22$, $p= .001$, and an interaction between the two types of group and time of the intervention program administration, $F(2, 100)= 6.78$, $p= .002$, showing that parents of the intervention group scored their children as less impulsive compared to the controls. Moreover, analysis of the Attentional Focusing subscale data showed that there was a significant main effect of group $F(1, 50)= 7.95$, $p= .007$, a significant main effect of intervention time, $F(2, 100)= 13.12$, $p= .001$, and a significant interaction between the group and intervention time, $F(2, 100)= 4.28$, $p= .017$, showing that children of the intervention program were regarded by their parents as more attentive than children of the control group. In addition, similar results were found in the analysis of the Inhibitory Control subscale data, where parents of the intervention group reported better inhibitory function for their children compared to the controls. Specifically, there was a main effect of group, $F(1, 50)= 8.58$, $p= .005$, a main effect of intervention time, $F(2, 100)= 60.03$, $p= .001$, and an interaction between the two types of group and time of the intervention program administration, $F(2, 100)= 4.25$, $p= .017$.

Following the analysis of parent-rated CBQ-SF, temperament issues were also rated by the teachers of children that participated in this study. Mixed model ANOVAs were used in order to investigate the interactions between group and time of application

Table 3. Means and Standard Deviations for parent-rated temperament issues at pre-test, post-test and follow-up between control and intervention groups.

CBQ-SFP	Control			Intervention			Group x Intervention Time	
	Pre *M* (*SD*)	Post *M* (*SD*)	FU *M* (*SD*)	Pre *M* (*SD*)	Post *M* (*SD*)	FU *M* (*SD*)	*F*	η_ϱ^2
Anger/ Frustration	23.91 (9.69)	24.83 (7.67)	25.74 (10.04)	21.83 (8.26)	26.86 (7.79)	26.52 (8.76)	.68	.01
Discomfort	26.87 (8.58)	28.30 (8.21)	27.35 (8.81)	24.21 (9.56)	25.48 (8.29)	21.66 (9.61)	.56	.01
Fears	21.83 (7.82)	22.52 (10.29)	23.91 (8.89)	26.79 (8.79)	25.79 (7.61)	23.79 (8.76)	1.11	.02
Reactivity/ Soothability	23.48 (9.99)	25.35 (7.51)	24.78 (9.48)	25.10 (9.27)	25.21 (9.13)	27.17 (7.86)	.31	.01
Sadness	29.61 (10.01)	29.48 (8.58)	27.52 (8.20)	26.48 (11.37)	28.31 (10.92)	29.24 (9.27)	.76	.02
Shyness	24.74 (8.40)	20.00 (8.71)	23.13 (9.06)	25.45 (9.96)	24.66 (8.65)	26.45 (8.88)	.56	.01
Activity Level	27.43 (7.52)	29.91 (9.68)	30.39 (9.73)	27.24 (9.87)	27.14 (9.25)	24.31 (9.88)	1.33	.03
Impulsivity	30.96 (4.71)	23.65 (9.11)	26.74 (10.19)	31.93 (4.49)	18.21 (4.10)	18.59 (4.25)	6.78**	.12
High Intensity Pleasure	21.26 (9.43)	25.65 (8.46)	26.52 (9.83)	24.17 (8.33)	27.10 (10.13)	26.59 (9.48)	.39	.01
Positive Anticipation	25.04 (7.59)	25.17 (9.05)	23.61 (10.13)	26.79 (8.21)	26.07 (8.53)	26.10 (8.83)	.12	.01
Attentional Focusing	31.78 (5.05)	30.30 (4.08)	29.87 (3.51)	32.38 (3.82)	26.21 (3.41)	27.79 (4.49)	4.28*	.08
Inhibitory Control	31.61 (4.71)	23.04 (9.66)	24.22 (6.78)	32.10 (4.14)	19.93 (3.84)	18.28 (4.32)	4.25*	.08
Low Intensity Pleasure	34.87 (10.86)	32.52 (9.25)	35.30 (10.09)	32.24 (9.36)	33.14 (9.94)	32.38 (9.76)	.57	.01
Perceptual Sensitivity	26.96 (7.91)	22.09 (9.12)	24.04 (9.38)	24.45 (8.31)	24.14 (10.20)	23.17 (9.72)	.44	.02
Smiling and Laughter	26.87 (7.45)	26.61 (8.64)	27.30 (9.39)	25.97 (8.08)	27.62 (9.26)	24.48 (8.56)	.46	.02

Notes: *= p <.05; **= p <.01.

of the executive function training program (Table 4). Similarly with the parent-rated CBQ-SF data, teachers' scoring did not reveal any significant difference and interaction except for the Impulsivity, Attentional Focusing and Inhibitory control subscales. The analysis regarding scores on the Impulsivity subscale revealed a main effect of group, $F(1, 50)= 20.62$, $p= .001$, a marginally insignificant main effect of intervention time, $F(2, 100)= 2.86$, $p= .062$, and a significant interaction between the two types of group and time of the intervention program administration, $F(2, 100)= 3.47$, $p= .035$, showing that teachers of the control group scored their students as more impulsive compared to the intervention group. Furthermore, analysis of the Attentional Focusing subscale data showed a significant main effect of group $F(1, 50)= 16.85$, $p= .001$, a significant main effect of intervention time, $F(2, 100)= 3.24$, $p= .043$, and a significant interaction between group and intervention time, $F(2, 100)= 4.54$, $p= .014$, showing that children of the control group were regarded by their teachers as less attentive than children of the intervention group. Additionally, analysis of the inhibitory control subscale data concluded that children of the control group were perceived by their teachers as less able to control their inhibitory functioning compared to teachers of the intervention group. Specifically, there was a main effect of group, $F(1, 50)= 17.62$, $p= .001$, but not a main effect of intervention time, $F(2, 100)= 2.49$, $p= .08$. However, the analysis revealed a significant interaction between the two types of group and time of the intervention program administration, $F(2, 100)= 4.93$, $p= .009$.

Table 4. Means and Standard Deviations for teacher-rated temperament issues at pre-test, post-test and follow-up between control and intervention groups.

CBQ-SFT	Control			Intervention			Group x Intervention Time	
	Pre *M (SD)*	Post *M (SD)*	FU *M (SD)*	Pre *M (SD)*	Post *M (SD)*	FU *M (SD)*	*F*	η_p^2
Anger/ Frustration	25.17 (8.75)	22.83 (8.23)	24.78 (8.29)	27.41 (7.41)	25.01 (8.25)	25.83 (8.65)	.09	.01
Discomfort	22.87 (9.68)	25.83 (8.59)	23.61 (8.31)	23.83 (8.78)	24.86 (9.98)	24.28 (7.45)	.19	01
Fears	22.70 (9.01)	27.17 (7.33)	24.91 (8.67)	26.72 (9.23)	26.10 (8.64)	24.01 (8.76)	1.39	.03
Reactivity/ Soothability	24.52 (9.38)	23.39 (9.44)	24.74 (11.46)	24.86 (8.86)	21.62 (8.28)	22.34 (9.69)	.27	.01
Sadness	30.74 (12.38)	30.87 (10.29)	28.65 (9.07)	30.66 (9.93)	27.48 (10.01)	26.72 (9.45)	.31	.01
Shyness	23.39 (9.98)	24.48 (8.96)	27.43 (9.19)	25.79 (8.61)	27.34 (9.45)	25.24 (8.92)	1.19	.02
Activity Level	27.13 (9.84)	30.57 (9.33)	26.48 (10.42)	28.31 (10.16)	30.83 (10.44)	32.03 (8.53)	1.06	.02
Impulsivity	25.83 (8.91)	25.91 (6.31)	26.35 (6.91)	24.79 (7.46)	19.07 (3.14)	19.62 (4.72)	3.47*	.07
High Intensity Pleasure	25.35 (9.05)	24.91 (9.53)	25.96 (9.63)	24.62 (9.68)	23.66 (9.69)	22.86 (9.37)	.81	01
Positive Anticipation	26.61 (9.68)	26.52 (11.51)	23.65 (8.45)	26.55 (8.74)	25.69 (9.05)	24.14 (9.89)	.08	.01
Attentional Focusing	25.39 (8.34)	24.35 (7.64)	27.01 (9.54)	26.10 (2.51)	21.41 (3.61)	20.93 (4.74)	4.45*	.08
Inhibitory Control	24.83 (8.70)	26.09 (5.86)	25.17 (8.09)	24.84 (5.45)	19.07 (4.39)	20.03 (4.54)	4.93**	.09
Low Intensity Pleasure	31.09 (11.04)	30.96 (9.13)	33.78 (10.47)	34.21 (10.06)	36.03 (10.47)	33.24 (9.86)	1.06	.02
Perceptual Sensitivity	24.09 (8.73)	25.74 (9.79)	22.35 (9.33)	24.58 (7.32)	23.48 (8.83)	24.07 (9.42)	.67	.01
Smiling and Laughter	26.13 (9.77)	24.39 (8.95)	23.35 (9.88)	20.55 (8.09)	27.34 (9.26)	23.14 (8.52)	2.88	.05

Notes: *= p <.05; **= p <.01.

Table 5 presents the results of Mixed Model ANOVA's for executive function performance at different time of assessment between control and intervention group. The analysis of Tower Task performance revealed a significant main effect of group, $F(1, 50)= 670.84$, $p= .001$, a significant main effect of intervention time, $F(2, 100)= 5.05$, p= .008, and a significant interaction between group and intervention time, $F(2, 100)= 16.39$, $p= .001$, showing that participants of the intervention group scored higher in the Tower Task compared to the controls. Moreover, the analysis of TSVA data presented a main effect of group, $F(1, 50)= 662.35$, $p= .001$, but not a significant main effect of time, $F(2, 100)= 2.08$, $p= .13$. However, there was a significant interaction between group and intervention time, $F(2, 100)= 4.62$, $p= .012$, showing that participants of the intervention group responded better in the selective visual attention task compared to the controls. The analysis of TSAA-omission data showed a significant main effect of group, $F(1, 50)= 450.35$, $p= .001$, a main effect of intervention time, $F(2, 100)= 2.65$, $p= .076$, and a significant interaction between group and intervention time, $F(2, 100)= 36.93$, $p= .001$, with participants of the intervention group getting less omission errors in the TSAA compared to the controls. In similar manner, commission data from the same task showed a significant main effect of group, $F(1, 50)= 2.26$, $p= .016$, a main effect of intervention time, $F(2, 100)= 1.73$, $p= .181$, and a significant interaction between group and intervention time, $F(2, 100)= 18.34$, $p= .001$, with participants of the control group getting more commission errors in the TSAA compared to the intervention. Furthermore, the analysis of digit span-backwards data showed a significant main effect of group, F(1,

Table 5. Means and Standard Deviations for executive function tasks at pre-test, post-test and follow-up between control and intervention groups.

Measures	Control			Intervention			Group x Intervention Time	
	Pre *M* *(SD)*	Post *M* *(SD)*	FU *M* *(SD)*	Pre *M* *(SD)*	Post *M* *(SD)*	FU *M* *(SD)*	*F*	η_{ρ}^{2}
Tower Task	3.17 (1.44)	2.22 (1.17)	2.83 (1.30)	3.38 (1.63)	6.07 (1.65)	5.59 (2.56)	6.39**	.25
TSVA	12.65 (6.61)	13.04 (5.19)	14.04 (5.69)	12.93 (6.14)	8.45 (3.82)	8.10 (5.31)	4.62*	.09
TSAA Omission	5.30 (1.58)	6.65 (1.85)	6.91 (2.17)	5.79 (2.48)	3.24 (2.33)	3.45 (1.76)	36.93**	.43
TSAA Comission	3.57 (1.08)	4.43 (1.37)	4.48 (1.47)	4.24 (1.99)	2.55 (1.66)	3.07 (1.46)	18.34**	.27
Digit span Forward	9.96 (2.12)	9.30 (1.94)	10.83 (3.56)	10.14 (2.39)	10.21 (1.95)	10.10 (3.42)	1.24	.02
Digit span Backwards	4.09 (1.76)	4.26 (1.82)	4.09 (1.88)	4.24 (1.57)	6.07 (1.81)	5.66 (1.79)	3.26*	.06
Raven	72.91 (12.78)	72.13 (11.64)	72.74 (11.36)	76.24 (12.24)	75.14 (10.58)	76.48 (10.72)	.19	.01

Notes: *= p <.05; **= p <.01.

50)= 108.60, *p*= .001, a significant main effect of intervention time, *F*(2, 100)= 4.32, *p*= .016, and a significant interaction between group and intervention time, *F*(2, 100)= 2.36, *p*= .043, showing that controls scored lower in the backwards digit span scale than intervention group. However, the scales of Digit Span Forwards and Raven did not reveal any significant interaction through the different times of assessment between the intervention and control groups.

Discussion

The present study investigated the effects of a newly developed executive function training program and its transferable effects over the course of time on ADHD children. Specifically, this intervention targeted the enhancement of various executive functions of pre-school and primary school aged ADHD children through executive function training tasks with the goal of transferring its beneficial effects to different than trained executive function tasks. In addition, parent and teacher perceived behaviors where measured in order to examine the potential transferability of the aforementioned effects to different context, such as the family and school environment.

Parent rated scales analysis showed that parenting stress and the intensity of core ADHD symptoms of children that participated in the intervention group were reduced compared to the controls, however, no particular differences were found in other aspects of their behavior. More specifically, lower scores of parenting distress were found for parents of children that participated in the executive function training program than parents of the controls. There is little evidence regarding the effects of executive function problems of ADHD children and parenting stress, which shows that as the executive dysfunction of the child increases, parents experience significantly more stress (Joyner, Silver, & Stavinoha, 2009). Greater executive dysfunction of ADHD children may be inducing greater parental distress, and as such an enhancement of executive function may lead to a decrease in the previously experienced parental distress.

Moreover, the intervention group's parents reported lower temperament issues even after three months after the treatment than parents of children that did not participate in the executive function training program. Specifically, children of the intervention group were perceived as presenting less emotional, conduct and peer problems after the treatment and compared to children of the control group. Research suggests that children with deficits in executive functions show impairments in externalizing behavior, as well as difficulties in regulating and expressing their emotions (Romero López, Quesada Conde, Bernardo, & Justicia Arráez, 2017). Likewise, deficits in executive functions were found to highly correlate with inappropriate social behavior, emotional control, aggressiveness and poor judgment of consequences (Ogilvie, Stewart, Chan, & Shum, 2011; Riccio, Hewitt, & Blake, 2011). Thus, training of working memory, inhibitory control and sustained attention may lessen the value of factors that play a crucial role in developing and expressing the aforementioned temperament issues.

Furthermore, parents and teachers reported the general difficulties children of both groups were presenting before, immediately after and three-months following the executive functions training program. Both parent and teachers of the intervention group showed lower scores in three subscales of the CBQ-SF, Impulsivity, Attentional Focusing and Inhibitory Control, even three months after the treatment as compared to the controls. Children who are able to inhibit disruptive behaviors, focus and sustain their attention through intervention programs are able to extend these beneficial effects to other contexts (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Dias & Seabra, 2015; Moffitt *et alia*, 2011), which may explain the findings of the current study regarding parent and teacher perceptions.

Except for the parent and teacher rated scales, promising results were also found during the analysis of executive performance measures. Children of the executive function training program showed greater scores than the control group immediately and after three months after its final session in working memory, visual and auditory sustained attention, inhibitory control and problem solving. Similar to other executive function training programs, these results suggest that various aspects of executive functions may be improved through systematic practice (Klingberg, 2010; Klingberg *et alia*, 2005). According to Klingberg (2005), when the capacity of executive functions increases, it is highly probable that individuals might get occupied with tasks of greater executive function load, such as academic tasks. By engaging in more demanding executive function tasks individuals might maintain and even increase through practice the beneficial performance effects gained through the training programs, elucidating the nature of the additional gains observed from immediately to three months after assessments. This notion has been previously noted through evidence of a working memory enhancement program that showed mathematical gains in children even after 6 months after its completion (Holmes, Gathercole, & Dunning, 2009).

A limitation of the present study was the absence of an active control group during the training period. The intervention group participated in a number of training sessions, while participants of the control group did not receive any conventional treatment. Moreover, the evaluation and validity of this study's training program could have been benefited from independent testers, unaware of the intervention's design, as well as from greater sample size. Another potential limitation refers to the individual analyses of variance conducted in order to assess the effectiveness of the training program. A possible option was multivariate analysis of variance, which could decrease the chance of error, however the testing of each variable individually, while controlling for its previous performance was a necessity in order to further investigate the training program's value. Future research should control the aforementioned factors.

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