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Is it possible to promote executive functions in preschoolers? A case study in Brazil

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Abstract

Executive functions (EF) provide top-down control of thoughts, emotions, and behaviors. Such abilities are related to learning, emotional control, and adjustment. A promising line of research on EF examines early interventions to promote EF development; however, in developing countries, evidence of EF-related early interventions remains limited. In this study, 70 five-year-old preschool children and their four teachers were divided into an experimental group (EG) and a control group (CG). EG teachers were trained to administer the *Intervention Program for Self-regulation and Executive Functions* in a classroom context over four and a half months. All children were assessed with tests to measure EF at two time points: before and after the intervention period. EG children exhibited significant gains in attention and inhibition post-intervention. The results suggest that the intervention program is more effective at promoting EF development than the regular curriculum. This finding may have practical relevance to public politics in education, primarily in disadvantaged contexts, as in certain developing countries.

Keywords: Self-regulation; Early intervention; Cognitive development; Child education

Background

In recent years, many studies have highlighted the importance of executive functions (EF) for academic achievement and learning (Blair & Diamond, 2008; Bodrova & Leong, 2007; Diamond, Barnett, Thomas, & Munro, 2007; Rosário et al. 2007a; von Suchodoletz et al. 2013), mental health (Barnett et al., 2008; Dawson & Guare, 2010; Diamond & Lee, 2011), and success throughout life (Bodrova & Leong, 2003; Diamond & Lee, 2011; Moffitt et al., 2011). It is also known that certain variables can affect EF development at early ages, such as socioeconomic status (Hook, Lawson, & Farah, 2013; Noble, Norman, & Farah, 2005), culture (Carlson, 2009; Lahat, Todd, Mahy, Lau, & Zelazo, 2010), and parent–child interactions (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012; Bibok, Carpendale, & Müller, 2009; Hammond, Müller, Carpendale, Bibok, & Lebermann-Finestone, 2012), indicating the role of the environment in EF development.

In this regard, several studies have also shown that EF can be improved with training (Blair & Diamond, 2008; Diamond et al., 2007; Diamond & Lee, 2011; Rosário et al. 2007b), but such studies remain limited in number and are geographically concentrated in North America and Europe; few such studies have been undertaken in developing countries. Given that good EF can serve as protective factors for children

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developing in chaotic environments (Wenzel & Gunnar, 2013), this area of research could have an important impact in such disadvantaged contexts.

EF enable the individual to exert top-down control over his behaviors, cognitions, and emotions and are usually grouped according to three core abilities: working memory, inhibition, and cognitive flexibility (Diamond, 2013; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Working memory refers to the ability to hold information in mind and operate on it. This ability enables the individual to organize and relate ideas to each other and is related to reading and arithmetic competence (Baddeley, 2000; Diamond, 2013). Inhibition refers to the ability to inhibit inappropriate behaviors (response inhibition or self-control), as well as to control attention and thoughts (interference control). This ability enables the individual to stop and think before answer or make choices and to avoid being distracted by irrelevant stimuli. In this sense, the construct also incorporates selective attention (Diamond, 2013; Nigg, 2001). Inhibition closely resembles the concept of self-regulation, which allows the adjustment and adaptation of the individual through monitoring, regulation and control of his motivational, emotional and cognitive states (Blair & Diamond, 2008). According to Diamond (2013), the concepts of inhibition and self-regulation overlap, and the latter also include emotional and motivational activation. The third core EF is cognitive flexibility, that is, the ability to adjust behavior to environmental demands, which can require changing perspectives, priorities, and rules, as well as taking different approaches to a situation. Flexibility is linked to creativity and is important for functioning in a changeable world. It enables the individual to address novelty without behaving in a rigid way. Other abilities such as planning, reasoning and problem solving are considered higher-order EF and emerge from the three core abilities (Diamond, 2013).

EF develop over a lengthy course from early childhood until early adulthood (Diamond, 2013; Dias, Menezes, & Seabra, 2013). The acquisition of EF starts approximately 12 months (García-Molina et al. 2009). At this age, the first skill to emerge is inhibition. Nevertheless, this ability has hardly begun and even the three-year-old children's behaviors are predominantly spontaneous, reflecting reactions to the environment (Bodrova & Leong, 2007; Dawson & Guare, 2010). Between four and five years, children become increasingly able to inhibit the initial reaction and act in a more thoughtful way. Between three to five years of age, children begin to need less and less of the presence and physical manipulation of the object to think about it (Bodrova & Leong, 2007), suggesting development of working memory. As flexibility looks more similar to a complex ability, in the sense that it involves inhibition and working memory to a certain extent, its development occurs later (Diamond, 2013), with evidence suggesting a significant development between five and seven years old, despite continued growth throughout childhood and adolescence (Best & Miller, 2010).

In brief, between four and five years, children gradually develop the skills of focusing attention, remembering events deliberately, ignoring distractors, delaying gratification, stopping inappropriate behavior, and adapting their behavior to demands and social rules, including controlling their emotions. After this age, from five to six years, children become able to engage in more complex behaviors and make decisions and plans (Bodrova & Leong, 2007; Dawson & Guare, 2010; Dias & Seabra 2013a; García-Molina et al. 2009; Rosário et al. 2007a). Hence, in the course of the preschool years, there is a significant increase in self-regulatory capacity of children, which is reflected in their performance on standardized tests, behavior in social situations, and understanding of causality and morality (Zelazo & Müller, 2002). Such data corroborate the idea that this is an important period for the development of EF, supporting intervention studies in this age range. Nevertheless, while recognizing the impact of EF on learning and daily life, including performance on academic activities and social interactions (Bodrova & Leong, 2007; Dawson & Guare, 2010; Diamond, 2013; Meltzer, 2010), few studies and models have been developed under an early approach (Diamond et al., 2007). Focusing on stimulating the development of these skills in childhood could lead to a preventive approach in cognitive psychology and neuropsychology. Despite the need for longitudinal studies in the area, corroborating evidence does exist. For instance, children with better EF are more successful and healthy three decades later (Moffitt et al., 2011).

Several EF intervention programs have been tested. The ones that provide computerized training, such as the working memory training from Cogmed Systems, appear to improve performance in the specifically trained ability but provide no generalization or transfer of training to other abilities or activities (Thorell, Lindqvist, Nutley, Bohlin, & Klingberg, 2009). Alternatively, ecological programs appear to stimulate EF more globally and promote generalization of gains, as has been observed in school curricula and complementary curriculum programs. In this regard, there is evidence showing the effectiveness of the *Tools of the Mind* (Diamond et al., 2007; Barnett et al., 2008) and the *Sarilhos do Amarelo* (Rosário et al. 2007b) programs in improving EF in preschool children. Other curricula mentioned as effective in promoting EF development include PATH - Pr*omoting Alternative Thinking Strategies* and the CSRP - *Chicago School Readiness Project* (Diamond & Lee, 2011).

Effective EF programs (Bodrova & Leong, 2003; Dawson & Guare, 2010; Diamond & Lee, 2011; Dias & Seabra, 2013b; Meltzer, 2010; Rosário et al. 2007b) have some characteristics in common that are relevant to the promotion of abilities, such as the following: 1) focusing on 'how to learn' and not just on the final product; 2) promoting opportunities for the child to practice and exercise EF in different situations; 3) emphasizing the use of language as a self-regulatory tool; 4) conducting activities in pairs or larger groups to allow mutual regulation of behavior; 5) using and teaching mediators and strategies; 6) giving direct and explicit instruction, using modeling and practice; 7) requiring the involvement and engagement of the child in the entire process; 8) the teacher's role and interaction having an emphasis on providing greater initial support but providing increased autonomy to the child.

As mentioned earlier, studies in the area tend to concentrate primarily on North America and certain countries in Europe, that is, developed countries. Most of these EF programs are not available in underdeveloped or developing countries. Because developing countries have poorer socioeconomic conditions and this can affect EF (Hook et al., 2013; Noble et al., 2005), our study is an effort to expand this research area to this different context. We need to investigate if we can promote EF in the reality of developing countries, which is different from the realities of Canada, the USA and countries in Europe. In this scenario, the objective of this study is to investigate the efficacy of an intervention program conducted by teachers in a classroom context in promoting EF in preschool children from low and medium-low socioeconomic backgrounds in a developing country.

We are interested in providing some insights to the following question: Is it possible to promote EF in preschool children with an intervention program conducted by teachers in a classroom context, even in a disadvantaged context, as in the case of some public schools in Brazil? We believe that such findings could have practical relevance to public politics in education because promoting EF in children could have greater importance in such disadvantaged contexts.

Method

Participants

Data were collected on 70 children from four preschool classes. The children and their teachers were divided into an experimental (two classes) and a control (two classes) groups (Table 1). All children were students of the early childhood education program of a public preschool in the center of Sao Paulo city. Their average age was 5.5 years (SD = .21). The students at this school came from low and medium-low socioeconomic status homes (SES). In particular, 80.8% of the families had monthly household incomes of ≤ $804.45, and only 4% of the students' mothers and 1% of the students' fathers had a college degree. The teachers from the experimental and control groups had different teaching schedules; therefore, they did not meet each other and could not share information concerning the intervention program activities. The assignment of teachers/classes to experimental and control groups was based on the teachers' availability for the training. That is, teachers who had pedagogical breaks at the same time were assigned to the experimental group to facilitate the conducting of meetings for training. This criterion was indicated by the school principal. Despite not being exactly aleatory and the fact that teachers in experimental group were consulted for agreement (they agreed), the assignment to groups did not consider teacher's motivation or preference.

The experimental and control groups were equivalent with regard to the schooling of the parents, household income, gender, number of siblings, duration of schooling, and time at the present school (Table 1). A difference between groups was found in the school attendance level, as measured at the end of the school year (Table 1), with higher attendance in the control group (attendance refers to the number of child presences/absences in the school year, and it was obtained from the gradebook, in which teachers recorded attendance daily). From this final sample (N = 70), we excluded three children (one from the experimental group and two from the control) with syndromic or neurological conditions, as reported by their parents in a demographic information questionnaire. After these exclusions, none of the children in our sample had intellectual disabilities according to their scores on the Columbia Mental Maturity Scale.

Materials

The intervention program for self-regulation and executive functions

The Intervention Program for Self-Regulation and Executive Functions or PIAFEx (the acronym is from the original name in Portuguese, *Programa de Intervenção em Autorregulação e Funções Executivas*) (Dias & Seabra 2013b, Dias & Seabra 2015a) was developed based on the work of Bodrova and Leong (2007), Dawson and Guare (2010), Meltzer (2010), and Rosário et al. (2007a). The program consists of a set of activities

Table 1 Sample Description, Including N, Participants' Age, Parents' Schooling, Familial Household Income, Gender, Number of Siblings, Duration of Schooling, Time at the Present School, and Attendance During the School Year

	Sample description					
	N (%)		Age in years (SD)			
CG	37 (52.9)		5.5 (.21)			
EG	33 (47.1)		5.6 (.21)			
Total	70		5.5 (.21)			
	Mother schooling (frequency)					
	Elementary		high school	college	x^2	*p*
CG	14		15	2	4.100	.129
EG	3		13	2		
	Father schooling (frequency)					
	Elementary		high school	college	x^2	*p*
CG	19		10	1	.214	.899
EG	10		6	1		
	Household income (frequency) *					
	Up to 1 salary		1 to 3 salaries	More than 3 salaries	x^2	*p*
CG	8		20	4	2.427	.297
EG	4		10	6		
	Gender (frequency)					
		Female	Male		x^2	*p*
CG		19	18		1.075	.300
EG		21	12			
	Number of siblings					
	M	SD			*t*	*p*
CG	1	1.3			.900	.372
EG	1.4	1.6				
	Duration of schooling in months					
	M	SD			*t*	*p*
CG	25.6	16.3			.302	.764
EG	26.5	12.9				
	Time at the present school in months **					
	M	SD			*t*	*p*
CG	12.2	10.5			.373	.711
EG	13.2	10.8				
	Attendance in school year (%)					
	M	SD			*t*	*p*
CG	89.5	6.8			−2.028	.048
EG	85.1	10.7				

*Considering the exchange rate in U.S. dollars: U$ 2.70 = R$ 1.00 (Brazilian Real)
1 salary = $268.15 - it is the minimum value allowed, in Brazil, to be paid to a worker
**refers to the number of months the child is in the current school
CG – Control Group / EG – Experimental Group

designed to be implemented in a classroom context, by the teacher, to stimulate and promote the development of EF and to increase self-regulation.

The program activities engage EF in a variety of tasks, situations, and contexts, offering opportunities for children to practice and learn how to use these skills to organize their behavior when planning tasks and problem-solving in their daily lives. The PIAFEx has an ‘essential aspects’ session that explains its fundamental principles (Teacher-child/class interaction; External mediators; Private speech; Encouraging heteroregulation) and 43 structured activities, which are divided into 10 basic modules and a supplementary module.

The PIAFEx modules are as follows: Module 1 – ‘Organization of materials/routine and time management’; Module 2 – ‘Organization of ideas, goal-setting and planning: Strategies for the day to day’; Module 3 – ‘Organization of ideas, goal-setting and planning: Stimulation activities’; Module 4 – ‘EF in physical/motor activities’; Module 5 – ‘Communication and conflict management’; Module 6 – ‘Regulating emotions’; Module 7 – ‘Working with colleagues: Opportunities for exercising hetero- and self-regulation’; Module 8 – ‘Playing with the meanings of words’; Module 9 – ‘Talking about the activities’; Module 10 – ‘Planned Play’; and Supplementary Module: ‘Nina’s Diary’. Figure 1 illustrates some of the PIAFEx activities. The Appendix (Additional file 1) provides a detailed description of all of the components of the PIAFEx.

Fig. 1 Illustrations of activities from the PIAFEx: Strategies to support **(a)** time management and **(b)** organization and planning. Children playing together supports **(c)** the need to respect and follow rules, adapt their behavior to the demands of the game, and pay attention. Strategies for resolving conflicts and regulating emotions include **(d)** time to talk, discuss, and solve problems and conflicts in the classroom, and **(e)** a strategy for regulating emotions based on Meltzer (2010). In the figure, the pictures represent 1 – Know your feelings; 2 – Stop and think; 3 - Reflect and breathe deeply three times; 4 – Now, think about a solution. Working together with the support of **(f)** mediators; in this type of activity, **(g)** each child has a specific role, and they learn to respect rules and collaborate. Planned Play includes **(h)** a plan for the planned play and **(i)** children in the planned play

The regular preschool curriculum

The National Curricular Referential for Children Education – NCR (Brasil, 1998) offers a set of principles to guide professionals in the curriculum elaboration. In this sense, these are not specific rules, which can cause difficulties in planning and transposing theoretical propositions into practical activities. The NCR has two objectives: to promote personal and social education and to promote general knowledge. There is a large focus on socialization and play, but it is a free kind of play (different from the planned play in PIAFEx). The school day in preschool is 6 h, in which children should be presented with the basic concepts of mathematics and language in addition to movement, music, visual arts, and culture. The proposal is, indeed, interesting. However, it is not in tune with more recent research about children development and evidence-based interventions because NCR has not been updated since 1998. Additionally, there is a focus on content without enough orientation or focus on how to develop important abilities such as memory, attention, and also EF.

The most recent national data reveal that 81.7% of children between 4–5 years old are enrolled in preschool (Brasil, 2013). In practice, teachers find it difficult to transpose NCR principles into structured activities. Play is free and activities are elaborated without a focus on underlying abilities, in part due to teachers' training and the absence of a psychologist in the pedagogical team. In fact, teachers and coordinator of the school admire the PIAFEx structure and systematization. In this sense, regular preschool curriculum has a greater focus on socialization and playful activities, whereas PIAFEx has a focus on abilities/strategies. This property makes it possible to use PIAFEx as a complementary curriculum.

Instruments for pretest and posttest assessment

All of the measures were translated, adapted and validated in previous studies. These studies were conducted with Brazilian children and preschoolers. They found evidence for validity based on developmental changes, correlation with external criterion (as ADHD symptoms), and convergent validity for all our measures (Dias et al., 2013; Montiel & Seabra, 2012; Trevisan, 2010; Seabra & Dias, 2012). The measures included the following:

Demographic information questionnaire: We used a questionnaire to obtain some socio-demographic information, such as family income and parents' education. The questionnaire also posed questions about the child, such as the number of siblings, years of schooling, time at that school, and issues concerning health, such as the presence of diseases. The data were used to characterize the sample. It is worth noting, however, that some questionnaires were not returned by parents, and we proceed with some missing data. The demographic information questionnaire was returned by 74.3% of the parents.

Trail Making Test for Preschoolers (Espy & Cwik, 2004): This test has two conditions, known as A and B. In condition A, children receive an instruction sheet containing the figures of five dogs. The dogs must be organized in order of size, beginning with the "baby" and moving up to the "father". In condition B, figures of bones in the respective sizes of the dog figures are introduced, and the children must match the dogs with their appropriate bones in order of size, alternating between dog and bone stimuli. We measured each child's total score for conditions A and B. The test was administered individually, with no time limit for completing this task. The Trail Making Test for Preschoolers assesses cognitive flexibility. The test has appropriated psychometric properties and is standardized for Brazilian preschool children from age four to six. The test and norms are available in Seabra and Dias (2012).

Cancellation Attention Test (Montiel & Seabra, 2012): The test assesses children's selective attention in a visual search task. The test was administered individually and consists of three matrices (parts 1 to 3) containing different types of stimuli with a fixed time (one minute) to identify the targets using the cancellation paradigm. Parts 1 and 2 assess selective attention, and part 3 assesses selective attention with some demand for shifting. We measured the total number of hits. The test has appropriated psychometric properties and is standardized for Brazilian children and adolescents from age five to young adulthood. The test and norms are available in Seabra and Dias (2012).

Semantic Stroop Test (Berwid, Kera, Santra, Bender, & Halperin, 2005; Brocki & Bohlin, 2006): This test is computerized and was administered individually. The Semantic Stroop Test assesses inhibitory control by presenting pairs of images (i.e., sun-moon; girl-boy). In the first part of the test, children have to name the images, whereas, in the second part, they have to name the opposite images. Accuracy and reaction time (RT) during each part were recorded, and an interference effect (performance in part 2 *minus* performance in part 1) was calculated for the score and RT. There is validity evidence for children from four to seven years (Trevisan, 2010). Cronbach's alpha for all measures in the pre-test and for part 2 in the post-test was satisfactory (Pre-test: Part 1 = .75; Part 2 = .94 / Post-test: Part 2 = .90). For Part 1, in the post-test, Cronbach's alpha was very low (.11). This could be due the fact that, in post-test, there was little variability in such items (some of them were correctly performed by all students). Indeed, in part 1, children had to name the images, and the task may have been easy for students at post-test with only random errors. For the purpose of this study, part 2 is the most important.

Go NoGo Task (Strauss, Sherman, & Spreen, 2006): This test is computerized and uses a touch screen monitor. The test was administered individually and assesses sustained attention and inhibitory control. The test consists of white background screens on which red or blue squares are shown. The children's task is to respond by pressing a button only when the stimulus shown (i.e., the square) is red. They should not respond when the presented stimulus is blue. We measured children's total score and RT. There is validity evidence for children from four to seven years (Trevisan, 2010). Cronbach's alpha in pre- and post-test was satisfactory (Pre-test = .89/ Post-test = .90).

Simon Task (Davidson, Amso, Anderson, & Diamond, 2006): The test is computerized and uses a touch screen monitor. The test has three parts or conditions. In part 1, the figures of a butterfly and a frog were presented on the screen, and the children were asked to press the corresponding button with either the figure of a butterfly or a frog on it. In part 2, arrows were presented on the screen, and the children were asked to press the button that was on the side that the arrow was pointing to, which was independent of where on the screen the arrow actually was. Parts 1 and 2 assessed inhibitory control. In part 3, striped or gray spheres were presented on the screen. Children were asked to press the button on the same side of the presented stimulus if the sphere was striped, whereas, if the sphere was grey, the children were asked to press the button on the opposite side of the screen. Part 3 measured both inhibition and working memory. There were congruent and incongruent items for each part of the test. The test was administered individually, and accuracy was recorded for congruent and incongruent trials. There is validity evidence for children from four to seven years (Trevisan, 2010). Cronbach's alpha for all measures in pre- and post-test was satisfactory (Pre-test: Part 1 = .72; Part 2 = .82; Part 3 = .81 / Post-test: Part 1 = .60; Part 2 = .85; Part 3 = .81).

Columbia Mental Maturity Scale (CMMS): The CMMS is a standardized test that assesses the general level of nonverbal reasoning in children between three years and six months and nine years and 11 months of age (Alves & Duarte, 2001). Children are presented with boards that have three to five pictures each, and their task is to choose which design is different or does not relate to the others. To do so, children must discover the rule underlying the organization of the figures, so that they can reject just one design. The test has been shown to have acceptable reliability and validity. In the present study, this measure of reasoning was used to identify children with intellectual problems.

Procedure

The Ethics Research Committee approved this project. A consent form was sent to the School Board of Directors and to the students' parents to obtain their consent to conduct the research. The research was conducted according to the following three steps: the pretest, the intervention, and the posttest.

Pre- and post-test assessment

In the pretest, all children were assessed using the Trail Making Test for Preschoolers Cancellation Attention Test, the Semantic Stroop Test, the Go NoGo Task, and the Simon Task. Additionally, children were assessed with the CMMS to screen for problems in reasoning. The pretest assessment took place in a room at the school and was conducted in six individual sessions of approximately 20 min' duration for each session. Parents were asked to answer the Demographic information questionnaire. After the pretest, we implemented the intervention in the school (described below). This phase of the research lasted approximately four-and-a-half months (from late April to October 1st, excluding winter vacation in July) and was followed by the posttest assessment, in which the same procedure used for the pretest was repeated (except that the CMMS and Demographic information questionnaire were not administered, so five individual sessions of approximately 20 min were performed).

The intervention phase

For the intervention, teachers from two classes received training with regard to the intervention program. Their classes constituted the experimental group. Two other teachers' classes comprised the control condition, and their classes remained unchanged. The teachers of the Experimental group received a kit, containing a copy of the PIAFEx, with all activities and an initial part developed for introduction and training in the program. These teachers attended three training meetings (two hours each, one per week) at the beginning of the school year and at the end of the pretest (approximately six hours of training). The training was conducted by the author and its contents included the concept of EF, discussion on the results of studies of interventions conducted by teachers and on the importance of teachers' role in stimulating the development of EF, problems associated with impairments in EF and, lastly, the objectives and activities of the PIAFEx, with examples, modeling, and some time for practice.

After this first period, the teachers initiated activities in the classroom on a daily basis. The first author conducted observation sessions in the classroom (approximately 1 h) and provided supervision for each teacher (approximately 30 min), twice a week. Observations were made in the classroom during implementation of the activities. During these events, the author took notes on the teacher's and children's behavior, and the notes were discussed with the teachers later in the supervision meetings, to improve the teachers' skills in the implementation of the PIAFEx. Additionally, in the supervision meetings, teachers had an opportunity to resolve their doubts and discuss activities. These events also helped bring about dialogue concerning forms of teacher-class interaction and integration of activities with academic content. Such observations and supervision were extended until the end of the school year, when we started the post-test. The intervention lasted approximately four-and-a-half months (late April to Jun, and August to October, 1st). In this period, there were 32 meetings with teachers. The control group teachers received no training, and their classes remained within the regular program activities. However, it is worth noting that the control group was not a group without any activity because these children participated in the regular activities of their school level, which was also expected to promote skills. All of the materials used in the intervention (such as games and toys) were donated by the researchers and could be used by all of the teachers and students.

The teachers themselves implemented the activities during the regular school day. Many of the activities were integrated into the school curriculum (Modules 1 and 2, for example), whereas others were implemented in specific periods. The choice of activities was driven by a calendar available in the PIAFEx. The calendar illustrated the frequency and distribution of activities in the week. For example, activities from modules 1, 2, 5, and 7 could be proposed on Tuesday. Thus, the teacher could choose any activity from each of those modules to carry out with the children. Generally, the teachers chose an activity that was more related (or could be better integrated) with the regular subject that they were expected to teach that day, which gave some flexibility to the implementation of the PIAFEx and, at the same time, provided teachers with guidelines.

To evaluate the adherence of teachers to PIAFEx and have some fidelity measurement, one blind observer (a psychologist who did not know the assignment of the classes in the groups) performed one day (four hours) of observation in each class (This happened on two occasions, June and October). To systematize this process, we developed an observation protocol, in which the observer could score how much the activity proposed by the teacher, as well as their posture/behavior in class, could promote EF. A hypothetical index for each group was computed considering the scores of each teacher in the observation protocol. This index was considered to be indicative of adherence to the procedure. As expected, teachers in the experimental group

(57.9) showed higher scores than the colleagues in the control group (16.9). Due to the small number of children in each class within the experimental group, an analysis of the adherence of each class to the intervention was not performed. We also recorded all activities performed by each teacher during the entire intervention period; thus, we had a reasonable control regarding what each teacher did. This information was important to document and systematize the attitude and commitment of teachers regarding the intervention program.

Statistical analyses

First, we performed an ANOVA to investigate any group effects on the performances at pretest. After that, analyses of covariance (ANCOVA) were performed for each measure (posttest measures) to determine any group effects on the performances. The group level (experimental vs. control) was used as the independent variable. The pretest performance in each measure was used as the covariate, as suggested by Dancey and Reidy (2006); because of this, ANCOVAs were performed for each measure independently. As our study is an exploratory one, we chose not to use a composite score. The level of confidence was set at .05 for all of the comparisons. For all of the tests, eta squares were used to estimate the effect size (ES _ small – from .0099; medium – from .0588; and high – from .1379).

Results

We conducted an ANOVA examining any group effect (experimental vs. control) on pretest performances. These results are presented in Table 2. There were no significant

Table 2 Descriptive and Inferential Statistics Obtained After an ANOVA (Pretest) for Children's Performances on Each Measure, with F and P Values for the Experimental (EG) and Control (CG) Groups

Variable	EG (M, SD)	CG (M, SD)	F (df)	*p*
Trail Making Test for Preschoolers –Total part A	4.36 (3.1)	4.03 (3.52)	.185 (1, 71)	.669
Trail Making Test for Preschoolers –Total part B	4.81 (3,8)	3.68 (2.95)	2.048 (1, 71)	.157
Cancellation Attention Test – Total score	29.19 (13.3)	30.27 (12)	.132 (1, 71)	.718
Semantic Stroop Test - Score in part 1	15.41 (1.4)	15.09 (1.2)	1.041 (1, 64)	.311
Semantic Stroop Test - Score in part 2	13.44 (3.4)	12.59 (4.9)	.671 (1, 64)	.416
Semantic Stroop Test – Reaction time in part 1*	.65 (.2)	.66 (.2)	.009 (1, 61)	.926
Semantic Stroop Test – Reaction time in part 2*	1.16 (.4)	1.33 (.4)	3.516 (1, 61)	.066
Semantic Stroop Test – Interference score	−1.97 (3.0)	−2.50 (4.6)	.305 (1, 64)	.583
Semantic Stroop Test – Interference – reaction time	.51 (.3)	.85 (1.0)	3.367 (1, 61)	.071
Go NoGo Task – Total score	.76 (.1)	.72 (.2)	1.879 (1, 68)	.175
Go NoGo Task – Reaction time*	.67 (.2)	.74 (.2)	2.394 (1, 68)	.126
Simon Task - Score on part 1 – congruent items	.82 (.2)	.84 (.1)	.179 (1, 61)	.673
Simon Task - Score on part 1 – incongruent items	.91 (.2)	.89 (.2)	.194 (1, 61)	.661
Simon Task - Score on part 2 – congruent items	.80 (.2)	.79 (.2)	.027 (1, 61)	.870
Simon Task - Score on part 2 – incongruent items	.71 (.3)	.73 (.3)	.080 (1, 61)	.778
Simon Task - Score on part 3 – congruent items	.70 (.3)	.69 (.3)	.017 (1, 61)	.896
Simon Task - Score on part 3 – incongruent items	.82 (.2)	.71 (.3)	3.591 (1, 61)	.063

*seconds

differences between groups; however, there were some marginal effects that justify the use of pretest performances as covariates in the posttest analyses.

We conducted covariance analyses examining any group effect (experimental vs. control) on posttest results while controlling for the children's pretest performances. These results are presented in Table 3.

Our results showed some covariate effects, which reveal that the pretest performance control was, indeed, necessary. Despite controlling for previous performance in each measure, some significant results were evidenced. We found that children in the experimental condition had significantly better scores for the total number of hits in the Cancellation Attention Test as well as for part 2 of the Semantic Stroop Test. For the latter instrument, children in the experimental group also suffered less from interference (on score) than did the control group. They also had better scores for incongruent items on part 1 of the Simon Task, and they used more time to answer (greater RT) in the Go NoGo Task than did their peers in the control condition.

In addition, some tendencies, with marginal effects, were found. Children in the experimental condition tended to perform better than their control peers in terms of total scores for part A of the Trail Making Test. The experimental group also showed a tendency to take more time to answer in part 2 of the Semantic Stroop Test (showing a greater RT) (see Tables 2 and 3 for all of the pretest and posttest scores and for the F and p values).

Discussion

The findings of the study show that the children in the experimental group had more improvement than did their peers in the control condition, supporting the assertion that PIAFEx may promote greater development of abilities than the regular curriculum in the control group. The children in the experimental group exhibited gains in attention and inhibition, and importantly, the results were obtained using tasks (performance tests) that differed from those used in the intervention (that was ecological), revealing a transfer of gains (as shown in Barnett et al., 2008, and Diamond et al., 2007). Among the significant differences, there were effect sizes (eta squared) from small to medium.

On the Trail Making Test for Preschoolers, part A, there was only a marginal trend between the groups. This part of the test measures attention, speed, and visual search, and the experimental group tended to have some gain in these skills compared to the control. Despite this, no gains were observed on part B, the more complex portion of the test. One hypothesis to explain this is that because the differences between the dogs and the bones were subtle in size, the test was a little difficult for the participants. In fact, many children made mistakes because they were not able to distinguish between dogs of similar sizes. This type of observation was not observed in studies with older children (Dias & Seabra 2015b), and it may indicate that this version of Trails is not appropriate or sensitive for preschool children.

The children in the experimental group, however, showed better attentional abilities, as measured by the total number of hits in the Cancellation Attention Test. That is, children in experimental condition were better able to focus their attention on performing a task. They also presented more gains in inhibition, as assessed by indices of the Semantic Stroop Test, Go NoGo Task, and Simon Task.

Table 3 Statistics Corrected by ANCOVA (Posttest) for Children's Performances on Each Measure, with F and P Values for the Experimental (EG) and Control (CG) Groups (Controlling for Pretest Performance in the Respective Measure)

Variable		EG M (SE)	CG M (SE)	F (df)	*p*	Eta Square
Trail Making Test for Preschoolers – Total part A	Group effect	7.24 (.5)	6.11 (.5)	2.711 (1, 66)	.100	.039
	Covariant effect	–	–	4.952 (1, 66)	.029	.070
Trail Making Test for Preschoolers – Total part B	Group effect	7.93 (.7)	7.54 (.7)	.158 (1, 66)	.692	.002
	Covariant effect	–	–	6.066 (1, 66)	.016	.084
Cancellation Attention Test – Total score	Group effect	48.48 (2.2)	41.65 (2.1)	4.930 (1, 66)	.030	.070
	Covariant effect	–	–	8.941 (1, 66)	.004	.119
Semantic Stroop Test - Score in part 1	Group effect	15.82 (.1)	15.79 (.1)	.042 (1, 63)	.838	<.001
	Covariant effect	–	–	.162 (1, 63)	.689	.003
Semantic Stroop Test - Score in part 2	Group effect	15.73 (.3)	14.75 (.3)	5.081 (1, 63)	.028	.075
	Covariant effect	–	–	11.969 (1, 63)	.001	1.6
Semantic Stroop Test – Reaction time in part 1*	Group effect	.51 (.03)	.47 (.03)	1.172 (1, 63)	.283	.018
	Covariant effect	–	–	3.234 (1, 63)	.077	.049
Semantic Stroop Test – Reaction time in part 2*	Group effect	1.06 (.04)	.96 (.04)	2.964 (1, 60)	.090	.047
	Covariant effect	–	–	30.265 (1, 60)	<.001	.335
Semantic Stroop Test – Interference score	Group effect	-.04 (.3)	−1.08 (.3)	5.724 (1, 63)	.020	.083
	Covariant effect	–	–	8.142 (1, 63)	.006	.114
Semantic Stroop Test – Interference – reaction time	Group effect	.52 (.04)	.51 (.04)	.026 (1, 60)	.872	<.001
	Covariant effect	–	–	2.297 (1, 60)	.135	.037
Go NoGo Task – Total score	Group effect	.81 (.02)	.85 (.02)	2.270 (1, 64)	.137	.034
	Covariant effect	–	–	6.317 (1, 64)	.014	.090
Go NoGo Task – Reaction time*	Group effect	.70 (.2)	.63 (.2)	4.669 (1, 64)	.034	.068
	Covariant effect	–	–	22.682 (1, 64)	<.001	.262
Simon Task - Score on part 1 – congruent items	Group effect	.88 (.02)	.92 (.02)	2.426 (1, 60)	.125	.039
	Covariant effect	–	–	2.265 (1, 60)	.138	.036
Simon Task - Score on part 1 – incongruent items	Group effect	.99 (.02)	.93 (.02)	5.402 (1, 60)	.024	.083
	Covariant effect	–	–	.065 (1, 60)	.800	.001
Simon Task - Score on part 2 – congruent items	Group effect	.87 (.04)	.85 (.04)	.248 (1, 60)	.620	.004
	Covariant effect	–	–	5.229 (1, 60)	.026	.080
Simon Task - Score on part 2 – incongruent items	Group effect	.79 (.04)	.75 (.04)	.448 (1, 60)	.506	.007
	Covariant effect	–	–	12.248 (1, 60)	.001	.170
Simon Task - Score on part 3 – congruent items	Group effect	.83 (.03)	.91 (.03)	2.612 (1, 60)	.111	.042
	Covariant effect	–	–	.443 (1, 60)	.508	.007
Simon Task - Score on part 3 – incongruent items	Group effect	.89 (.03)	.90 (.03)	.070 (1, 60)	.792	.001
	Covariant effect	–	–	.218 (1, 60)	.642	.004

*seconds

With regard to scores on the Stroop Task, the experimental condition group had greater scores in part 2 (incongruent items), smaller interference scores (smaller difference between scores in part 2 and part 1), and, marginally, greater reaction time in part 2 (spending more time to answer). These results suggest that children in the experimental group were better able to inhibit the automatic tendency, showing a pattern of better performance in conflict situations (that is, in the face of incongruent situations), which seems to be accompanied by a tendency of a greater time to respond. Note that significant differences were observed in part 2 but not in part 1, as in Diamond et al. (2007), who found effects only on the most difficult items. Considering time measures, this finding argues against a general effect on speed processing, corroborating a specific improvement in interference control situations. It is interesting to note that, among the significant effects, those in score in part 2 and interference score on the Stroop Test are some of the highest observed in the study, which suggests that this task demand is sensitive to the PIAFEx intervention carried out, which taught thinking before answering, thereby avoiding prepotent answers.

The Stroop Task performance is also consistent with the greater reaction times observed in the experimental group on the Go NoGo Task. Again, it is likely that the experimental group children took more time to answer because they were thinking more before doing so. In this case, however, taking more time could affect the children's performance because there was a limited time for stimuli presentation (between 800 and 1200 milliseconds). It is possible that some experimental group children lost the opportunity to score and thus failed the trial if they were slow to press the button.

The group's performance on the Simon Task corroborates the Stroop Test results, that is, children in the experimental group showed greater gains than the control ones on the score in incongruent items of part 1 but not in congruent items. In this way, the experimental group children were better able to inhibit the tendency to respond by pressing the button on the same side of the stimuli; however, in congruent items, which did not require inhibition, there was no difference between the groups.

It is worth noting that the intervention effects appear for attention and inhibition, and, for the latter, both response inhibition and interference control (which involves cognitive inhibition) showed gains in the experimental group. However, we did not observe intervention effects on the measures of cognitive flexibility (Trails) and working memory (part 3 of the Simon Task). In the case of Trails, we hypothesized that the test was not sensitive for the sample, but another hypothesis that can be applied to the Trails and Simon tasks involves developmental trends. There is evidence that attention and inhibition begin developing early in childhood, whereas working memory and flexibility are more complex abilities and begin to develop later (Dawson & Guare, 2010; Diamond, 2013; Dias et al., 2013). It may be harder to address these abilities in our sample age range, with effective intervention requiring a longer intervention period. With respect to these questions, we believe that the intervention period in this study, limited to approximately four months, was not sufficient to stimulate the development of these skills and that longer periods may be needed to affect flexibility and working memory, as was reported in previous studies with one- or two-year interventions (Barnett et al., 2008; Diamond et al., 2007). Anyway, we can hypothesize that the fact we did not find more effects from our intervention occurred because the children did not experience adequate quality or quantity of training. We strongly suggest that teacher training should be more intensive and the intervention period longer. It could be important because teachers presented some difficulty in integrating PIAFEx in their daily routine at the beginning of the intervention, and, as the weeks passed by, they became increasingly more able to do so, as they learnt and understood the principles of the program.

Despite some evidence of PIAFEx effectiveness in first graders (Dias & Seabra 2015b), this is the first investigation with preschoolers. Overall, PIAFEx proved to be effective in promoting gains in attention and inhibition in 5-year-old children, and these gains exceeded effects from regular schooling (control group). Conducting a brief comparison, we found effects of the PIAFEx on attention and inhibition, whereas others, with different approaches to EF stimulation, reported gains in flexibility and working memory (Diamond et al., 2007), social behavior (Barnett et al., 2008), attention, inhibition and flexibility (Diamond and Lee, 2011), and in children's ability to use trained strategies (planning, execution, and checking) in activities in the classroom context (Rosário et al. 2007b). Concerning play, also included in a PIAFEx module, there is evidence of its role in stimulating language, including vocabulary, besides attention, impulse control, cooperation, imagination and empathy (Bodrova & Leong, 2003).

Additionally, complementing previous research in the area (e.g., Barnett et al., 2008; Bodrova & Leong, 2010; Dawson & Guare, 2010; Diamond et al., 2007; Diamond, 2013; Meltzer, 2010; Rosário et al. 2007b), our findings suggest that it is possible to promote the development of EF in children, even in a developing country with a population with low socioeconomic status. Therefore, despite potential differences between the Brazilian context and the context in which other interventions were performed, one can assume that, to some extent, there is some degree of universality in the possibility of gains on EF resulting from interventions in the school context.

Because we know culture may influence EF development (Carlson, 2009; Lahat et al., 2010), it is especially important to test the effect of interventions to promote EF in these different contexts. We also know that socioeconomic status is related to EF and can affect the development of such skills (Hook et al., 2013; Noble et al., 2005), whereas EF can be considered as protective for children developing in chaotic environments (Wenzel & Gunnar, 2013). Therefore, it is imperative to develop and apply interventions to promote EF in such at-risk populations who most need them. This takes on even greater relevance if one considers that even small gains in EF can promote substantial changes in learning, health and behavior (Diamond & Lee, 2011; Moffitt et al., 2011). In this sense, our research extends the previous data and supports taking an early-intervention approach in more disadvantaged contexts, such as developing countries.

Early childhood experiences and abilities such as EF are the foundation for success throughout life, in academic, occupational, and social contexts (Diamond, 2013; Moffitt et al., 2011). In this sense, and to the extent that PIAFEx overcomes the regular preschool curriculum and proves to be effective in improving EF, efforts to expand knowledge and application of this program (or even new activities to stimulate EF) deserve attention in the design of educational programs. Policies focused only on literacy instruction can be less efficient than policies that include activities for EF development (Center on the Developing Child at Harvard University 2015). Therefore, knowledge about EF should be included in the teacher education/training to allow them to support EF development in their students. Practice must be guided by scientific evidence. The study offers some promising results and presents a tool to teachers and policy administrators, providing some contributions to early childhood education and care policy.

Limitations of the current study and next steps

One of the limitations of this study is the small sample, with only one school taking part in the study. However, for our primary objective – testing the newborn PIAFEx – the small sample was considered sufficient. For the future, the authors suggest studies using bigger samples, different schools, and children from different age and grade levels. It would also be interesting to look for interactions between the intervention effects and SES. In our study, SES was relatively controlled because children were from the same school/neighborhood and we did not find differences between groups in some of these variables. The authors suggest as well the use of different measures to assess the intervention effects, as more functional instruments can capture 'hotter' aspects of the PIAFEx.

Additionally, although the teachers from the groups had different teaching schedules, and did not meet each other to share information about the intervention, one can suggest that it could be more reliable to have experimental and control groups divided in different schools. However, groups in the same school can control for variables such as educational philosophy, coordination strategies, type of materials, environment, and even SES. Concerning the missing data from our Demographic information questionnaire, this could be due to parents' low schooling, and future investigation should consider an interview. In addition, our intervention period was too short, despite the promising results. In this way, future studies should consider a longer period of intervention, comparing, for example, the effect of one *versus* two *versus* three years of intervention on EF in preschoolers and children in the initial years of elementary school. Last, this study did not include a follow-up test in the program evaluation design. Some recent findings with first graders of elementary suggest that EF gains remain after a one-year follow-up, with transfer of effects for behavior and learning (Dias & Seabra: Intervention for executive functions development in early elementary school children: Effects on learning and behavior, submitted), but this has not been investigated for preschoolers until now. We are aware of our study limitations and we agree that ecological interventions, indeed, allow for less experimenter control, while, at the same time, they allow for relevant implications for practice in the real world. We hope that such initial but promising results stimulate research in cognitive interventions applied in school.

Conclusions

Five-year-old preschool children exhibited gains in attention and inhibition abilities after a four-and-a-half-month intervention applying PIAFEx. Thus, the program is more effective in promoting EF than the regular preschool curriculum. This finding may have particular importance in developing countries, but to date, this topic has rarely been studied. The results validate the concept of early intervention underlying the PIAFEx: the promotion of EF development can be a result of intentional practice through an educational approach with activities that require such abilities.

Additional file

Additional file 1: The Intervention Program for Self-regulation and Executive Functions (PIAFEx).

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

This paper is derived from the PhD thesis of NMD, which was supervised by AGS. Both authors participated in the design of the study, objectives, data analysis and discussion. Both authors read and approved the final manuscript.

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