Trends in Neuroscience and Education 4 (2015) 15–25

Contents lists available at ScienceDirect

Trends in Neuroscience and Education

journal homepage: www.elsevier.com/locate/tine

Research Article

Cognitive neuroscience, developmental psychology, and education: Interdisciplinary development of an intervention for low socioeconomic status kindergarten children

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ARTICLE INFO

Article history:
Received 5 September 2014
Received in revised form
27 February 2015
Accepted 9 March 2015

Keywords:
Intervention
Executive functions
Academic achievement
Cognitive neuroscience
Developmental psychology
Education

ABSTRACT

The current study presents a 32-week intervention for kindergarten children from low socio-economic backgrounds. The main contribution of this study resides in the interdisciplinary development of the intervention, made in close collaboration between educational researchers, and researchers in cognitive neuroscience and developmental psychology. The intervention was implemented by teachers through class activities, to promote executive functions and academic achievement. These activities were articulated into the current kindergarten curriculum and, at the same time, built upon concepts and methodologies of developmental psychology and cognitive neuroscience for executive functions training. Results showed: (1) non-significant differences between groups in cognitive performance from pre- to post-training assessment, and (2) significant differences in academic achievement for *Language*, *Mathematics*, *Autonomy*, and *Contact with peers* in first grade. Our study sets a precedent for future interdisciplinary work bridging the gap between developmental psychology and education, which we believe will prove key to improving academic success.

1. Introduction

1.1. Developmental psychology, cognitive neuroscience, and education

In the past two decades the interest of neuroscientists in building bridges between neuroscience and education has increased significantly [1–5]. Inspired by the idea that knowledge about neural development of cognitive and emotional processes could be incorporated and applied to learning and teaching, neuroscientists began working towards a model for integration. However, there are still relatively few proposals for building such bridges [3]. An increasing body of the literature, which analyses the theoretical factors linking these disciplines, stands in contrast to the considerably low number of existing applications of neuroscientific knowledge in the classroom [6]. This paucity of data derives, in part, from practical difficulties for conducting experimental research in schools [7,8]. For example, when classes, and not children, are the units of analysis it is important to increase as much as possible the number of classes used, but this will add additional sources of variation that might confound the results. On the other hand, comparisons of few classes from the same school make it necessary to consider the potential differences between teachers [9]. Specifically, when comparing academic achievement in a few classes it is necessary to control for the "teacher effect", that is, the possible tendency of one teacher to assign higher grades than other teachers at the same school [10–12]. Those difficulties should be addressed in order to develop scientific approaches for educational problems. In this complex, but promising, context, this paper presents an intervention aimed at unifying the theory and practice of three disciplines (i.e., developmental psychology, cognitive neuroscience, and education) to advance in the direction of an evidence-based research practice.

1.2. Executive functions

Executive functions (EF) can be defined as the abilities to inhibit and manipulate thoughts and actions, leading to goal-directed behaviours [13,14]. The involved skills in this control-processing are critical for success in school and life, since they allow us to inhibit impulses, anticipate situations, start novel actions, set goals and plans, and to design strategies and modify them if they do not work. Core EF include: attention (alerting, orienting, and executive attention) inhibitory control (resisting habits, temptations, or distractions), working memory (mentally holding in mind and manipulating information), and planning (creating and maintaining an appropriate sequence of steps for solving a task) [15–19].

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http://dx.doi.org/10.1016/j.tine.2015.03.003

EF are considered critical in achieving success at school as they have been associated with reading ability [20], mathematics and standardized measures of academic achievement [21], mathematics and processing speed [22], mathematics and reading/writing skills [23], teacher report of learning behaviours and social competence in the classroom [24], and reasoning skills [25]. Several studies document the concurrent relationships between school-based functioning and EF, and the predictive relationships between both [26–32]. The flip side of this argument is also true: deficits in EF have been associated with difficulties in school readiness, for example, in mathematics, writing, and reading [32–34].

In addition, EF are considered critical factors in emotion regulation and play a significant role in all complex behaviours in a social context (e.g., school). For example, Neuenschwander and colleagues [23] found effortful control and EF to be independently important in improving early learning success and good classroom adjustment in children making the transition to school life. Successful adaptation to school does not seem depend only on achievement in mathematics, reading, and writing, but also on classroom behaviours such as engagement, motivation and persistence in learning situations, learning-related behaviours, classroom participation, and relationships with teachers and peers [23,35].

With the aid of neuroimaging technology [36–38] and the structural and functional analysis of lesions [39,40] different studies have associated the development and function of EF with the prefrontal cortex. In the same way that neural circuits involving the prefrontal areas develop slowly and become mature in early adulthood [41–43], EF develop slowly throughout childhood and adolescence. Behaviourally, although EF follow different developmental pathways, there is a common aspect across them: the rapid advances in performance between three and five years of age with respect to planning, inhibitory control, and working memory processing tasks, as has been shown in several longitudinal studies [11,44,45]. According to these studies, the period from three to five years of age seems to be an optimal time to implement EF training interventions.

1.3. Poverty impact on cognitive development

Beyond all debates about the definition of poverty and the different ways of measuring it [46,47], children with a low socio-economic status (SES) tend to have poorer EF and poorer school achievement, compared with middle or high SES children [48,49]. Psychometric and educational studies [50,51], and also studies that are part of a cognitive neuroscience paradigm [49,52–55], have largely verified the impact of poverty in EF. In general, low SES has been negatively associated with attention processes, inhibitory control, working memory, flexibility, planning, phonological awareness, self-regulation, and theory of mind in infants, kindergarten, primary, and secondary school children [56–62]. Brain activation patterns associated with tasks demanding EF are also influenced by prevailing SES factors [56,59,63,64]. Given such disparities, children living under vulnerable conditions constitute a priority target for interventions aimed at optimising EF.

1.4. Interventions aimed at optimising cognitive functioning

In recent years, several interventions targeting cognitive development have been implemented and evaluated [65]. Overall, the main goal of such early interventions has been the furtherance of cognitive development in early childhood, expecting this will then influence broader, longer-term outcomes such as academic and social adjustment. In general, these studies reached their goals [66,67]; however, there have been difficulties in replicating successful outcomes in the long term or on larger scales [68]. Since most of these interventions are based on theories of developmental psychology, the inclusion of aspects from the perspectives of cognitive neuroscience could magnify gains in cognitive and academic outcomes [69].

During recent years, several studies have shown that EF can be improved following a systematically-increasing EF-demand schedule [70–79]. However, few of those trainings have been conducted by teachers in classes. Although EF can be trained, teachers receive little instruction in how to improve them [71]. Furthermore, teachers do not usually learn about these kinds of processes, neither their development, nor how they are a fundamental part of everyday activities in school [80].

There are two areas that provide appropriate opportunities for applying developmental cognitive and neuroscientific proposals: teacher training and school curriculum. On one hand, teachers study child development during their training, although not from a neuroscientific point of view [81]. During their training teachers usually do not receive information about brain development and functioning. Stimulation of EF from a developmental cognitive neuroscience perspective is not covered during the training. Teachers' training in general-neuroscience knowledge would help them to understand the developing minds and brains of students, their behaviours, the constraints on learning, and the adequate times for learning, among other things [82]. Besides that, teachers' training in general neuroscience would provide teachers with an additional level of analysis that could help them evaluate problems in education, and would contribute to an informed, research-oriented, multifaceted perspective based on empirical evidence. This kind of training will ultimately encourage teachers to appreciate their roles as key players in building bridges between disciplines. On the other hand, the content of the school curriculum is relatively flexible, in the sense that teachers can design their own specific class activities [83]. The curriculum provides teachers with a content outline and general guidelines within which they must build activities aimed at teaching key topics. However, since each teacher designs their own specific activity, they can construct them in such a way as to train EF or not. Instead of that, a sequence of activities specially designed for EF stimulation ensures that the training of EF is not left to chance.

These opportunities open a double gateway for developmental psychology and cognitive neuroscience. First, they provide a chance to train teachers in issues of developmental psychology and cognitive neuroscience that are directly bound up with their profession (by understanding these processes teachers could enrich their class methods). Second, these opportunities allow for the creation of curriculum-based activities that train EF.

1.5. Objective

The objective of the study was to design, implement and evaluate an intervention to promote EF and academic achievement in kindergarten children. Our hypotheses were that (1) kindergarten children in the intervention group will have higher cognitive performances, compared to children in the control group, and (2) these benefits will transfer to academic grades along first grade. The intervention was designed by an interdisciplinary team made up of educational researchers, and researchers in cognitive neuroscience and developmental psychology. Only part of the team (researchers in cognitive neuroscience and developmental psychology) conducted the study in the school. The teachers implemented the intervention, through class activities. The activities were in agreement with the current curriculum of the City of Buenos Aires, but articulated with concepts and methodologies of developmental psychology and cognitive neuroscience for the training of EF.

2. Materials and methods

2.1. Study design

The study consisted of a longitudinal quasi-experimental design in which kindergarten classes were randomly assigned to control and intervention groups. Following a pre-training cognitive assessment (see Section 2.3.3), 32 intervention activities were implemented in the intervention group (see Section 2.4), while the control group continued with the traditional class activities. We implemented intervention activities twice a week during 16 weeks. Simultaneously, external observers (blind to the hypotheses under study) registered 14 activities in each group (control and intervention) following a qualitative observation protocol. At the end of the school year, there was a post-training cognitive assessment (one week after the intervention had finished), which included the same tasks as those administered in the pre-cognitive assessment. During the following year we collected academic grades for both groups (in four different grading periods during first grade of primary school), alongside two additional external control groups (children who attended other kindergartens—they were not intervention nor control groups—but the same first grade classrooms).

2.2. Participants

We recruited 49 children (30 girls, mean age in years: $M=5.26$, $SD=0.29$) from one public kindergarten of the City of Buenos Aires in 2009. They were predominantly from low SES backgrounds [60]. Children had a full time school schedule (8:45 a.m./04:00 p.m.), including naptime and three meals (breakfast, lunch, and an afternoon snack). Attrition rate from pre- to post-cognitive assessment evaluation was 0%.

The school also had primary-school education, which allowed us to collect data on the children's academic achievements during the year that followed the intervention. We lost contact with 22 participants during the follow-up stage of the study (attrition rate 44.89%) because these children moved to other primary schools. Children in the control and intervention groups continued in the same classes during their first year of primary school (that is, children in the control group were not mixed with children from the intervention group during first grade). Therefore, to diminish the potential effects of the influence of the primary school teachers on academic-grade assignments ("teacher effect") we included two external control groups, one per classroom (Table 1). In total, four groups were available for the academic achievement comparisons: intervention group, control group, external control group A (children from a different kindergarten -without intervention- in the same classroom as those children from the intervention group), external control group B (children from another kindergarten—without intervention— in the same classroom as children from the control group). Because all children attended the same school, we controlled for principals, curriculum and modalities of the school, school schedule (all children had the same routine in school, that is activities, lunch and nap at the same hours), and the school's geographic location.

We obtained informed consent from parents/caregivers and an ethical approval from the institutional IRB (CEMIC, Protocol #320). The procedures of the study followed international and national children's rights and research norms

Table 1
Number of participants by study stage, group and gender.

		Study groups	*n*	Girls	Boys
Intervention		Intervention	26	16	9
		Control	23	14	10
	Total		49	30	19
Follow up	First grade A	Intervention	16	10	6
		External control A	7	3	4
	First grade B	Control	11	4	7
		External control B	15	9	6
	Total		49	26	23

2.3. Procedures

2.3.1. Socio-demographic information

We provided a SES scale (NES) [70,84] to each mother to obtain individual and environmental information (i.e., health history, SES, child education), in order to address potential differences between control and intervention groups at the beginning of the study. To determine SES of each family, four dimensions were considered: (1) parents' education, (2) parents' occupation, (3) housing/dwelling conditions, and (4) overcrowding.

2.3.2. Child temperament and mother mental health

We administered the Spanish short-form of the Child Behaviour Questionnaire (CBQ) [75] to each mother, in order to obtain information about three temperamental dimensions (i.e., surgency, negative affect, effortful control). Additionally, we used the Anxiety and Depression Hamilton scale [85] to assess these two aspects of the mother's mental health involved in self-regulation from the early stages of child development [86]. This information was used to evaluate potential differences between control and intervention groups at the beginning of the study.

2.3.3. Cognitive assessment procedures

Children were tested individually at school, in a testing room, during three 40-min sessions (two tasks in the first and second sessions, and three tasks in the third session). Testing was scheduled at times, reported by teachers, not to interfere with regular meals and activities. Examiners were blind to the hypotheses of the study. We evaluated the cognitive performance with a non-verbal battery of tests, including three computerised (ANT, Stroop, and Self-ordered search) and four manual tasks [Tower of London (TOL), Corsi blocks, K-BIT (Kauffman Battery) matrix subscale, and K-ABC (Kauffman Battery) digits subscale] (Table 2). Computerised tasks were displayed on laptops using E-Prime to present the stimuli and record responses. Children were positioned at approximately 50 cm from the computer screen (25 cm × 35 cm). For ANT and Stroop tasks children used their index fingers to press the right and left arrow keys, located at the bottom-centre of the keyboard. In the Self-ordered search task, children used a computer mouse (5 cm × 4 cm), for which they were previously trained in its use. All the tasks had practice trials and, in TOL, Corsi blocks, and the Kaufman subscales, the practice trials were considered as pre-test trials. If children answered incorrectly to more than half of the practice trials, the data were not considered.

2.3.4. Academic assessment procedures

We collected children's grades for each subject during each bimester of the first grade of primary school. Primary school teachers were blind to the objectives of the study. We selected only some academic subjects for the analysis, from the complete list offered at school, based on two criteria: first, considering the EF literature, we selected subjects related to executive and self regulation demands; second, given the large number of subjects and the need to reduce variability, we selected those in which the classroom teacher assigned the grades; subjects under the charge of specialised teachers, such as "Physical Education", were excluded from the analyses. Specifically, the subject areas included in our analyses were *Language*, *Mathematics*, *Collaboration on tasks*, *Autonomy in task resolution*, *Acceptance of rules*, and *Contact with peers*. The grades obtained in these subjects are the way in which teachers usually evaluate children's academic achievement.

Each student received one grade per bimester for each subject, so that a total of 24 variables were analysed. The grades assigned to each child include the following options: *O* (outstanding), VG (very good), *G* (good), *R* (regular), and *B* (bad). For statistical analytical

Table 2
Administered tasks by target EF and dependent variables.

Test	EF targeted	Dependent variables
ANT [75]	Alert, orientation and control attentional networks	Alert, orientation and control reaction times. Total correct trials
Stroop-like Heart/flower [69]	Inhibitory control	Reaction times and consecutive correct responses for each block (Congruent, Incongruent, and Mixed)
Tower of London [87]	Planning	Number of correct trials per difficulty level and maximum level reached with 100% of efficacy
Corsi blocks [88]	Spatial working memory	Number of correct trials per difficulty level and maximum level reached with 100% of efficacy
Self Ordered Search [89]	Object working memory	Amount of correct selections in each block
Kaufman assessment battery for children test digits span [90]	Verbal working memory	Total correct trials
Kaufman intelligence battery matrix test [91]	General cognitive performance	Total correct trials

purposes, a number was assigned to each one of these values (i.e., $O=5$, VG=4, $G=3$, $R=2$, $B=1$).

2.4. Intervention

The activities were designed by an interdisciplinary team of researchers in developmental psychology, cognitive neuroscience, and education, who conducted weekly meetings for one year. Specifically, the six educational researchers that were part of the interdisciplinary team were also professors at different education programs and courses for kindergarten teachers. Four researchers in cognitive neuroscience and developmental psychology, experienced in interventions in poverty contexts [76], completed the team. During the meetings the team designed sequences of activities aimed at training EF.

We designed a module of activities for small and large groups of 5-year-old children. The module contained: (1) a summary of the project, (2) general information about cognitive development, (3) information about the associations between EF, mathematics, and language teaching, and (4) 16 mathematic and 16 language activities.[1] These activities were organised according to their difficulty from lower to higher EF demand. Examples of basic EF activities include visual searches for objects (attention), remembering and reproducing object locations (working memory), when seeing a card with a body position putting the body in the opposite position (inhibitory control), and drawing a plan for a block construction before constructing it (planning). More demanding EF activities were, for example, dramatic play (attention, working memory, inhibitory control, and planning training), and verbal fluency games -saying words that start with a particular syllable (attention, working memory). Each activity required the following six conditions:

(a) It had to be based on the current official curriculum of the City of Buenos Aires [80].
(b) It had to be structured as a game, as this is the usual pedagogical strategy used in Argentinean kindergartens to teach and foster learning skills [92].
(c) It had to increase the EF demand progressively. As children solved one activity, teachers presented the next one in the planned sequence (i.e., more EF-demanding than the previous one). Also, when appropriate, within the same activity it was possible to increase or decrease the level of difficulty depending on the performance of each group of children.
(d) #It had to be structured in three stages: (1) planning: the teacher explained the objective of the task, indicated the group organisation, presented the material, and tried to verify whether the task objective had been understood, (2) execution: children had to plan how they would solve the task, if possible by verbalising their ideas, discussing ways of solving the problems, and then executing their plan, and (3) integration: children evaluated the execution of the plan explaining the strategies and actions they followed.
(e) It had to include novelty: each of the activities had to be different to the previous one, since EF are greatly required in novel situations [14].
(f) It let teachers to easily identify the EF demand. While all school activities require EF to some extent, the intervention activities were designed in such a way as to allow teachers to easily understand which parts of the activity trained the EF.

Finally, it is important to state that during the implementation of the intervention, some activities required an adaptation to each particular class, in which teachers in charge of intervention classes participated actively, as it is explained in the following section.

2.5. Teachers' training and follow up

Teachers in control and intervention groups received two training sessions in general aspects of cognitive development (each one two hours long). Besides that, the teachers in the intervention group received an additional two-hour session of training on basic EF knowledge, intervention activities, and suggestions about possible strategies to demand EF during the activities. In addition, before and after the implementation of each intervention activity teachers and researchers in cognitive neuroscience and developmental psychology had ten-minute meetings to approach the following issues:

a) *Improve intervention fidelity:* before the activity, teachers and researchers reviewed and clarified doubts about it.
b) *Adjustments*: research in schools sometimes requires adaptation of the activities, depending, for example on the school schedule or the number of children attending school that day. These adjustments were aimed at facilitating teacher's work and at maintaining adequate levels of EF demand. Teachers in charge of the classes worked together with the researchers to adjust activities following the necessities of teachers and the methodological requirements of the study. For example, for activities in groups, teachers and researchers agreed on an adequate number of children in each group: teachers suggested it based on their experience in their class and researchers made sure the number of children did not affect the EF demand.

[1] All the material was registered for public use at the Dirección Nacional de Derechos de Autor (National Direction of Author Rights) as "Activities booklet: Building a multidisciplinary teaching approach" ("Cuadernillo de actividades: construcción de una propuesta interdisciplinaria de enseñanza"), registration #740208).

Table 3
Selection of dependent variables for cognitive assessment analyses.

	Excluded variables	Pearson's *r*	*p*	Selected variables
ANT				
	Incorrect answers	1	0.000	Total score
	Proportion of correct answers	1	0.000	
Stroop-like heart/flower				
	Total correct answers (congruent)	0.861	0.000	CCT (congruent)
	Proportion of correct answers(congruent)	1	0.000	
	Total correct answers (incongruent)	0.895	0.000	CCT (incongruent)
	Proportion of correct answers (incongruent)	1	0.000	
	Total correct answers (mixed)	0.834	0.000	CCT (mixed)
	Proportion of correct answers (mixed)	1	0.000	
Tower of London				
	Total correct answers	0.965	0.000	Correct trials per difficulty level
	Number of new levels reached	0.313	0.000	
Corsi blocks				
	Total correct answers	0.975	0.000	Correct trials per difficulty level
	Number of new levels reached	0.879	0.000	
K-ABC digits span				
	Proportion of correct answers	0.843	0.000	Total score
K-BIT matrix test				Total score
	Proportion of correct answers	0.803	0.000	Total score

Note. CCT=consecutive correct trials.

c) *Discussion*: after the implementation of the activity, teachers and researchers discussed the educational- and EF-demand aspects of the activity. The main objective of this discussion was to analyse the execution of the activity in detail (especially to recognise EF demand on the activity) and to have the possibility of making suggestions for the next activities based on the previous ones. We designed a questionnaire for guiding those discussions and registered teachers' answers qualitatively (analyses of those discussion questionnaires are not included in this manuscript). The questionnaire included the following guiding questions: a) did the children understand the instruction?; b) did the children self monitor their work while they were doing it?; c) what were the difficulties during the activity?; d) was the level of difficulty of the activity adequate for the group?; e) did the teacher consider the activity demanded EF?; f) did the teacher have suggestions for improving the activity in future interventions?; g) did the teacher implement changes from the "activities booklet" (describe modifications and reasons).

2.6. Intervention fidelity

Examiners blind to the study hypotheses, who completed a classroom dynamic scale designed by the interdisciplinary team (researchers in cognitive neuroscience, developmental psychology, and education) observed 14 intervention and 14 control-group activities. We used this assessment for two reasons: first, in the intervention group, to confirm intervention fidelity (i.e., if the activities were being applied in compliance with the intervention plan) and second, in the control group to control for the potential effect of the presence of an external observer in the intervention classrooms.

We trained the examiners (psychologists or advanced students in psychology) during two eight-hour sessions. The training focused on how to complete the classroom dynamic scale; examiners were not informed about the objectives of the study. We randomly assigned each examiner to each class. Unfortunately, it was not possible to analyse inter-examiners validity, because a requisite for working in the school was that each examiner should observe the same class from activity 1 to activity 14 in order to allow children to become habituated to their presence. Observations (each one 40 min long) were made twice a week, every two weeks, throughout the intervention period (with the exception of the last two observations that could not be executed because of changes in the school schedule). To ensure that the examiners did not receive any information about the groups, intervention examiners went to the school on even weeks, while control examiners went during odd weeks to avoid juxtaposition.

2.7. Data analysis

We identified only one child with a developmental disorder and excluded this case from the analyses.

We obtained 34 dependent variables from cognitive assessment. We applied a *Pearson Correlation* analysis to identify variables with significant and high associations (Pearson coefficient over 0.7 and $p < 0.05$). For these cases of high association, we selected only one of the two correlated variables for the following steps (the selection was made based on the published literature on social vulnerability and cognitive development [50,51,93–96]). Results of *Pearson Correlation* analysis, and selected variables are presented in Table 3. The 20 variables that we finally used are those described in the Section 2.3 for each of the assessment instruments.

We evaluated assumptions for variance analyses, including normality, homoscedasticity, and independence. For this purpose, we used descriptive and univariate analyses, histograms and plot graphics, as well as Levene, Kolmogorov Smirnov and Durbin Watson tests for each variable. All dependent variables showed violations of the above-mentioned criteria and therefore these variables were transformed (using square root or arcsine transformations; in case of negative values, variables were transformed into Z scores).

We conducted univariate ANCOVA models to check basal cognitive homogeneity between the intervention and control-group performances, and homogeneity regarding socio-demographic variables (age, gender, SES, children's health history, children's temperament and mother's mental health).

Later, we used analyses of variance for Repeated Measures to evaluate the impact of the intervention on cognitive performance and determine whether potential differences were modulated by any of the aforementioned covariates.

To avoid teachers' biases on the academic grades, we included one external group per classroom. Given the number of subjects in each group and the variability in frequencies of grades, we used Mann Whitney analyses to assess the impact of the intervention on academic performance through two comparisons: (1) academic performance between the two external control groups to assess differences between classrooms, and (2) between intervention and control groups to assess intervention impact.

3. Results

In order to identify basal differences between groups (intervention/control), we ran univariate ANCOVA models with the pre-selected variables as independent variables (separate analyses for each variable); *group* (intervention/control) as the fixed factor; and *age* and *gender* as covariables. Socio-demographic variables were selected according to the criteria previously mentioned. The results showed non-significant differences between intervention and control groups for all the socio-demographic pre-selected variables (Table 4). We found a predominantly low SES for children in the school [60].

Non-significant differences were found between groups with regard to age at the beginning of the programme, health history (addressed by the number of exposed risk factors), years of kindergarten attendance, child temperament, and mother's mental health.

3.1. Intervention impact on cognitive assessment

Results of basal cognitive comparisons between groups (ANCOVA, including *age*, *gender*, and *SES* as covariates) indicated non-significant differences in basal assessment in all the analysed variables, with the exception of the variable *selections block 4* (*Self Ordered Search*) for which, on average, the intervention group showed more correct selections than the control group ($F_{1,43}=4.324$; $p=0.044$).

Following this, we conducted Repeated Measures analyses with the pre-selected variables as dependent variables, *group* (intervention/control) as the fixed factor, and *age* and *gender* as covariables. Of the 20 variables analysed, 19 did not show significant differences between groups, with the exception of the variable *Total Score* in ANT, in which the intervention group increased its basal score significantly more than the control group ($F_{1,44}=4.655$; $p=0.036$) (Table 5). Given that there were basal cognitive differences between groups in *selections block 4* (*Self Ordered Search*), we did not interpret them as intervention impact.

3.2. Intervention impact on academic achievement

We analysed 24 variables of academic achievement (6 academic areas evaluated four times during the year). Each bimester was analysed separately. The difference in sample size across bimesters is due to the fact that 22 children stopped attending school during the period of our study. We compared four groups: intervention group ($n=16$), control group ($n=15$), external control group A ($n=7$), and external control group B ($n=15$).

First, we conducted Mann Whitney equality-of-median analyses to compare academic performance between the intervention and control groups, to evaluate the hypothesis that the control group would reach lower levels of academic achievement, on average, than the intervention group. The results of the test were in the expected direction and showed significant differences for the following variables: Language 4th bimester ($z=-2.634$; $p=0.011$), Mathematics 2nd bimester ($z=-2.750$; $p=0.011$) and 4th bimester ($z=-2.269$; $p=0.030$), Autonomy 1st bimester ($z=-2.852$; $p=0.009$), and Contact with peers 2nd bimester ($z=-2.406$; $p=0.039$). For the other variables, the intervention group had similar average grades to the control group. The medians for each group are reported in Table 6. Effect sizes were high (between 44 and 56) for variables that showed significant differences between groups.

Second, we compared the two external control groups' performances to evaluate the hypothesis that some teachers have a tendency to assign higher grades, compared to other teachers ("teacher effect"). We found non-significant differences between the grades of both external control groups in all variables considered.

Third, to avoid any potential teacher effect, we conducted Mann Whitney analyses to compare academic achievement between the

Table 4
Sociodemographic comparisons by study groups.

Sociodemographic area	Variable	Control		Intervention		ANOVA by study group	
		n[a]	Media (SD)	n	Media (SD)	F*	p*
Age	Child age (at baseline)	24	5.27 (0.28)	25	5.25 (0.31)	0.06	0.808
Health history*1	Number of risk factors[b]	24	0.46 (0.66)	25	0.44 (0.65)	0.004	0.948
Socioeconomic status	Parent's education score[c]	20	7.80 (2.93)[d]	24	7.50 (2.55)[d]	0.051	0.823
	Parent's occupation score[c]	20	4.65 (2.39)[e]	24	4.67 (2.70)[e]	0.03	0.864
	Dwelling score[f]	20	11.10 (1.71)	24	10.88 (1.94)	0.24	0.627
	Overcrowding score[g]	20	7.50 (2.28)	24	7,13 (2.63)	0.59	0.447
	Socioeconomic status score[h]	20	31.05 (6.89)	24	30.17 (6.98)	0.238	0.628
Child education	Preschool attendance	20	1.10 (0.91)	24	1,63 (0.82)	3.242	0.079
Temperament	Surgency	20	4.56 (0.94)	24	4.66 (0.82)	0.194	0.662
	Negative effect	20	4.39 (1.08)	24	4.53 (0.87)	0.048	0.827
	Effortful control	20	6.01 (0.84)	24	6.15 (0.65)	0.188	0.667
Mother mental health	Mother anxiety	19	6.42 (3.79)	23	7.13 (4.17)	0.287	0.595
	Mother depression	19	5.79 (4.37)	23	5.22 (3.61)	0.157	0.694

Note.
[a] Sociodemographic information could not be obtained in some cases (this is the reason for differences in sample sizes).
[b] Risk factors include low birth weight, premature birth, exposure to risks during pregnancy (reported mother drugs/tobacco use, high blood pressure, anaemia or infections that could have affect child nervous system development).
[c] Highest educational and occupational levels reached by parents.
[d] Incomplete secondary school level.
[e] Skilled worker (cadet, chauffeur, cook, waiter, maintenance).
[f] Scale range: 3–12 points, with higher scores for better housing conditions.
[g] Scale range: 0–9 points, with higher scores for better conditions.
[h] Score composed adding parent's education and occupation score, dwelling and overcrowding score.
* Univariate ANOVA was performed for each variable.

Table 5
Cognitive performance by group and repeated measures analyses results.

Test/dependent variable	Time 1				Time 2				Repeated measures analyses		
	Control group		Intervention group		Control group		Intervention group				
	n	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)	gl	*F*	*p*
ANT											
Total score	24	85.79 (8.17)	25	75.96 (21.94)	23	91.48 (4.41)	25	86.72 (12.12)	44	4.655	**0.036**
RT alerting	24	21.19 (112.84)	24	63.23 (191.20)	23	34.13 (119.19)	25	68.84 (160.02)	43	1.557	0.219
RT orienting	24	39.48 (121.46)	25	−41.96 (138.83)	23	−2.50 (98.02)	25	8.60 (108.84)	44	2.066	0.158
RT executive attention	24	88.52 (113.62)	25	93.44 (205.11)	23	74.98 (56.07)	25	84.94 (66.23)	44	0.352	0.556
Stroop-like heart/flower											
CCT (congruent)	24	10.33 (2.73)	25	10.28 (2.99)	23	40.65 (2.29)	25	11.64 (1.08)	44	0.335	0.556
CCT (incongruent)	22	7.36 (4.01)	23	8.65 (3.14)	23	9.13 (2.72)	25	10.40 (2.63)	40	2.651	0.111
CCT (mixed)	24	7.92 (5.96)	25	6.84 (4.98)	23	11.78 (7.58)	25	10.36 (5.16)	44	0.334	0.566
RT congruent	24	857.03 (291.63)	25	1003.41 (269.59)	23	958.14 (220.24)	25	904.41 (219.66)	44	0.718	0.401
RT incongruent	22	1181.37 (308.20)	23	1236.43 (336.77)	23	1114.66 (295.33)	25	1057.29 (213.90)	40	0.003	0.957
RT mixed	24	1362 (402.56)	25	1459.50 (320.27)	23	1370.80 (239.98)	25	1363.91 (255.95)	44	0.355	0.554
Tower of London											
Correct trials per difficulty level	24	19.75 (15.23)	23	21.71 (12.76)	23	29.78 (13.86)	25	33.92 (16.42)	42	0.454	0.504
Maximum level with 100% efficacy	24	1.46 (1.10)	23	1.04 (0.88)	23	1.52 (0.85)	25	1.80 (1.12)	42	0.736	0.396
Corsi blocks											
Correct trials per difficulty level	24	11.38 (6.93)	22	8.09 (5.89)	23	19.13 (13.86)	25	22.04 (14.46)	41	0.007	0.932
Maximum level with 100% efficacy	24	0.88 (0.68)	22	0.73 (0.70)	23	1.30 (0.97)	25	1.52 (0.87)	41	0.139	0.711
Self Ordered Search											
Selections block 1	24	4.17 (0.76)	25	4.12 (0.83)	23	5.57 (0.51)	25	5.16 (0.55)	44	1.467	0.232
Selections block 2	24	3.67 (0.87)	25	3.84 (0.75)	23	4.74 (0.75)	25	4.76 (0.72)	44	0.456	0.503
Selections block 3	24	5.46 (1.10)	25	5.44 (1.04)	23	6.74 (0.69)	25	6.64 (0.86)	44	0.001	0.981
Selections block 4	24	4.58 (0.88)	25	5.00 (1.08)	23	6.35 (0.78)	25	5.96 (0.79)	44	0.246	0.623
K-ABC digits span											
Total score	24	5.71 (2.01)	25	2.24 (1.96)	23	6.04 (1.77)	24	5.58 (1.82)	43	1.105	0.299
K-BIT matrix test											
Total score	24	13.46 (4.10)	25	12.60 (4.40)	23	15.57 (3.92)	25	13.20 (3.49)	44	2.595	0.114

Note. RT=reaction time; CCT=consecutive correct trials; Time 1=pre-intervention cognitive assessment; Time 2=post-intervention cognitive assessment; bold text indicates significant differences between groups ($p < 0.05$).

Table 6
Academic performance by study groups.

Subject	Bimester	Median		Mann Whitney analyses			*r* (effect size)
		Control (*n*=11)	Intervention (*n*=16)	*U*	*Z*	*p*	
Language	1st	3.00	4.00	48.00	−2.237	0.050	0.44
	2nd	3.00	4.00	63.00	−1.330	0.231	0.26
	3rd	3.00	4.00	63.50	−1.306	0.231	0.26
	4th	**3.00**	**4.00**	37.00	−2.634	**0.011**	**0.52**
Mathematics	1st	3.00	3.50	60.50	−1.538	0.178	0.30
	2nd	**3.00**	**4.00**	37.50	−2.750	**0.011**	**0.54**
	3rd	3.00	4.00	61.50	1.409	0.195	0.28
	4th	**3.00**	**4.00**	44.00	−2.269	**0.030**	**0.44**
Collaboration in tasks	1st	3.00	3.00	57.50	−1.902	0.134	0.37
	2nd	3.00	3.00	53.00	−2.097	0.089	0.41
	3rd	3.00	4.00	59.00	−1.627	0.162	0.32
	4th	3.00	4.00	57.50	−1.731	0.134	0.34
Autonomy	1st	**3.00**	**4.00**	36.00	−2.852	**0.009**	**0.56**
	2nd	3.00	4.00	54.00	−1.799	0.099	0.35
	3rd	3.00	4.00	72.50	−0.824	0.451	0.16
	4th	3.00	4.00	60.50	−1.536	0.178	0.30
Acceptance of rules	1st	3.00	4.00	61.00	−1.432	0.195	0.28
	2nd	3.00	4.00	58.00	−1.609	0.148	0.32
	3rd	3.00	4.00	61.00	−1.432	0.195	0.28
	4th	3.00	4.00	56.50	−1.769	0.121	0.35
Contact with peers	1st	3.00	4.00	49.00	−2.235	0.056	0.44
	2nd	**3.00**	**4.00**	46.00	−2.406	**0.039**	**0.47**
	3rd	3.00	4.00	54.00	−1.970	0.099	0.39
	4th	3.00	4.00	48.00	−2.329	0.050	0.46

Note. Bold text indicates significant differences between groups ($p < 0.05$).

external control group A and the intervention group (both in the same classroom evaluated by the same teacher). Since the same teacher graded both groups, if the intervention group showed higher grades than their classroom peers, results would suggest higher academic achievement for intervention children, regardless of any teacher tendency in grading. The results showed significantly higher grades for children in the intervention group in the following variables: Language 4th bimester ($z = -2.826$; $p = 0.005$), and

Table 7
Academic performance by intervention and external control groups.

Area	Bimester	Median		Mann Whitney results			*r* (effect size)
		Intervention ($n=16$)	External control group A ($n=7$)	*U*	*Z*	*p*	
Language	1st	4.00	3.00	43.00	−0.982	0.413	0.20
	2nd	4.00	3.00	44.50	−0.829	0.452	0.17
	3rd	4.00	3.00	27.00	−2.119	0.055	0.44
	4th	4.00	2.00	11.00	−2.826	**0.005**	**0.59**
Mathematics	1st	3.50	3.00	39.00	−1.302	0.278	0.27
	2nd	4.00	3.00	33.50	−1.644	0.135	0.34
	3rd	4.00	3.00	25.00	−2.236	**0.039**	**0.47**
	4th	4.00	2.00	17.00	−2.399	**0.021**	**0.50**
Collaboration in tasks	1st	3.00	3.00	39.50	−1.335	0.278	0.28
	2nd	3.00	3.00	47.50	−0.671	0.579	0.14
	3rd	4.00	3.00	48.50	−0.579	0.624	0.12
	4th	4.00	3.50	32.50	−1.344	0.261	0.28
Autonomy	1st	4.00	3.00	37.00	−1.435	0.222	0.30
	2nd	4.00	3.00	29.00	−2.005	0.076	0.42
	3rd	4.00	3.00	36.50	−1.458	0.198	0.30
	4th	4.00	3.00	23.00	−2.149	0.070	0.45
Acceptance of rules	1st	4.00	3.00	47.00	−0.651	0.579	0.14
	2nd	4.00	3.00	44.00	−0.879	0.452	0.18
	3rd	4.00	3.00	41.00	−1.076	0.341	0.22
	4th	4.00	3.50	36.50	−1.034	0.407	0.22
Contact with peers	1st	4.00	3.00	37.00	−1.466	0.222	0.31
	2nd	4.00	4.00	46.00	−0.838	0.535	0.17
	3rd	4.00	4.00	54.00	−0.176	0.922	0.04
	4th	4.00	4.00	41.00	−0.710	0.641	0.15

Note. Bold text indicates significant differences between groups ($p<0.05$).

Mathematics 3rd bimester ($z=-2.236$; $p=0.039$) and 4th bimester ($z=-2.399$; $p=0.021$). In the other variables analysed, the intervention group had similar grades than the external control group A (Table 7).

Finally, the only difference between the control group and the external control group B is in the variable Acceptance of rules 3rd bimester, where the external control group B showed significantly higher grades ($Z=-2.411$; $p=0.024$) than peers of their same classroom (control group). There were no differences between control group and external control group A.

4. Discussion

The main contribution of this study resides in the design and methodology implemented. To the best of our knowledge there are no previous intervention studies based on the integration of perspectives from developmental psychology, cognitive neuroscience, and education, designed with education, cognitive neuroscience and developmental psychology researchers, and implemented by teachers. There were two levels of interdisciplinary interaction among experts: first, the design of the intervention came from the collaborative work of people from those disciplines. Second, the adaptation of the activities to particular groups of children derived from an active dialogue between intervention classroom teachers, and researchers in cognitive neuroscience and developmental psychology. That is, educational researchers created the activities, intervention teachers adapted them, and researchers in cognitive neuroscience and developmental psychology participated in each phase (design and adaptation) ensuring in each activity EF demand. While there is a claim that studies developed in ecological contexts are integrative in this respect [7], most studies aimed at integrating neuroscience and education fields have been developed in laboratories [97] and were carried out by experimenters, usually giving the teachers the only role of applicators. In this regard, our work sets a precedent for future joint work and represents a contribution for bridging the gap between disciplines. In addition, in Argentina, as in other countries, education methods are nearly always based on traditions and qualitative opinions [98]. Different teaching methods have been used, but there is little empirical comparison of their efficacies [9]. Argentinean kindergarten curriculum and educational research is more focused on the content than on the process of learning and EF development [83]. In the search for best evidence-based education methods, this study is a local precedent for scientific comparisons of teaching approaches.

Contrary to the hypotheses outlined in the introduction, only the variable *ANT Total Score* showed significant differences between groups, suggesting a differential improvement on attention skills. No other impacts of the intervention on cognitive performances were verified, and given the number of variables for which we expected to find strong impacts on academic achievement, we consider that the gain was small. It is worth highlighting, however, that the academic profiles during first grade suggested that these intervention children had enhanced performance compared to the control and to the external control groups. Specifically, five of the 24 variables analysed regarding academic achievement showed differences between study groups. In all of them, the intervention group had significantly higher values than the control group. We found differences in 4 of the 6 academic areas where we expected to find an impact of the intervention method (Language, Mathematics, Autonomy, and Contact with peers). Those differences were observed in 1st, 2nd, and 4th bimesters, and it remains unclear why those differences were spread along the year and no concentrated in any particular time. Moreover, when we observed the median grades for each subject, children in the intervention group presented higher values than children in the control group in 22 of 24 variables, that is, the intervention group performed better than the control in all academic areas, although the difference between groups did not always reach statistical significance. Those results showed a general tendency of the intervention group to increase academic achievement, even though it is not possible to conclude that those differences were necessarily associated to the intervention.

As mentioned above, a question to be addressed is the possibility of a “teacher effect” [10–12]. To control for this factor, two external control groups (one for each classroom) were compared. We found no differences between them, suggesting that both teachers evaluated children based in similar criteria. Furthermore, children in the intervention group and in the external control group A (both in the same classroom with the same teacher) were compared to test the same hypotheses. Results indicated differences in three of the 24 variables analysed, with children in the intervention group showing higher grades than their control classrooms partners. Most importantly, 20 of the 24 variables analysed showed higher medians in the intervention group compared with the control group. These results emphasise the differences between control and intervention groups, showing a tendency of children in the intervention group to have higher grades.

Although we anticipated that the intervention would produce impacts on cognitive achievement, this approach failed to attain significant results, a result similar to that obtained by other intervention programs [99,100]. Possible reasons for the absence of cognitive effects of the intervention should be considered: for example, tasks used for evaluation, timing, and conformation of study groups.

First, it is possible that the battery of tests used for cognitive assessment was not the most adequate one to detect the impact of this type of intervention put into practice by teachers in class, while grades may be a more general and sensitive measure of changes in achievement. Although the EF tests presented here had been used in previous studies and proved to be useful in detecting changes produced by other types of interventions [76], it is possible that they failed to detect the effects of this broader intervention whereas grades performed better. However, whether the battery used had enough sensitivity remains an open question and cannot be answered with the applied design.

Second, another explanation for the results obtained in this study could be related to a timing effect. It is possible that the evaluation of the cognitive impact was too close to the first cognitive assessment and EF changes in the context of these types of interventions need more time to be revealed in the tasks we used. In general, interventions aimed at optimising EF (in laboratory or community settings) usually show immediate intelligence quotient gains and subsequent fade-outs, and many years later, a positive impact on ecological variables (e.g., study, work, crime) [55]. In our study, the cognitive gains have been lower (regarding only attention) than the ecological gains (grades), which brings into the discussion the importance of a further analysis of the research design, the intervention content, the type of evaluation instrument, and the optimal time for impact assessment. Another issue related with time is the frequency of the activities: higher frequencies of activities have shown greater effects in different intervention programs [67,69]. Therefore, the implemented schedule of two activities per week may have been a scheme of insufficient intensity to generate substantial impacts. It is important to consider and test different activity-schedules in the design of future studies to determine the optimal number of activities, their duration and frequency—aspects that represent a challenge for schools when this type of studies competes with other school projects.

A final issue to consider is the sample conformation. Given ethical standards and school norms, it was impossible to apply an experimental design in which children would be assigned randomly to intervention and control groups [101]. Likewise, the units of analysis were classes and not individual children, due to the aims of the study: the intervention was expected to work in common classes, with their own dynamics. Additionally, as in the present study only two classes were compared, we were unable to control for a number of variables that could have influenced results (e.g., teacher's personal and pedagogical styles). In this sense, it would be important to include more schools and classes in future studies to arrive to broader conclusions. The current study included control for EF levels, SES, maternal mental health, child temperament, and nutritional condition. Also, as all children attended the same school, principals, curriculum and modalities of the school, school schedule, and school spatial location were controlled for (all factors that have been suggested as a good practice for these types of studies [102]). To increase the number of classes involved we would have had to increase the controls for these and other variables. In addition, at least in the city of Buenos Aires, there are no schools with more than two classes per age, which would require running the intervention in at least several different schools. Consequently, it would be important to take into consideration all these potential sources of variation in order to include an appropriate number of classrooms/schools but, at the same time, keeping the number of variables under control as high as possible.

Although the effects of the intervention developed by the interdisciplinary team were not the expected ones, this is a first attempt at working together in an educational project of this type. It is important to continue working in this direction, in order to increase the knowledge about how to improve these collaborations, to have a lasting and positive impact on children's cognitive and social development.

5. Conclusion

This study shows a way of conducting a true interdisciplinary study between the fields of developmental psychology, cognitive neuroscience, and education, which represents a contribution for bridging the gap between these disciplines. Although we did not find a significant impact of the intervention on the pre- to post-training cognitive assessment, results showed significant differences in some academic areas during first grade. This study shows that it is possible (a) to design work in concert between the fields of developmental psychology, cognitive neuroscience, and education, and (b) to generate pedagogic cognitive training approaches that mix scientific and educational advances.

Conflicts of interest

Conflicts of interests do not exist.

Acknowledgements

Study supported by Fondo para la Investigación Científica y Tecnológica (FONCYT) (Grants: PICT-2005 No. 38202 and PICTO No. 36393), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Centro de Educación Médica e Investigación Clínica “Norberto Quirno” (CEMIC). The authors thank to Fundación Conectar, Juan Gilli, Dora Maglione, Valentina Ferretti, Ministry of Education of the City of Buenos Aires, and the school community from School 1 (at the VIII District).

References

[1] Bruer JT. Education and the brain: a bridge too far. Educ Res 1997;2:4–16.
[2] Byrnes JP, Fox N. The educational relevance of research in cognitive neuroscience. Educ Psychol Rev 1998;10:297–342.
[3] Sigman M, Peña M, Goldin A, Ribeiro S. Neuroscience and education: prime time to build the bridge. Nat Neurosci 2014;17:497–502. http://dx.doi.org/10.1038/nn.3672.
[4] Szúcs D, Goswami U. Educational neuroscience: defining a new discipline for the study of mental representations. Mind Brain Educ 2007;3:114–27.
[5] Varma S, McCandliss BD, Schwartz DL. Scientific and pragmatic challenges for bridging education and neuroscience. Educ Res 2008;3:140–52.
[6] Howard Jones PA (2014) Neuroscience and education: a review of educational interventions and approaches informed by neuroscience. Full report and executive summary for the education endowment foundation. Avail-

able at ⟨http://educationendowmentfoundation.org.uk/uploads/pdf/NSED_LitReview_Final.pdf⟩.

[7] Alibali MW, Nathan MJ. Conducting research in schools: a practical guide. J Cogn Dev 2010;11(4):397–407.

[8] Dinella L. Conducting science-based psychology research in schools. Washington: American Psychological Asociation; 2009.

[9] Towne L, Wise LL, Winters TM. Advancing scientific research in education. Washington D.C: The National Academies Press; 2004.

[10] Hughes N, Gleason KA, Zhang D. Relationship influences on teachers' perceptions of academic competence in academically at-risk minority and majority first grade students. J Sch Psychol 2005;43(4):303–20. http://dx.doi.org/10.1016/j.jsp.2005.07.001.

[11] Jussim L, Harber KD. Teacher expectations and self-fulfilling prophecies: knowns and unknowns, resolved and unresolved controversies. Pers Soc Psychol Rev 2005;9(2):131–55.

[12] Speybroeck S, Kuppens S, Van Damme J, Van Petegem P, Lamote C, Boonen T, et al. The role of teachers' expectations in the association between children's SES and performance in kindergarten: a moderated mediation analysis. PLoS One 2012;7:4. http://dx.doi.org/10.1371/journal.pone.0034502.

[13] Best JR, Miller PH. A developmental perspective on executive function. Child Dev 2010;81:1641–60.

[14] Garon N, Bryson SE, Smith IM. Executive function in preschoolers: a review using an integrative framework. Psychol Bull 2008;134:31–60.

[15] Posner M, Rothbart M. Attention, self-regulation and consciousness. Philos Trans R Soc Lond Ser B 1998;353:1915–27.

[16] Diamond A, Doar B. The performance of human infants on a measure of frontal cortex function, the delayed response task. Dev Psychobiol 1989;22:271–94.

[17] Diamond A, Kirham N, Amso D. Conditions under which young children can hold two rules in mind and inhibit a prepotent response. Dev Psychol 2002;38:352–62.

[18] Baddeley A. Working memory. Science 1992;255:556–9.

[19] Shallice T. Specific impairments of planning. Philos Trans R Soc Lond 1982;298:199–209.

[20] Cartwright K. Insights from cognitive neuroscience: the importance of executive function for early reading development and education. Early Educ Dev 2012;23(1):24–36.

[21] Coldren JT. Cognitive control predicts academic achievement in kindergarten children. Mind Brain Edu 2013;7(1):40–9.

[22] Clark CAC, Nelson JM, Garza J, Sheffield TD, Wiebe SA, Espy KA. Gaining control: changing relations between executive control and processing speed and their relevance for mathematics achievement over course of the preschool period. Front Psychol 2014;5:207. http://dx.doi.org/10.3389/fpsyg.2014.00107.

[23] Neuenschwander R, Ruthlisberger M, Cimeli P, Roebers CM. How do different aspects of self-regulation predict successful adaptation to school? J Exp Child Psychol 2012;113:353–71.

[24] Denham SA, Warren-Khot HK, Basset HH, Wyatt T, Perna A. Factor structure of self-regulation in preschoolers: testing models of a field-based assessment for predicting early school readiness. J Exp Child Psychol 2012;111:386–404.

[25] Richland LE, Burchinal M. Early executive function predicts reasoning development. Psychol Sci 2013;24(1):87–9.

[26] Blair C, Diamond A. Biological processes in prevention and intervention: the promotion of self-regulation as a means of preventing school failure. Dev Psychopathol 2008;20:899–911. http://dx.doi.org/10.1017/S0954579408000436.

[27] Brock LL, Rimm-Kaufman SE, Nathanso L, Grimm KJ. The contributions of 'hot' and 'cool' executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten. Early Child Res Q 2009;24:337–49.

[28] Clark CAC, Sheffield TD, Wiebe SA, Espy KA. Longitudinal associations between executive control and developing mathematical competence in preschool boys and girls. Child Dev 2013;84(2):662–77. http://dx.doi.org/10.1111/j.1467-8624.2012.01854.x.

[29] Lan X, Legare CH, Ponitz CC, Li S, Morrison FJ. Investigating the links between the subcomponents of executive functioning and academic achievement: a cross-cultural analysis of Chinese and American preschool children. J Exp Child Psychol 2011;108(3):677–92.

[30] Posner MI, Rothbart MK. Influencing brain networks: implications for education. Trends Cogn Sci 2005;9:99–103.

[31] Wiebe SA, Sheffield T, Nelson JM, Clark CA, Chevalier N, Espy KA. The structure of executive function in 3-year-olds. J Exp Child Psychol 2011;108:436–52.

[32] Willoughby MT, Blair CB, Wirth RJ, Greenberg M. The family life project investigators the measurement of executive function at age 5: psychometric properties and relationship to academic achievement. Psychol Assess 2013;24(1):226–39. http://dx.doi.org/10.1037/a0025361.

[33] Engel de Abreu PMJ, Gathercole SE, Martin R. Disentangling the relationship between working memory and language: the roles of short-term memory storage and cognitive control. Learn Individ Differ 2011;21:569–74.

[34] Peng P, Congying S, Beilei L, Sha T. Phonological storage and executive function deficits in children with mathematics difficulties. J Exp Child Psychol 2012;112(4):452–66. http://dx.doi.org/10.1016/j.jecp.2012.04.004.

[35] Diamond A, Lee K. Interventions shown to aid executive function development in children 4 to 12 years old. Science 2011;333(6045):959–64 http://dx.doi.org/10.1126/science.1204529.

[36] Aron AR. Progress in executive-function research, from tasks to functions to regions to networks. Curr Dir Psychol Sci 2008;17:124–9.

[37] Badre D. Cognitive control, hierarchy, and the rostro–caudal organisation of the frontal lobes. Trends Cogn Sci 2008;12(5):193–200.

[38] Brumback Peltz C, Gratton G, Fabiani M. Age-related changes in electrophysiological and neuropsychological indices of working memory, attention control, and cognitive flexibility. Front Psychol 2011;2:1–12.

[39] Tsuchida A, Fellows LK. Lesion evidence that two distinct regions within prefrontal cortex are critical for n-back performance in humans. J Cogn Neurosci 2009;21(12):2263–75.

[40] Boes AD, Grafft AH, Joshi C, Chuang NA, Nopoulos P, Anderson SW. Behavioral effects of congenital ventromedial prefrontal cortex malformation. BMC Neurol 2011;2(11):151. http://dx.doi.org/10.1186/1471-2377-11-151.

[41] Crone EA, Ridderinkhof KR. The developing brain: from theory to neuroimaging and back. Dev Cogn Neurosci 2011;1(2):101–9. http://dx.doi.org/10.1016/j.dcn.2010.12.001.

[42] Lenroot KR, Giedd JN. Brain development in children and adolescents: insights from anatomical magnetic resonance imaging. Neurosci Biobehav Rev 2006;30:718–29.

[43] Paus T. Mapping brain maduration and cognitive development during adolescence. Trends Cogn Sci 2005;9(2):60–8.

[44] Hughes C, Ensor R. Individual differences in growth in executive function across the transition to school predict externalizing and internalizing behaviours and self perceived academic success at 6 years of age. J Exp Child Psychol 2011;108:663–76.

[45] Willoughby MT, Wirth RJ, Blair CB. Executive function in early childhood: longitudinal measurement invariance and developmental change. Psychol Assess 2012;24(2):418–31. http://dx.doi.org/10.1037/a0025779.

[46] Duncan G, Magnuson K. Socioeconomic status and cognitive functioning: moving from correlation to causation. Wiley Interdiscip. Rev.: Cogn. Sci 2012;3:377–86. http://dx.doi.org/10.1002/wcs.1176.

[47] Lipina SJ, Simonds J, Segretin MS. Recognizing the child in child poverty. Vulnerable Child Youth Stud 2011;6:8–17.

[48] Lipina SJ, Colombo JA. Poverty and brain development during childhood. Washington D.C: American Psychological Association; 2009.

[49] Lipina SJ, Posner M. The impact of poverty on the development of brain networks. Front Hum Neurosci 2012;6:238. http://dx.doi.org/10.3389/fnhum.2012.00238.

[50] Bradley RH, Corwyn RF. Socioeconomic status and child development. Annu Rev Psychol 2002;53:371–99.

[51] Brooks-Gunn J, Duncan GJ. The effects of poverty on children. Future Child 1997;7:55–71.

[52] Fernald L, Weber A, Galasso E, Ratsifandrihamanana L. Socioeconomic gradients and child development in a very low income population: evidence from Madagascar. Dev Sci 2011;14(4):832–47.

[53] Hackman DA, Farah MJ. Socioeconomic status and the developing brain. Trends Cogn Sci 2009;30:1–9.

[54] Hackman DA, Farah MJ, Meany MJ. Socioeconomic status and the brain: mechanistic insights from human and animal research. Nat Rev Neurosci 2010;11:651–9.

[55] Raizada RD, Kishiyama MM. Effects on socioeconomic status on brain development and how cognitive neuroscience may contribute to leveling the playing field. Front Hum Neurosci 2010;4:1–18.

[56] D´Angiulli A, Herdman A, Stapells D, Hertzman C. Children's event related potentials of auditory selective attention vary with their socioeconomic status. Neuropsychology 2008;22:293–300.

[57] Farah MJ, Shera DM, Savage JH, Betancourt L, Giannetta JM, Brodsky NL, et al. Childhood poverty: specific associations with neurocognitive development. Brain Res 2006;1110:166–74.

[58] Hackman DA, Betancourt LM, Gallop R, Romer D, Brodsky NL, Hurt H, et al. Mapping the trajectory of socioeconomic disparity in working memory: parental and neighborhood factors. Child Dev 2014;85(4):1433–4445. http://dx.doi.org/10.1111/cdev.12242.

[59] Kishiyama MM, Boyce WT, Jimenez AM, Perry LM, Knight RT. Socioeconomic disparities affect prefrontal function in children. J Cogn Neurosci 2009;10:1–10.

[60] Lipina SJ, Segretin MS, Hermida MJ, Prats L, Fracchia C, Lopez Camelo J, et al. Linking childhood poverty and cognition. Dev Sci 2013;16(5):697–707 http://dx.doi.org/10.1111/desc.12080.

[61] Noble KG, McCandliss BD, Farah MJ. Socioeconomic gradients predict individual differences in neurocognitive abilities. Dev Sci 2007;10:464–80.

[62] Raizada RD, Richards TL, Meltzoff A, Kuhl P. Socioeconomic status predicts hemispheric specialization of the left inferior frontal gyrus in young children. Neuroimage 2008;40:1392–401.

[63] Noble KG, Wolmetz ME, Ochs LG, Farah MJ, McCandliss BD. Brain-behavior relationships in reading acquisition are modulated by socioeconomic factors. Dev Sci 2006;9:642–51.

[64] Stevens C, Lauinger B, Neville H. Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: an event-related brain potential study. Dev Sci 2009;12:634–46.

[65] Burger K. How early childhood care and education affect cognitive development? An international review of the effects of early interventions for children from different social backgrounds Early Child Res Q 2010;25:140–65.

[66] Barnett WS. Effectiveness of early educational intervention. Science 2011;333(6045):975–8. http://dx.doi.org/10.1126/science.1204534.

[67] Ramey S, Ramey CT. Understanding efficacy of early educational programs: critical design, practice, and policy issues. In: Reynolds AJ, Wang MC, Walberg HJ, editors. Early childhood programs for a new century. Washington D.C.: CWLA Press; 2003. p. 118–36.
[68] Crane J, Barg M. Do early childhood intervention programmes really work? Washington: Coalition for Evidence Based Policy; 2003.
[69] Hermida MJ, Segretin MS, Lipina SJ, Benarós S, Colombo JA. Abordajes neurocognitivos en el estudio de la pobreza infantil: consideraciones conceptuales y metodológicas. Int J Psychol Clin Psychother 2010;10:205–25.
[70] Colombo JA, Lipina SJ. Hacia un programa público de estimulación cognitiva infantile: fundamentos, métodos y resultados de una experiencia de intervención preescolar controlada. Buenos Aires: Paidós; 2005.
[71] Diamond A, Barnett WS, Thomas J, Munro S. Preschool program improves cognitive control. Science 2007;318:1387–8.
[72] Goldin AP, Hermida MJ, Shalom DE, Costa ME, Lopez-Rosenfeld M, Segretin MS, et al. Far transfer to language and math of a short software-based gaming intervention. Proc Natl Acad Sci 2014;111(17):6443–8. http://dx.doi.org/10.1073/pnas.1320217111.
[73] Klingberg T, Fernell MD, Olesen PJ, Johnson M, Gustavsson P, Dahlstrom K, et al. Computerized training of working memory in children with ADHD. A randomized, controlled trial. J Am Acad Child Adolesc Psychiatry 2005;44:177–86.
[74] McCandliss BD, Beck IL, Sandak R, Perfetti C. Focusing attention on decoding for children with poor reading skills: design and preliminary tests of the Word Building Intervention. Sci Stud Read 2003;7:75–104.
[75] Rueda MR, Rothbart MK, McCandliss BD, Saccomanno L, Posner MI. Training, maturation, and genetic influences on the development of executive attention. Proc Natl Acad Sci 2005;102:14931–6.
[76] Segretin MS, Lipina SJ, Hermida MJ, Sheffield TD, Nelson JM, Espy KA, et al. Predictors of cognitive enhancement after training in preschoolers from diverse socioeconomic backgrounds. Front Psychol 2014;5:205. http://dx.doi.org/10.3389/fpsyg.2014.00205.
[77] Stevens C, Fanning J, Coch D, Sanders L, Neville H. Neural mechanisms of selective auditory attention are enhanced by computerized training: electrophysiological evidence from language-impaired and typically developing children. Brain Res 2008;1205:55–69.
[78] Thorell LB, Lindqvist S, Bergman Nutley S, Bohlin G, Klingberg T. Training and transfer effects of executive functions in preschool children. Dev Sci 2009;12:106–13.
[79] Wilson AJ, Dehaene S, Dubois O, Fayol M. Effects of an adaptive game intervention on accessing number sense in low-socioeconomic-status kindergarten children. Mind Brain Educ 2009;3(4):224–34.
[80] Dubinsky JM. Neuroscience education for pre kindergarten–12 teachers. J Neurosci 2010;30(24):8057–60.
[81] Instituto nacional de formación docente, recomendaciones para la elaboración de diseños curriculares: profesorado de educación inicial. Ministerio de Educación Buenos Aires; 2009.
[82] Ansari D, Coch D. Bridges over troubled waters: education and cognitive neuroscience. Trends Cogn Sci 2006;10(4):146–51.
[83] Gobierno de la Ciudad Autónoma de Buenos Aires. Diseño curricular para la Educación Inicial. Niños de 4 y 5 años, Secretaría de Educación, Buenos Aires; 2000.
[84] Lipina SJ, Martelli MI, Vuelta BL, Colombo JA. Performance on the A-not-B task of Argentinean infants from unsatisfied basic needs homes. Interam J Psychol 2005;39:49–60.
[85] Hamilton M. The assessment of anxiety states by rating. Br J Med Psychol 1959;32:50–5.
[86] Buss C, Davis EP, Hobel CJ, Sandman C. Maternal pregnancy-specific anxiety is associated with child executive function at 6–9 years age. Stress 2011;14 (6):665–76.
[87] Shallice T. Specific impairments of planning. Philos Transcr R Soc Lond 1982;298:199–209.
[88] Pickering SJ. The development of visuo-spatial working memory. Memory 2001;9:423–32.
[89] Luciana M, Nelson C. Assessment of neuropsychological function through use of the Cambridge neuropsychological testing automated battery: performance in a 4 to 12 year old children. Dev Neuropsychol 2002;22(3):595–624.
[90] Kaufman AS, Kaufman NL. Kaufman assessment battery for children. Circle Pines: American Guidance Service; 1983.
[91] Kaufman AS, Kaufman NL. Kaufman brief intelligence test. 3rd ed. Bloomington: Pearson; 2002.
[92] Ashiabi GS. Play in the preschool classroom: its socioemotional significance and the teachers' role in play. Early Child Educ J 2007;35(2):199–207 http://dx.doi.org/10.1007/s10643-007-0165-8.
[93] Burchinal MR, Roberts JE, Hooper S, Zeisel SA. Cumulative risk and early cognitive development: a comparison of statistical risk models. Dev Psychol 2000;36:793–807.
[94] Gassman-Pines A, Yoshikawa H. The effects of antipoverty programs on children´s cumulative level of poverty-related risk. Dev Psychol 2006;42:981–99.
[95] McLoyd VC. Socioeconomic disadvantage and child development. Am Psychol 1998;53:185–204.
[96] Segretin MS, Lipina SJ, Petetta DR. Methodological and conceptual considerations for the analysis of school performance predictions, based on home and school context indexes. Rev Iberoam Eval Educ 2009;2:104–23.
[97] Lipina SJ, Sigman M. La pizarra de babel: Puentes entre neurociencia, psicología y educación. Buenos Aires: Libros del Zorzal; 2011.
[98] Seidenberg MS. Politics (of reading) makes strange bedfellows. Perspect. Lang. Lit Summer 2012:9–11.
[99] Redick TS, Shipstead Z, Harrison TL, Hicks KL, Kane MJ, Fried DE, et al. No evidence of intelligence improvement after working memory raining: a randomized, placebo-controlled study. J Exp Psychol 2013;142(2):359–79.
[100] Tidwell JW, Dougherty MR, Chrabaszcz JR, Thomas RP, Mendoza JL. What counts as evidence for working memory training? Problems with correlated gains and dichotomization Psychon Bull Rev 2014;21:620–8. http://dx.doi.org/10.3758/s13423-013-0560-7.
[101] Capella E, Massetti GM, Rigorous S Yampolsky. responsive and responsible: experimental designs in school intervention research. In: Dinella L, editor. Conducting science-based psychology research in schools. Washington: American Psychological Asociation; 2009. p. 67–180.
[102] Cary MS. Navigating institutional review boards when conducting school based research. In: Dinella L, editor. Conducting science-based psychology research in schools. Washington: American Psychological Asociation; 2009. p. 205–22.