ISSN online1688-4221

Ciencias Psicológicas July-December 2024; 18(2), e-3274
DOI: 10.22235/cp.v18i2.3274

Intervention in cold executive functions and emotion regulation: impact of the application of two programs on executive-emotional processing in schoolchildren

Intervenção em funções executivas e regulação emocional: impacto da aplicação de dois programas no processamento executivo-emocional de escolares

Intervención en funciones ejecutivas frías y regulación emocional: impacto de la aplicación de dos programas en el procesamiento ejecutivo-emocional en escolares

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Received: 02/28/2023
Accepted: 09/12/2024

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How to cite:
Cervi Colling, A. P., Cardoso, C. O., Zimmermann, N., & Fonseca, R. P. (2024). Intervention in cold executive functions and emotion regulation: impact of the application of two programs on executive-emotional processing in schoolchildren. *Ciencias Psicológicas*, *18*(2), e-3274. https://doi.org/10.22235/cp.v18i2.3274

Data availability:
The data set supporting the results of this study is not available.

Abstract: Executive functions (EF) and emotion regulation (ER) are associated with the basis of children's cognitive and socio-emotional development. In view of the current of neuropsychological interventions in EF, the present study sought to investigate whether an EF intervention (PENcE program) would be equivalent, superior or inferior in relation to the EF intervention in conjunction with ER strategies (PENcE and REPENcE programs) in performance executive, emotional and school performance of elementary school students who underwent performance programs exclusively focused on EF (PENcE) versus a mixed EF and ER program (PENcE+REPENcE) versus controls. One hundred and eleven children participated, divided into three groups: group 1 received a mixed intervention with the PENcE and REPENcE programs, group 2 performed only the PENcE, and group 3 was the control group (school curriculum). The group submitted to the mixed intervention showed superior performance in a greater number of domains, such as initiation, processing speed, body awareness, and communication of emotions, in the post-intervention evaluation. Thus, it is clear that a program focused on ER skills can enhance and increase the outcomes of a cognitive stimulation program exclusively for EF.
Keywords: executive functions; emotional regulation; neuropsychological intervention; childhood

Resumo: As funções executivas (FE) e a regulação emocional (RE) estão associadas à base dos desenvolvimentos cognitivo e socioemocional de crianças. Em vista da corrente de intervenções neuropsicológicas em FE, o presente estudo buscou investigar se uma intervenção de FE (programa PENcE) seria equivalente, superior ou inferior em relação à intervenção de FE em conjunto com estratégias de RE (programas PENcE e REPENcE) no desempenho executivo, emocional e escolar de alunos do Ensino Fundamental I que foram submetidos a programas de desempenho exclusivamente focados nas FE (PENcE) versus programa misto de FE e RE (PENcE+REPENcE) versus controles. Participaram 111 crianças, dividida em três grupos: grupo 1 recebeu uma intervenção mista com os programas PENcE e REPENcE, grupo 2 realizou somente o PENcE, e grupo 3 foi o grupo controle (currículo escolar). O grupo submetido à intervenção mista apresentou na avaliação pós-intervenção desempenho superior em um maior número de domínios, como, iniciação, velocidade de processamento, consciência corporal, e comunicação das emoções. Deste modo, percebe-se que um programa focado em habilidades de RE pode potencializar e incrementar os desfechos de um programa de estimulação cognitiva exclusivamente de FE.
Palavras-chave: funções executivas; regulação emocional; intervenção neuropsicológica; infância

Resumen: Las funciones ejecutivas (FE) y la regulación emocional (RE) se asocian a partir de los desarrollos cognitivos y socioemocionales de los niños. En vista de las intervenciones neuropsicológicas actuales en FE, el presente estudio buscó investigar si una intervención de FE (programa PENcE) sería equivalente, superior o inferior en relación a la intervención de FE en conjunto con estrategias de RE (programas PENcE y REPENcE) en el desempeño ejecutivo, emocional y académico de estudiantes de la escuela primaria sometidos a programas de desempeño enfocados exclusivamente en FE (PENcE) versus un programa mixto de FE y RE (PENcE+REPENcE) versus controles. Participaron 111 niños, divididos en tres grupos: el grupo 1 recibió una intervención mixta con los programas PENcE y REPENcE, el grupo 2 recibió solo PENcE, y el grupo 3 fue el grupo de control (currículo escolar). El grupo sometido a la intervención presentó un desempeño superior en la evaluación posintervención en un gran número de dominios, como iniciación, velocidad de procesamiento, conciencia corporal y comunicación de emociones. Así, es claro que un programa centrado en las habilidades de RE puede potenciar y aumentar el resultado de un programa de estimulación cognitiva exclusivamente de FE.
Palabras clave: funciones ejecutivas; regulación emocional; intervención neuropsicológica; infancia

Executive functions (EF) and emotional regulation skills (ER) have been the focus of studies due to their strong relationship with cognitive and emotional functioning in childhood, as well as with various outcomes in adulthood, such as academic, occupational, and personal success (Diamond & Ling, 2020). Early preventive programs aimed at stimulating EF and ER are being developed worldwide to optimize child development within the school context (Cardoso et al., 2016; Pandey et al., 2018), prior to any cognitive impairment in the child's life. Such interventional actions aim for a broad reach of prevention and/or early stimulation approaches, providing a better cost-benefit balance for global health and economics compared to the more limited outcomes of clinical and individual remedial interventions (Diamond & Ling, 2020; Pandey et al., 2018).

There are conceptual aspects in the knowledge of EF and ER that overlap and differentiate them, as well as a diversity of theoretical models and a series of unanswered questions about these constructs (Cardoso et al., 2020). More specifically, there is little consensus on the integration between them, as neuropsychological theoretical models tend not to clearly explain the relationship between EF and emotions, and largely fail to investigate the role of emotions in executive functioning and its outcomes (Blair & Ursache, 2011). However, longitudinal research that has investigated the development of these abilities in children reports that EF and ER can be considered components of a broad function called self-regulation (SR) (Blair, 2002; McClelland et al., 2010). Thus, they integrate emotion and cognition in a neurobiological model of child functioning (Blair, 2002; Blair & Diamond, 2008; Carlson & Wang, 2007). This model of SR unites different cognitive, emotional and behavioral processes.

In general, EF can be considered as cognitive self-regulation and are characterized as a varied set of cognitive processes necessary for regulating behavior, which allow individuals to engage in planned, goal-oriented behavior towards solving problems more effectively (Diamond, 2013; Zelazo et al., 2016). Diamond (2013) suggests that EF are made up of three main components: inhibitory control, cognitive flexibility and working memory. This model suggests that EF act as mediators of emotional aspects, despite emphasizing more logical and rational aspects.

Emotional SR is related to the expression of emotions in a more adaptive way, involving emotional management, modulation and inhibition with a view to better social adaptation (Calkins, 2009). The concept of emotional SR sometimes overlaps with that of ER, since both can be considered skills that encompass both emotion processing and emotion regulation, inhibition and flexibility (Berger, 2011). ER is related to the individual's ability to manage and regulate their own behavior, feelings and physiological responses arising from emotions, enabling them to adapt adequately to environmental demands (2). Like EF, ER is used in different contexts and is part of individuals' daily lives throughout their lives.

Given the importance of EF and ER for children's positive development, intervention programs have been developed to promote strategies to stimulate these components (Blair & Diamond, 2008; Cardoso & Fonseca, 2016; Cardoso et al., 2020). Within this theme, Diamond and Ling (2016) mention that the stimuli the brain receives are considered essential for the formation and improvement of these skills, and that among these stimuli are early-preventive neuropsychological stimulation programs.

In this context, EF stimulation programs in childhood have shown positive and significant results in terms of improving working memory skills (Bierman et al, 2008), inhibitory control (Dias & Seabra, 2016), cognitive flexibility, metacognition, and better academic performance (Lizarraga et al, 2003). In parallel, ER programs for schoolchildren have also shown positive outcomes in terms of improved

emotional problem solving, focused attention skills (Arda & Ocak, 2012), monitoring of risk-taking behavior and aggression (Arda & Ocak, 2012; O'Connor et al., 2014), intensity levels of anxiety and depression (Essau et al., 2012), academic performance (O'Connor et al., 2014), among others. It is not yet clear, however, whether there are differences or superiority in the application of such interventions alone for EF, or for ER, or in a combined-consecutive manner, and in which outcomes. The relevance of investigating the difference, equivalence or superiority of the application of existing intervention programs in schoolchildren is to make the provision of these programs cost-effective, as there is limited time for the application of complementary interventions in school curricula.

Regarding childhood stimulation programs, the "Program for Neuropsychological Stimulation of Cognition in Schoolchildren: emphasis on executive functions (PENcE)" (Cardoso & Fonseca, 2016) was developed in Brazil, which aims to stimulate executive skills. Aiming to expand the PENcE program, Cardoso et al. (2020) published "REPENcE Emotional Regulation", a program that aims to stimulate ER according to the bidirectional model proposed by Blair and Ursache (2011). In view of the current of neuropsychological interventions in EF, the present study sought to investigate whether the intervention exclusively of EF (PENcE) would be equivalent, superior or inferior in relation to the intervention of mixed EF in conjunction with ER strategies in schoolchildren (PENcE+REPENcE). More specifically, it sought to verify whether there is a difference in the executive, emotional and school performance of elementary school students who were submitted to performance programs exclusively focused on EF (PENcE) versus a mixed program of EF and ER (PENcE+REPENcE) versus controls. The hypothesis is that the group that underwent the combined EF and ER intervention will have a better outcome than the group that underwent the EF-only intervention and the control group. This hypothesis is based on literature which suggests that the integration of emotional regulation strategies with the development of executive functions enhances the benefits, according to Blair and Ursache's bidirectional model (2011). In addition, it is expected that the EF-only intervention group will outperform the controls in the outcomes, given that they participated in a targeted intervention and based on previous evidence demonstrating the significant benefits that stimulating executive functions can provide (Diamond & Ling, 2020).

Materials and methods

Participants

The initial sample consisted of 145 children, of which 34 were excluded for the following reasons: a) intellectual impairment (25th percentile or lower on the Raven Progressive Matrices test, adapted for Brazilian Portuguese by Angelini et al. (1999)) (n = 15), b) uncorrected sensory deficits, medical conditions of a genetic, psychiatric, or neurological nature (identified through questionnaires completed by parents and reports from teachers) (n = 6), c) a total of more than four absences during the intervention (n = 6), d) failure to complete both stages of the assessment (n = 3), and e) changing schools during the semester (n = 4). Thus, the final sample comprised 111 children from three public schools in the metropolitan area of Porto Alegre (Rio Grande do Sul, Brazil). The distribution of the groups can be viewed in Table 1.

Eight classes participated in the study, divided into three groups: one group that received a mixed intervention, consisting of PENcE followed by the REPENcE program (four classes; n = 60), one group that exclusively completed the PENcE program (two classes; n = 29), and a control group that continued with regular school activities as outlined in the school calendar, with no additional activities proposed for this group (two classes n = 22). The grade levels involved were 3rd and 4th grades, with the REPENcE + PENcE group consisting of 15 students from the 3rd grade, the PENcE group having 19 students from the 4th grade, and the control group comprising 7 students from the 4th grade. Participants included students whose parents voluntarily consented to their participation through the signing of the Informed Consent Form (ICF), students in the 3rd or 4th grade of elementary school from the selected schools, aged between 8 and 11 years, with no prior retention and who had attended preschool. The intervention and assessments were conducted in the year 2019, prior to the SARS-CoV-2 pandemic.

Table 1
Distribution of groups by school and grade level

School	Grade level	Group	Final sample
School 1	31-3º	Control	7
	32-3º	PENcE+REPENcE	15
	41-4º	PENcE+REPENcE	14
	42-4º	PENcE	10
School 2	31- 3º	PENcE	19
	41-4º	PENcE+REPENcE	15
	43-4º	Control	15
School 3	41-4º	PENcE+REPENcE	16
Total			111

Procedures and Instruments

Ethical Procedures

This study was approved by the Research Ethics Committee (approval number 4.292.810). It is emphasized that this study adhered to the conditions established in Resolution 510/2016 of the National Health Council (CNS), ensuring respect for human dignity and the necessary protection of participants involved in scientific research with human subjects. The study was conducted in several stages: 1) meeting with school administration and coordination, 2) meeting with parents and guardians explaining the research and its objectives, and distributing questionnaires and consent forms for parents (for all groups), 3) pre-intervention assessment (for all groups), 4) implementation of PENcE (for both mixed and exclusive EF groups), 5) implementation of REPENcE (for the mixed group only), and 6) post-intervention assessment (for all groups). Blind assessments were conducted by evaluators (n = 15) who received prior training in the application of the instruments used. The evaluators were graduate students and undergraduate research assistants from the university to which the project is affiliated. Assessments were carried out individually, lasting approximately 1 hour and 10 minutes in a classroom provided by the school for this purpose.

Instruments Administered in Pre- and Post-Intervention Assessment

For parents or caregivers

1) Sociodemographic and Health Questionnaire: This questionnaire investigates issues related to the participant's health, developmental history, and educational aspects, as well as assesses the family's socioeconomic level based on the Economic Classification Criteria of Brazil (Associação Brasileira de Empresas de Pesquisa, 2016). The sociodemographic questionnaire includes the Frequency of Reading and Writing Habits Scale (FRWH; Holz et al., 2017), which examines the frequency of reading and writing habits among parents/caregivers. This questionnaire was completed by the parents or guardians of the students and assessed the FRWH of the respondents themselves, rather than that of the students.

All subsequent instruments were administered individually in a suitable location, with the evaluation lasting approximately 1 hour and 10 minutes. The tests were applied in the following sequence:

Cognitive Assessment

1) Raven's Colored Progressive Matrices (adapted for Brazilian Portuguese by Angelini et al., 1999): This instrument measures non-verbal intelligence associated with the evaluation of fluid intelligence. The cutoff point adopted was the 25th percentile or lower.

2) Hayling Test (Burgess & Shallice, 1997; adaptation for the Brazilian population by Siqueira et al., 2016): This test assesses the following constructs: inhibitory control, initiation, cognitive flexibility, and processing speed.

3) Go/No-Go Task from the Brief Neuropsychological Assessment Instrument NEUPSILIN-Inf (Salles et al., 2016): This task evaluates inhibition and initiation. It considered the total number of correct responses, omissions, and errors.

4) Verbal Fluency Tasks: Free, phonemic, and semantic fluency tasks (Jacobsen et al., 2016) assess various executive constructs, such as inhibition, monitoring, flexibility, planning, initiation, and processing speed, as well as lexical-semantic memory and language skills. The total number of correct responses for each modality and the total number of clusters were considered.

5) Digits Subtest of the Wechsler Intelligence Scale, 3rd Edition (adapted by Figueiredo, 2002): This subtest aims to evaluate components related to attention and working memory. The total number of correct responses in direct order, total correct responses in reverse order, total correct responses in both orders, and total correct responses in direct order minus reverse order were calculated.

6) Wisconsin Card Sorting Test (WCST) – Reduced version of 64 cards (Kongs et al., 2000): This test aimed to assess abstract reasoning, planning, cognitive flexibility, and the maintenance of successful rules. The variables considered included the number of trials administered, the number of correct responses, the number of categories completed, total errors, total perseverative errors, conceptual level responses, and failure to maintain context.

Emotional Assessment

1) Emotion Awareness Questionnaire (EAQ) (Rieffe et al., 2008; adapted for the Brazilian context by Seibert et al., 2023): This self-report instrument for children and adolescents consists of 30 items aimed at understanding how the target audience feels and thinks about their own emotions and those of others. It is divided into six dimensions: differentiating emotions, verbally communicating emotions, not hiding emotions, body awareness, attending to others' emotions, and analyzing one's own emotions.

Academic Performance

1) Arithmetic Subtest of the School Performance Test – 2nd Edition (TDE II; Stein et al., 2019): This subtest evaluates basic arithmetic skills. A collective administration of this instrument was conducted, and the raw score of total correct responses in the task was considered.

2) School Grades Assigned by the Teacher per Semester: This refers to the average calculated based on performance in all subjects, divided into three semesters. The average of the third semester was calculated minus the average of the first semester.

The programs

The PENcE program (Cardoso & Fonseca, 2016) aims to enhance and optimize the development of Executive Functions (EF) through structured and sequential cognitive and playful activities within the school curriculum. It consists of four modules: 1) Organization and Planning; 2) Inhibitory Control; 3) Working Memory; 4) Cognitive Flexibility. The program has undergone developmental studies and has evidence of content validity (Cardoso et al., 2017), as well as effectiveness, efficacy, and transferability (Cardoso et al., 2019). In the present study, PENcE was implemented three times a week, with each session lasting 50-60 minutes, totaling five months of application. The program was administered by the classroom teacher, with assistance from a member of the school neuropsychology extension project.

The REPENcE program, titled "Emotional Regulation: An Extension of the Neuropsychological Stimulation and Cognition Program with Emphasis on Hot Executive Functions" (Cardoso et al., 2020), aims to stimulate emotional regulation (ER) by providing children with knowledge about emotions, strategies for regulating them, and behavioral styles. The program includes the following aspects: 1) identification of emotions in oneself (primary emotions, secondary emotions, intensity parameters); 2) identification of emotions in others; 3) assertive, aggressive, and passive behavioral styles. REPENcE is grounded in clinical and school neuropsychology, as well as Cognitive-Behavioral Therapy (CBT). In this study, REPENcE was implemented following the PENcE program, occurring three times a week for one month, with sessions of approximately 50-60 minutes each. Activities were led by the classroom teacher, with the assistance of a member of the neuropsychology extension project.

Teachers received prior training divided into four sessions. Both PENcE and REPENcE followed a specific schedule, which was strictly adhered to. Before the implementation of the programs, the days and times available for the intervention were organized with each class to avoid disrupting the school calendar. The teacher was responsible for conducting the activities, while the assistant was present to address any questions that arose.

Data analysis

The comparison of sociodemographic characteristics among the groups was conducted using a one-way ANOVA and chi-square tests for continuous and categorical variables, respectively. A one-way ANOVA was also employed to investigate equivalences among the groups in the pre-test. To analyze potential gains resulting from the intervention by examining the difference in performance between the post-test and pre-test (delta), a Multivariate Analysis of Covariance (MANCOVA) was performed. The effect of the variable regarding parents' reading and writing habits was controlled, given that the parents of the PENcE+REPENcE group exhibited greater reading and writing habits compared to parents in the other groups. To identify which groups displayed differences, post hoc analyses using Bonferroni correction were conducted. Effect sizes were calculated using Eta Squared, with thresholds of 0.01 for small effect size, 0.06 for medium effect size, and 0.14 for large effect size (Field, 2009). In this study, findings with medium and large effect sizes were discussed. Results were considered significant if $p \leq 0.05$.

Results

Table 2 presents the sociodemographic characteristics of the sample for the three groups at baseline.

Table 2
Compared Sociodemographic Characteristics of the Three Sample Groups

Characteristics of the Sample	**PENcE+ REPENcE (*n* = 60)**	**PENcE (*n* = 29)**	**Control (*n* = 22)**	**Sig***	**Effect Size**
Student Data	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*p*-value	h2
Age	9.13 (0.74)	9.03 (0.49)	9.18 (0.85)	.742	0.006
Years of study	3.75 (0.43)	3.58 (0.50)	3.68 (0.47)	.294	0.02
Socioeconomic Score	21.88 (5.73)	21.17 (5.44)	22 (4.96)	.819	0.004
Sex	f (%)	f (%)	f (%)	.661	0,008
Male	31 (51.7)	12 (41.4)	11 (50)		
Female	29 (48.3)	17 (58.6)	11 (50)		
Parent data					
Mother's education	f (%)	f (%)	f (%)		
Illiterate	3 (5)	0 (0)	1 (4.5)		
Elementary School	16 (26.7)	8 (27.5)	7 (31.8)		
High School	27 (45)	18 (62.1)	10(45.4)	.972	0.001
Higher School	13 (21.6)	03 (10.3)	2 (9)		
No information	1 (1.7)	0 (0)	2 (9.1)		
Father's education	f (%)	f (%)	f (%)		
Illiterate	2 (3.3)	0 (0)	0 (0)		
Elementary School	27 (45)	10 (34.5)	13 (59.1)		
High School	22 (36.7)	13 (44.8)	7 (31.8)	.152	0.03
Higher School	5 (8.3)	3 (10.3)	0 (0)		
No information	4 (6.7)	3 (10.3)	2 (9.1)		
Total Frequency of Reading and Writing Habits of Parents/Caregivers	14.84 (4.9)	10.56 (5.5)	13.10 (7.1)	.038 **	0.08

Note. f: frequency; *M:* mean; *SD:* standard deviation. *Variables analyzed and compared using ANOVA between groups. **Significant difference at $p \leq .05$. Frequency analyzed using the chi-square test. 0 = no effect.

As observed in Table 2, the groups did not exhibit significant differences in the pre-intervention assessment regarding sociodemographic variables. However, the mixed PENcE+REPENcE group differed significantly in the frequency of reading and writing habits of their parents/caregivers compared to the PENcE group, showing greater habits with a medium effect size. Table 3 presents the comparison among the three groups in the pre-intervention assessment concerning performance in executive, emotional, and academic tasks at baseline for each group.

Table 3
Comparison among Groups Pre-Intervention at Baseline Regarding Executive, Emotional, and Academic Performance

Variables	Group	*N*	*M*	*SD*	*P**	Effect Size**
Raven's Progressive Colored Matrices Test***						
Total Time	PENcE+REPENcE	57	349.89	82.47	.735	0.006
	PENcE	25	345.96	80.08		
	Control	21	333.93	69.91		
Total Correct Answers	PENcE+REPENcE	60	26.72	4.68	.217	0.02
	PENcE	29	24.97	4.38		
	Control	22	25.59	4.59		
Go No Go						
Total Correct Answers	PENcE+REPENcE	59	53.10	5.83	.198	0.03
	PENcE	29	52.55	4.18		
	Control	22	55.05	3.83		
Omissions	PENcE+REPENcE	59	3.86	4.10	.372	0.01
	PENcE	29	3.90	2.83		
	Control	22	2.64	3.40		
Errors	PENcE+REPENcE	59	2.97	3.07	.328	0.02
	PENcE	29	3.55	3.03		
	Control	22	2.32	2.21		
Hayling Test						
Time for Part A	PENcE+REPENcE	59	25.90	18.25	.217	0.03
	PENcE	24	19.47	8.57		
	Control	20	22.27	13.27		
Errors in Part A	PENcE+REPENcE	59	0.54	0.89	.980	<0.001
	PENcE	26	0.50	0.81		
	Control	21	0.52	0.98		
Time for Part B	PENcE+REPENcE	59	49.17	35.30	.386	0.01
	PENcE	24	43.08	29.91		
	Control	20	57.63	38.07		
Errors Part B /10	PENcE+REPENcE	59	4.37	1.89	.115	0.04
	PENcE	25	5.28	1.96		
	Control	20	4.85	1.53		
Errors Part B/30	PENcE+REPENcE	59	10.42	5.06	.094	0.02
	PENcE	26	12.92	5.88		
	Control	21	12.24	4.67		
Time for Part B – Time for Part A	PENcE+REPENcE	59	23.27	28.68	.266	0.02
	PENcE	24	23.60	28.17		
	Control	20	35.35	32.76		

Variables	Group	*N*	*M*	*SD*	*P**	Effect Size**
Time B/Time A	PENcE+REPENcE	59	2.26	1.51	.455	
	PENcE	24	2.32	1.41		0.01
	Control	20	2.74	1.44		
WISC-III Digits						
	PENcE+REPENcE	55	6.40	1.24		
Direct Order Digits (DO)	PENcE	29	6.27	1.30	.908	0.007
	Control	22	6.31	1.35		
	PENcE+REPENcE	55	4.10	1.36		
Inverse Order Digits (IO)	PENcE	29	3.44	1.27	.063	0.03
	Control	22	3.54	1.37		
Verbal Fluency Tasks						
	PENcE+REPENcE	59	25.61	15.36		
Free - Total Correct answers	PENcE	27	26.11	15.45	.526	0.01
	Control	21	21.67	12.88		
	PENcE+REPENcE	59	4.78	3.69		
Free - Total Clusters	PENcE	27	4.41	3.14	.493	0.01
	Control	21	3.76	2.82		
	PENcE+REPENcE	59	10.14	4.93		
Phonemic - Total Correct answers	PENcE	28	8.36	5.53	.154	0.03
	Control	22	10.64	3.37		
	PENcE+REPENcE	59	1.95	1.27		
Phonemic - Total Clusters	PENcE	28	2.04	2.39	.470	0.01
	Control	22	2.45	1.47		
	PENcE+REPENcE	59	11.39	4.67		
Semantic- Total Correct answers	PENcE	28	10.79	4.03	.408	0.01
	Control	22	10.00	2.84		
	PENcE+REPENcE	59	2.16	1.20		0.02
Semantic - Total Clusters	PENcE	28	1.86	1.23	.264	
	Control	22	1.73	0.88		
Wisconsin Card Sorting Test						
	PENcE+REPENcE	54	56.87	9.97		
Number of trials	PENcE	22	58.31	8.50	.205	0.03
	Control	17	61.29	4.63		
	PENcE+REPENcE	54	22.33	11.89		
Total errors	PENcE	22	24.77	11.30	.468	0.01
	Control	17	25.64	7.27		
	PENcE+REPENcE	54	12.35	8.61		
Preservatives responses	PENcE	22	15.09	10.97	.076	0.01
	Control	17	18.56	11.53		
	PENcE+REPENcE	54	10.71	6.39		
Perseverative Errors	PENcE	22	13.13	8.35	.129	0.03
	Control	17	14.60	8.06		
	PENcE+REPENcE	54	2.14	0.93		
Number of categories	PENcE	22	2.13	0.88	.992	0.02
	Control	17	2.11	0.69		
	PENcE+REPENcE	54	28.40	9.41		
Conceptual level	PENcE	22	27.77	8.63	.958	0.01
	Control	17	28.05	6.94		
	PENcE+REPENcE	54	20.00	16.57		
First category trial	PENcE	22	22.86	18.12	.656	0.00
	Control	17	18.29	10.06		
	PENcE+REPENcE	54	0.61	1.48		
Failure	PENcE	22	0.40	0.73	.780	0.007
	Control	17	0.47	0.51		

Variables	Group	*N*	*M*	*SD*	*P**	Effect Size**
Emotional Awareness Questionnaire (EAQ)						
Differentiate emotions	PENcE+REPENcE	57	-14.94	3.14		
	PENcE	29	-14.17	3.44	.587	0.01
	Control	21	-14.57	3.57		
Verbally communicate emotions	PENcE+REPENcE	57	1.96	1.48		
	PENcE	29	2.55	1.61	.254	0.02
	Control	21	2.04	1.71		
Not hide emotions	PENcE+REPENcE	57	-11.19	2.76		
	PENcE	29	-11.10	2.39	.933	0.001
	Control	21	-11.38	2.49		
Body awareness	PENcE+REPENcE	57	-6.26	2.29		
	PENcE	29	-5.86	3.06	.539	0.01
	Control	21	-6.66	2.35		
Attend to other's emoticons	PENcE+REPENcE	57	-4.56	2.12		
	PENcE	29	-4.13	2.19	.632	0.009
	Control	21	-4.14	2.49		
Analyze one's own emotions	PENcE+REPENcE	57	12.05	2.22		
	PENcE	29	11.86	2.23	.243	0.02
	Control	21	12.04	1.49		
Total correct in arithmetic (TDE-II)	PENcE+REPENcE	35	20.82	4.01		
	PENcE	17	18.94	4.64	.186	0.05
	Control	8	21.75	2.54		
Grade	PENcE+REPENcE	60	73.30	12.03		
	PENcE	29	76.82	10.29	.368	0.01
	Control	22	72.18	17.34		

Note. M: Mean; *SD*: Standard Deviation. TDE-II: Academic Performance Test. *Variables compared and analyzed with ANOVA. 0 = no effect. ***Instrument used for inclusion/exclusion criteria of the sample.

As presented in Table 3, the groups did not show significant differences in the pre-intervention assessment concerning measures of executive functioning, emotional awareness, and academic performance. Thus, they can be considered indistinguishable at baseline. Table 4 displays the results of the comparison between groups considering the Delta for each variable, controlling for the effect of the frequency of reading habits of the parents/caregivers of the students. It was found that children in the mixed PENcE+REPENcE group had significantly better scores in Time A of the Hayling Test, as well as in the variables "Body Awareness" and "Verbally Communicate Emotions" from the Emotional Awareness Questionnaire (EAQ), compared to the PENcE group. Additionally, the mixed group exhibited significantly better scores in total correct responses on the Go No Go task, while the PENcE group made fewer errors on this same instrument, both compared to the control group. The two groups, PENcE+REPENcE and PENcE, showed significant differences in total correct responses on the WCST relative to the control group. The control group demonstrated better performance in the total number of trials administered on the WCST. Lastly, the PENcE and control groups achieved better scores in verbal fluency tasks. Furthermore, interesting results were noted regarding the covariate of total reading and writing habits of parents/caregivers, with significant outcomes observed in the direct order of the digit subtest and in the total correct responses on the WCST. In this study, no significant results were found regarding Delta for academic performance (arithmetic from TDE-II and grades) among the three groups.

Table 4

Comparison between groups at baseline pre-intervention regarding executive, emotional, and academic performance

Variables/Instruments	Effect	PENcE+ REPENcE	PENcE	Control	df	*F*	*p*	Effect Size	Post hoc
		M(*SD*)	*M*(*SD*)	*M*(*SD*)				Eta Square	
Verbal fluency – Free association									
Hits	Group	6.18 (16.34)	6.62 (15.89)	11.90 (13.81)	2	3.33	.041*	0.08 (medium)	PENcE+REPENcE<Control (*p* = .037)
	FRWH	--	--	--	1	0.01	.917	<0.001	
Total clusters	Group	6.59 (5.70)	7.66 (6.42)	8.80 (5.27)	2	2.21	.117	0.05 (small)	1
	FRWH	--	--	--	1	0.03	.847	<0.001	
Phonemic Verbal Fluency									
Hits	Group	0.05 (4.71)	2.75 (5.58)	1.27 (3.31)	2	2.44	.094	0.06 (medium)	1
	FRWH	--	--	--	1	0.51	.475	<0.001	
Total de clusters	Group	0.15 (1.56)	0.14 (2.51)	0.09 (1.68)	2	0.22	.802	<0.001	1
	FRWH	--	--	--	1	0.01	.914	<0.001	
Semantic Verbal Fluency									
Hits	Group	0.38 (5.34)	1.03 (9.72)	2.09 (4.01)	2	0.81	.451	0.02 (small)	1
	FRWH	--	--	--	1	2.12	.149	0.02 (small)	
Total clusters	Group	0.22 (1.95)	0.96 (1.79)	0.72 (1.83)	2	3.81	.027*	0.09 (medium)	PENcE+REPENcE<PENcE (*p* = .024)
	FRWH	--	--	--	1	0.41	.523	<0.001	
Go/ No Go									
Hits	Group	3.91 (6.43)	2.31 (4.75)	0.68 (3.46)	2	3.19	.047*	0.07 (medium)	PENcE+REPENcE>Control (*p* = .046)
	FRWH	--	--	--	1	0.203	.654	<0.001	
Omissions	Group	-2.47 (4.50)	-1.20 (3.33)	-0.31 (1.80)	2	1.63	.203	0.04 (small)	1
	FRWH	--	--	--	1	1.92	.662	<0.001	
Errors	Group	-1.37 (3.15)	-1.24 (3.69)	-0.36 (2.93)	2	2.88	.063	0.07 (medium)	1
	FRWH	--	--	--	1	0.107	.744	<0.001	

Variables/Instruments	**Effect**	**PENcE+ REPENcE** *M*(*SD*)	**PENcE** *M*(*SD*)	**Control** *M*(*SD*)	**df**	***F***	***p***	**Effect Size** Eta Square	**Post hoc**
Hayling Test									
		M(*SD*)	*M*(*SD*)	*M*(*SD*)				Eta Square	
	FRWH	--	--	--	1	0.031	.861	<0.001	
Errors part A	Group	-0.33 (1.02)	-0.19 (0.80)	0 (1.09)	2	0.11	.897	<0.001	1
	FRWH	--	--	--	1	0.038	.845	<0.001	
Time B/ Time A	Group	0.61 (1.76)	-0.19 (1.99)	-0.09 (1.14)	2	1.88	.161	0.05 (small)	1
	FRWH	--	--	--	1	0.127	.722	0.02 (small)	
Time B	Group	-8.69 (34.37)	-8.01 (30.86)	-22.90 (37.42)	2	2	.143	0.05 (small)	1
	FRWH	--	--	--	1	1.21	.275	0.01 (small)	
Errors part B/10	Group	-1.00 (1.83)	-0.16 (2.33)	-0.55 (2.35)	2	1.35	.267	0.03 (small)	1
	FRWH	--	--	--	1	1.31	.255	0.01 (small)	
Errors part B/30	Group	-2.03 (5.71)	-0.12 (5.52)	-1.2 (5.53)	2	0.57	.568	0.01 (small)	1
	FRWH	--	--	--	1	1.09	.299	0.01 (small)	
Digits									
Hits forward order	Group	0.37 (1.30)	0.28 (1.83)	0.40 (0.99)	2	0.76	.474	0.02 (small)	1
	FRWH	--	--	--	1	8.93	.004*	0.11 (medium)	
Hits backward order	Group	0.35 (1.34)	0.52 (1.58)	-0.05 (1.39)	2	0.16	.853	<0.001	1
	FRWH	--	--	--	1	2.05	.156	0.02 (small)	
Wisconsin Card Sorting Test (WCST)									
Number of trials administered	Group	-4.42 (10.30)	-3.50 (9.20)	-10.58 (9.16)	2	2.57	.084	0.07 (medium)	1
	FRWH	--	--	--	1	2.75	.102	0.04 (small)	

Variables/Instruments	**Effect**	**PENcE+ REPENcE** *M*(*SD*)	**PENcE** *M*(*SD*)	**Control** *M*(*SD*)	**df**	***F***	***p***	**Effect Size** Eta Square	**Post hoc**
Correct responses	Group	-0.01 (7.55)	2.27 (8.16)	-2.00 (7.45)	2	4.21	.019*	0.12 (medium)	PENcE+REPENcE e PENcE>Control (*p* = .020; .046)
	FRWH	--	--	--	1	5.33	.024*	0.07 (medium)	
Incorrect responses	Group	-3.63 (11.35)	-4.80 (13.59)	-6.92 (10.50)	2	0.18	.836	<0.001	1
	FRWH	--	--	--	1	0.01	.898	<0.001	
Perseverative errors	Group	-2.13 (6.14)	-2.90 (6.71)	-4.64 (7.41)	2	0.06	.944	<0.001	1
	FRWH	--	--	--	1	0.168	.683	<0.001	
Non-perseverative errors	Group	-1.60 (9.02)	-2.14 (10.36)	-2.21 (7.70)	2	0.12	.885	<0.001	1
	FRWH	--	--	--	1	0.29	.589	<0.001	
Conceptual level responses	Group	1.78 (12.09)	2.13 (12.96)	0.23 (12.38)	2	1.27	.287	0.03 (small)	1
	FRWH	--	--	--	1	0.26	.612	<0.001	
Number of completed categories	Group	0.30 (1.21)	0.27 (1.24)	0.35 (0.93)	2	0.51	.601	0.01 (small)	1
	FRWH	--	--	--	1	0.32	.572	<0.001	
Trials to complete the first category	Group	-0.40 (24.55)	-5.00 (24.45)	-1.82 (17.35)	2	0.25	.783	<0.001	1
	FRWH	--	--	--	1	0.04	.834	<0.001	
Failure to maintain context	Group	-0.18 (2.06)	-0.04 (0.99)	-0.17 (063)	2	0.42	.662	0.01 (small)	1
	FRWH	--	--	--	1	2.98	.089	0.04 (small)	
Emotional Awareness Questionnaire (EAQ)									
Attend to other's emoticons	Group	-0.80 (2.10)	-1.06 (2.40)	-2.09 (2.07)	2	1.63	.202	0.04 (small)	1
	FRWH	--	--	--	1	2.61	.11	0.03 (small)	
Not hide emotions	Group	0.84 (3.44)	1.37 (2.69)	0.90 (2.31)	2	0.63	.534	0.01 (small)	1
	FRWH	--	--	--	1	1.31	.255	0.01 (small)	

Variables/Instruments	**Effect**	**PENcE+ REPENcE** *M*(*SD*)	**PENcE** *M*(*SD*)	**Control** *M*(*SD*)	**df**	***F***	***p***	**Effect Size** Eta Square	**Post hoc**
Verbally communicate emotions	Group	0.22 (2.37)	-0.86 (2.37)	-0.28 (2.28)	2	4.64	.013*	0.11 (medium)	PENcE+REPENcE>PENcE (p = .015)
	FRWH	--	--	--	1	4.59	.035*	0.05 (small)	
Differentiate emotions	Group	4.46 (3.72)	3.17 (3.77)	4.15 (3.66)	2	0.66	.518	0.01 (small)	1
	FRWH	--	--	--	1	0.21	.647	<0.001	
Body awareness	Group	-1.00 (2.41)	0.62 (3.46)	- 0.85 (3.44)	2	5.13	.008*	0.12 (medium)	PENcE+REPENcE>PENcE (p = .006)
	FRWH	--	--	--	1	0.404	.527	<0.001	
Analyze one's own emotions	Group	0.22 (2.22)	0.13 (2.35)	0.23 (2.40)	2	0.41	.663	0.01 (small)	1
	FRWH	--	--	--	1	1.33	.251	0.01 (small)	
Total correct in arithmetic (TDE-II)	Group	2.48 (2.77)	3.58 (2.87)	0.37 (2.06)	2	0.58	.564	0.02 (small)	1
	FRWH	--	--	--	1	0	.95	<0.001	
Grades	Group	5.51 (6.57)	3.85 (6.31)	7.38 (9.28)	2	0.03	.969	<0.001	1
	FRWH	--	--	--	1	0.11	.734	<0.001	

*Note.*1= no differences between groups. < .001= no significant effect size. *Difference considered significant at p <

Discussion

This study aimed to investigate the differences between two cognitive stimulation modalities: one focused solely on executive functions (EF) and the other combining EF with emotional regulation (ER). Both were compared to a control group exposed only to the standard school curriculum. Students participating in the mixed EF and ER intervention demonstrated superior outcomes compared to those in the exclusive EF intervention in areas such as initiation, processing speed, body awareness, and emotional communication. Additionally, they exhibited greater cognitive flexibility and inhibitory control compared to the control group.

These findings suggest that an ER intervention can enhance EF stimulation and may be more effective than a traditional curriculum alone. Specifically, the mixed intervention group showed significantly better results in inhibitory control, achieving a higher total of correct responses with fewer impulsive errors. This indicates a reduction in impulsive responses among students engaged in both programs consecutively. These results align with previous findings by Dias and Seabra (2016), who reported improved inhibitory control in preschoolers who underwent a similar school-based intervention.

Both intervention groups exhibited significant improvements in cognitive flexibility compared to the control group. This supports findings from Dias and Seabra (2016) and Lizarraga et al. (2003), who also noted significant enhancements in this skill following interventions. Notably, the PENcE+REPENcE group showed more substantial improvements than the PENcE group in verbal initiation and processing speed. Zauza (2018) found positive and significantly better results for processing speed in a similar intervention context. This suggests that interventions targeting both emotional self-regulation and EF can significantly enhance processing speed and verbal initiation in school-aged children compared to a control group.

Conversely, the control and PENcE groups demonstrated significantly greater improvements than the mixed group in verbal fluency tasks. One possible explanation for this unexpected difference is the lack of internal transfer to the domain of verbal fluency. This may indicate that students in the mixed group were less rushed, thereby recalling fewer words and forming fewer clusters within the task duration, which could reduce impulsive responses. These results are consistent with the observed improvements in inhibitory control in the Go No Go task.

Furthermore, regarding emotional awareness, the mixed group showed better outcomes in body awareness and verbal communication of emotions compared to the PENcE-only group. This finding aligns with expectations, as the REPENcE program is specifically designed to enhance emotional regulation skills, including the recognition and expression of emotions. Domitrovich et al. (2007) found that children participating in the "PATHS" curriculum intervention exhibited improved emotion recognition and identification skills, although no significant differences were noted compared to the control group. Thus, these findings warrant further exploration in future research to better understand the nuances and combined effects of these interventions.

An important finding from this study is the potential impact of the higher frequency of reading and writing habits among the parents/caregivers of children in the mixed PENcE+REPENcE group. This sociocultural variable, which supports cognitive stimulation (Pawlowski et al., 2012), could influence outcomes related to short-term episodic memory and sustained attention, as well as cognitive flexibility. Research indicates that reading skills are closely tied to the child's environment, including parental habits, the frequency with which parents read to their children, the availability of reading materials, and parental education levels (Kiuru et al., 2013; van Bergen et al., 2015). Therefore, parental modeling and direct stimulation through more frequent reading and writing may cognitively benefit children in the mixed group.

Conclusions

The results of this study suggest that an emotional regulation (ER) intervention can enhance the outcomes of a specific executive function (EF) intervention. Overall, the majority of findings align with existing literature indicating that both EF and ER can be improved through targeted interventions (Cardoso et al., 2019; Diamond & Ling, 2016; Dias & Seabra, 2016). Notably, Diamond and Ling (2020) and Pandey et al. (2018) highlight the advantages of curricular interventions aimed at promoting self-regulation (both cognitive and emotional).

For instance, their implementation in classrooms can reach a large number of children simultaneously, promoting accessibility without the need for individual selection. Furthermore, these interventions are highly cost-effective, as they can be integrated into the school curriculum economically, eliminating the necessity for additional resources such as specialized professionals or specific materials.

Based on the findings of this study, several strategies are suggested to optimize potential transfer effects and enhance various cognitive and emotional outcomes: 1) incorporate specific stimulation of motivation and emotional self-monitoring during task execution; 2) include homework tasks that also involve parental participation; 3) encompass activities that stimulate reading and writing habits among both children and their parents; and 4) improve the quantity and quality of training for facilitators and multipliers. Regarding the limitations of this study and future directions, there is a need for longitudinal studies with follow-up assessments to evaluate the long-term effects of the programs and to determine whether the results observed here are maintained over time and developmental progress. Methodologically, a limitation was the lack of evaluation between the two intervention programs (between PENcE and REPENcE), which prevented the isolation of REPENcE's effects. Additionally, the absence of ecologically valid measures to examine the processing of ER represents another limitation. Furthermore, the control group was passive, meaning that children continued with their regular school activities without any additional intervention. This could have influenced the results, as the lack of intervention in the control group may not have allowed for a fully balanced comparison between groups. Moreover, the group receiving the combined PENcE+REPENcE intervention participated in a more extensive program than the group receiving only PENcE. The increased duration and intensity may have provided more opportunities for practice and skill development. These limitations suggest that future studies would benefit from including an active control group receiving an alternative intervention or a modified version of the program to better assess the specific effects of the interventions. Additionally, ensuring that intervention groups have similar durations could help clarify the impacts of different approaches on children's emotional skills development. It is emphasized that this study may serve as a foundation and inspiration for the development of public policies, institutional actions in schools, and training programs for educators and learning clinicians. These new tools can be integrated into pedagogical and clinical practices in both public and private schools, aiming to enhance the cognitive and emotional functions of school-aged children. Thus, schools can provide training for teachers and educational counselors using evidence-based programs, while clinicians can support at-risk children to prevent or mitigate early developmental setbacks.

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A.P.C.C. has contributed in 1, 2, 3, 5, 6, 13, 14; C.O.P. in 2, 3, 5, 6, 7, 14; N. Z. in 1, 2, 3, 6, 14; R. P. F. in 3, 4, 6, 10, 14.

Editora científica responsable: Dra. Cecilia Cracco.