Developmental Science

Developmental Science (2013), pp 1–11 DOI: 10.1111/desc.12080

PAPER

Linking childhood poverty and cognition: environmental mediators of non-verbal executive control in an Argentine sample

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Abstract

Tests of attentional control, working memory, and planning were administered to compare the non-verbal executive control performance of healthy children from different socioeconomic backgrounds. In addition, mediations of several sociodemographic variables, identified in the literature as part of the experience of child poverty, between socioeconomic status and cognitive performance were assessed. Results show: (1) significant differences in performance between groups in most dependent variables analyzed – however, not in all variables associated with attentional control domains; (2) significant indirect effects of literacy activities on working memory and fluid processing domains, as well as computer resources effects on fluid processing; and (3) marginal indirect effects of computer resources on attentional control and working memory domains. These findings extend analysis of the impact of poverty on the development of executive control, through information based on the assessment of combined neurocognitive paradigms and the identification of specific environmental mediators.

Introduction

Childhood poverty and development are complex phenomena involving dynamic interactions of biological and psychosocial components (Bradley & Corwyn, 2002; Gianaros & Manuck, 2010; Hackman & Farah, 2009; Hackman, Farah & Meany, 2010; Lipina & Colombo, 2009). From a developmental cognitive neuroscience (DCN) perspective, cognition is viewed as component codes, computed in different ways, and programmed to perform complex tasks, leading to new ways of thinking about how our brain organizes thought and emotional processes (Posner & Raichle, 1994). Specifically, processes involved in early cognitive control development, such as the different attention, working memory, and planning subsystems, are fundamental to cognition and social behavior throughout the lifespan in most cultures worldwide (Sperber & Hirschfeld, 2004). Given the multiplicity of factors that influence and modulate neurocognitive development, it is likely that basic cognitive functions would also be modulated by socioeconomic backgrounds (Hackman & Farah, 2009; Hackman *et al*., 2010; Lipina & Colombo, 2009; Lipina & Posner, 2012).

Among studies that assess effects of SES on neurocognition, many have focused on the prefrontal/executive system. In behavioral studies on infants, preschoolers, first graders, and middle school children, low SES children evidence reduced performance compared to middle SES children. These findings suggest that the prefrontal/executive system is one of the primary neurocognitive systems associated with social inequalities in early experience (Hackman & Farah, 2009; Hackman *et al*., 2010). Generally speaking, these studies have explored activation and performance aspects using the income and basic needs approaches to measuring poverty. These methods, which identify social inequalities in a general way, need to be revised because child poverty

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involves dimensions distinct from general poverty ones (Lipina, Simonds & Segretin, 2011). In this context, the exploration of mediating mechanisms leads to a better understanding of the effects of specific childhood experiences on cognitive and brain development.

In general, mediators of poverty's impact on cognitive development in Western literature reviews include: (1) peri- and postnatal physical health and nutrition; (2) home environment and stimulation; (3) parent–children interactions; (4) parental mental health and parenting styles; and (5) the social and material resources of the neighborhood (Guo & Mullan-Harris, 2000; Sarsour, Sheridan, Jutte, Nuru-Jeter, Hinshaw & Boyce, 2011). Mediation of poverty effects would be influenced by systematic differences among societies regarding cultural patterns, schooling practices, and psychological environments (Roselli & Ardila, 2003). Thus, skills prescribed by a given culture, together with the cognitive strategies varying among cultures, may interact with brain organization inherent patterns (Eviatar, 2000).

To contribute to the integration of childhood poverty and cultural specificities pertaining to behavioral neurocognitive paradigms, this study is aimed at: (1) evaluating the impact of poverty on executive control performance with a battery including tasks for different prefrontal/executive subsystems, in a sample of socioeconomically diverse Argentine children; and (2) analyzing mediation relationships among different environmental factors and cognitive control performance.

Method

Participants

Two hundred and fifty children (134 girls), aged $M = 4.87$, $SD = 0.59$ years, were recruited from three school districts of the City of Buenos Aires in 2009. Informed consent was obtained from parents/caregivers, and ethical approval was obtained from the ethical review committee of the CEMIC (Protocol Number 320). The study was conducted in accordance with APA's ethical standards, and international and national children rights laws.

Design and procedures

Children were tested individually at their schools, in a quiet testing room, during three 40-minute sessions (two tasks per session). Testing was scheduled at times reported by teachers not to interfere with regular meals and activities. Examiners were blind to the objectives of the study and the composition of the groups. A non-verbal cognitive battery including three computerized (ANT, Stroop and Self-ordered search) and three manual tasks (Tower of London, Corsi Blocks, and K-BIT matrices) was administered (see *Cognitive measures* and Table 1). Computerized tasks were presented on a laptop 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 a central fixation cross was presented on the screen, and only one stimulus was presented in each trial. In these tasks children used their index fingers to press the right and left arrow keys. In the Self-ordered search task, children used a mouse (5 cm × 4 cm), which they had been previously trained to use.

Sociodemographic variables

A socioeconomic scale (NES) (Lipina, Martelli, Vuelta & Colombo, 2005), was administered to each mother before the cognitive assessments to identify indicators of unsatisfied basic needs (UBN; Boltvinik, 1995), as well as other indicators associated with the specific experience of poverty for children (i.e. health history, preschool attendance, books in the household, frequency of reading, computer and Internet use in the household; Gordon, Nandy, Pantazis, Pemberton & Townsend, 2003; Minujin, Delamonica, Davidziuk & González, 2006) (Table 2). UBN criteria are based on the identi-

Table 1 *Battery of non-verbal executive control measures administered*

Task	Neurocognitive System/ Cognitive processes*	Dependent variable/s
Stroop-like Butterfly /Frog	Prefrontal-Executive Inhibitory control, Working Memory	RTs and Consecutive Correct Responses for Congruent, Incongruent and Mixed conditions
Childhood ANT	Prefrontal-Executive Alert, Orientation, Executive Attention networks	RTs for each network and Total Correct Responses
Self-ordered search	Prefrontal-Executive Object Working Memory, Self-monitoring	Total remembered items for each block
Tower of London	Prefrontal-Exceutive Planning	Total Score
Corsi Blocks	Prefrontal-Exceutive Planning	Total Score
K-BITM	Fluid intelligence	Total Score

Note: *Based on Noble, Farah and colleagues' classification (Noble *et al.*, 2005, 2006a, 2006b, 2007). ANT: Attentional Networks Test; RTs = reaction times; K-BITM: Kaufman Battery Intelligence Test Matrices.

Table 2 *Correlations for independent variables*

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Education Score	–												
2. Occupation Score	.61**	–											
3. Dwelling Score	44**	.43**	–										
4. Overcrowding Score	.37**	.45**	.39**	–									
5. Health history	.04	−.05	−.07	−.10	–								
6. Preschool attendance	.26**	.22**	.23**	.19**	−.07	–							
7. Amount of books in home	.47**	.58**	.46**	.34**	.01	.29**	–						
8. Frequency of reading to children	.34**	.51**	.21**	.32**	−.04	.07	.45**	–					
9. Computer use	.39**	.48**	.41**	.34**	−.04	.33**	.52**	.31**	–				
10. Internet use	.37**	.46**	.35**	.27**	−.04	.27**	.51**	.39**	.83**	–			
11. Effortful control	.13	−.27**	−.21**	−.12	−.12	−.01	−.16*	−.11	−.04	−.11	–		
12. Mother depression	.26**	−.37**	−.31**	−.34**	.01	−.26**	.34**	−.27**	−.25**	−.29**	.09	–	
13. Mother anxiety	−.24**	−.27**	−.23**	−.39**	.09	−.24**	−.16*	−.13**	−.25**	−.19**	.11	.49**	–

Note: *$p < .05$; **$p < .01$.

fication of at least one of the following conditions: (1) inappropriate dwelling (housing); (2) absence of waste discharge systems in households; (3) overcrowding; (4) presence of school-aged children who do not attend any educational system; and (5) head of household with incomplete primary school, with more than four dependents. Scores were assigned directly to mothers and fathers for educational and occupational backgrounds; however only the higher score was considered for the total scores. For the dwelling, scores were assigned based on type, floor, water, bathroom, ceiling, external walls and home property (see Supplementary Materials for scoring criteria).

Finally, the Spanish short-form of the Child Behavior Questionnaire (CBQ) was also administered to each mother. Only the temperamental effortful control dimension was considered, based on the associations with executive control competences (Rueda, Rothbart, McCandliss, Saccomanno & Posner, 2005). Finally, the Anxiety and Depression Hamilton scale (Hamilton, 1959) was administered to consider two of the most important aspects of mothers' mental health involved in self-regulation in early stages of child development (Buss, Davis, Hobel & Sandman, 2011).

Cognitive measures

More detailed descriptions of the tasks can be found in the Supplementary Materials.

Butterfly/Frog (Stroop) (Davidson, Amso, Anderson & Diamond, 2006)

This is a version of the Stroop task suitable for children. A color picture of either a frog or a butterfly was presented randomly on either the left or the right side of the computer screen. Each stimulus had an associated right- or left-located response (butterfly/left, frog/right). Six dependent variables were considered: reaction times and consecutive correct responses for each 20 trial block of Congruent (picture always on the side of the correct response), Incongruent (picture always on opposite side), and Mixed.

Childhood Attention Networks Test (ANT; Rueda *et al.*, 2005)

This is a version of the flanker task in which children press a right or left button depending on the direction an animal is facing on the computer screen. On some trials, 'flanker' animals appeared on either side of the target, facing in the same direction or in the opposite direction. Children were instructed to focus on and respond only to the orientation of the central target. Four dependent variables were considered: alert, orientation, control reaction times and total correct trials.

Self-ordered search (Self-ordered) (Luciana & Nelson, 2002)

This working memory task requires children to retain in memory the locations of drawings of common objects. Search complexity varies from searches of two consecutive blocks of six items, and another two of eight items (four blocks in total).

Tower of London (TOL; Shallice, 1982)

In this task, children have to solve problems by moving colored balls (blue, red, yellow). Each exercise block includes five trials wherein the child is required to reach a goal configuration of three colored balls from a start configuration (visible model), by moving one ball at a time, within a minimum number of moves (planning).

Any colored ball might be placed on top of any other, and children had to generate the appropriate action sequence to reach the configuration model. Levels of difficulty included exercises from one to nine movements. Total number of correct trials per level of difficulty was the dependent variable of interest (Total Score).

Corsi blocks (Corsi) (Pickering, 2001)

In this task, the child must remember and reproduce a sequence of lights (from one to eight, lighting time 1000 ms) that turn into a series of cubes arranged randomly in the apparatus (spatial working memory). Each child reproduces the sequence by pointing to the light-containing cubes. Each block included five trials; difficulty levels increased with the number of lights. Total number of correct trials per difficulty level was the dependent variable of interest (Total Score).

Kaufman Intelligence Battery Test Matrices (K-BITM)

We administered the Matrices subscale from the Kaufman Brief Intelligence Test to obtain a general measure of cognitive performance. The dependent variable was the total score (raw data).

Statistical analysis

After performing standard descriptive analysis for each dependent variable (mean, *SD*, *SE*, kurtosis, asymmetry), a correlation analysis was performed to identify performance variables with significant and high associations (Pearson coefficient over .50 and $p < .05$). Only one of the correlated variables was selected for the following procedures.

Based on the literature (Bradley & Corwyn, 2002; Hackman *et al.*, 2010) and the available sociodemographic information collected from parental report, a set of 13 variables were pre-selected as potential cognitive performance mediators. Standard descriptive analysis for each independent variable and a correlation analysis were also performed to identify associations.

Assumptions for univariate and multivariate ANOVA models were evaluated for each dependent variable, including residual normality, homoscedasticity, and independence. (Histograms, p-plot, Box's Test of Equality of Covariance Matrices, Bartlett's and Levene's Tests of Equality of Error Variances have been executed.) Whenever necessary, quadratic and arcsine transformations were applied. In univariate and multivariate ANOVA, *group* (UBN/Satisfied Basic Needs (SBN)) was the fixed factor; performance variables of each task, and sociodemographic, temperament and mother health variables were the dependent variables (separate analysis for performance and the other variables) and *age* was the covariable.

Each dependent variable was analyzed separately to identify significant mediators. For each dependent variable, scores were transformed into *z*-scores before their inclusion in the mediation analysis, to have a common metric element for comparisons across the tasks. An attentional control composite score was created by averaging the z scores for efficiency variables of Stroop and ANT, assuming that both belong to the same attentional control subsystem (Farah, Shera, Savage, Betancourt, Giannetta, Brodsky, Malmud & Hurt, 2006; Farah, Betancourt, Shera, Savage, Giannetta, Brodsky, Malmud & Hurt, 2008). In addition, selections for blocks 1 and 4 of the Self-Ordered task were also integrated into a composite score. Regarding the other tasks, only one dependent variable in each case was analyzed. Consequently, four subsystems were defined in terms of the cognitive demands of each composite or task: attentional control (Stroop and ANT), spatial working memory (Corsi Blocks), object working memory (Self-ordered), and planning (Tower of London). A fluid processing measure (K-BITM) was included to control mediation of SES on cognitive performance independently of intelligence, in addition to the analysis of its modulation by SES.

Before running mediation analysis and based on correlation analysis (see Results) and proximity of experiences for children, two composites were created by averaging the *z*-score of the variables *Amount of books in home* and *Frequency of reading to children* (Composite *Literacy activities*), and *Computer use* and *Internet use* (Composite *Computer resources*). The Sobel-Goodman mediation test was then applied to test whether the mediator variables (see variables in Table 2 and in Results) carry the influences of the independent variable (*group*) to the dependent variables (performance in cognitive tasks). All analyses were adjusted for age, gender and intelligence (score in K-BITM). For the number of comparisons ($n = 13$), the Bonferroni correction was used for a .05 level of significance (the final value of p was .004).

Results

The correlations between the independent variables were low, except for the association between computer and Internet use (Pearson Correlation = .83, $p < .000$) (Table 2).

Table 3 *Comparison of independent variables by socioeconomic group*

	SBN			UBN				
Variables	*n*	*M (SD)*	95% CI	*n*	*M (SD)*	95% CI	*F*	Sig
Education Score[1]	113	8.88 (2.30)	[8.36, 9.41]	99	7.10 (2.88)	[6.82, 7.96]	43.316	.000
Occupation Score[1]	113	6.34 (2.62)	[5.74, 6.93]	98	3.79 (2.20)	[3.60, 4.55]	90.513	.000
Dwelling Score[1]	114	11.87 (0.62)	[11.69, 11.99]	100	9.78 (1.84)	[9.58, 10.32]	136.795	.000
Overcrowding Score[1]	113	8.31 (1.26)	[8.03, 8.60]	97	6.09 (2.54)	[5.52, 6.62]	84.329	.000
Health history[1]	111	2.81 (0.45)	[2.81, 2.70]	96	2.75 (0.63)	[2.62, 2.89]	0.014	.910
Preschool attendance[1]	111	3.37 (1.01)	[3.15, 3.61]	92	2.49 (0.07)	[2.27, 2.73]	37.026	.000
Amount of books in home[1]	111	1.46 (0.90)	[1.26, 1.67]	93	0.55 (0.63)	[0.41, 0.69]	88.212	.000
Frequency of reading to children[3]	111	1.67 (1.08)	[1.42, 1.91]	93	0.97 (0.34)	[0.94, 1.36]	38.176	.000
Computer use[2]	110	2.82 (1.42)	[2.50, 3.14]	93	1.65 (0.21)	[1.38, 1.91]	58.664	.000
Internet use[2]	110	2.25 (1.48)	[1.92, 2.58]	93	1.37 (0.57)	[1.12, 1.57]	48.854	.000
Effortful control[1]	110	5.91 (0.69)	[5.76, 6.07]	92	6.04 (0.80)	[5.87, 6.23]	5.831	.170
Mother depression[1]	86	4.63 (2.03)	[3.97, 1.29]	88	6.71 (2.71)	[5.90, 7.51]	276.571	.000
Mother anxiety[1]	86	5.75 (3.09)	[5.07, 6.44]	88	8.24 (3.36)	[7.27, 9.20]	238.393	.000

Note: [1]Higher score indicates greater amount or frequency. [2]Higher score indicates lower amount or frequency. SBN: Satisfied Basic Needs; UBS: Unsatisfied Basic Needs. One-way ANOVA was performed, and analyses were adjusted for age and gender.

Table 4 *Correlations for dependent variables*

Task	Measure	1	2	3	4	5	6	7	8	9	10	11
Stroop	1.Consecutive Correct Congruent	–										
	2.Consecutive Correct Incongruent	.33**	–									
	3.Consecutive Correct Mixt	.31**	.51**	–								
ANT	4. Total Correct	.36**	.45**	.57***	–							
Self-ordered	5. Selections Block 1	−.01	.04	.11	.15*	–						
	6. Selections Block 2	−.02	.04	.23**	.12	.37**	–					
	7. Selections Block 3	.02	.10	.30**	.17**	.35**	.41**	–				
	8. Selections Block 4	−.02	−.01	.11	.07	.37**	.36**	.35**	–			
TOL	9. Total Score	.26	.32**	.36**	.40**	.10	.16*	.10	.07	–		
Corsi	10. Total Score	.14*	.25**	.34**	.34**	.08	.13*	.22**	.07	.13	–	
K-BITM	11. Total Score	.32**	.27**	.39**	.39**	−.02	.13*	.08	−.07	.26**	.22**	–

Note: $*p < .05$; $**p < .01$.

Scores for parental education and occupation for the UBN group were significantly lower than for the SBN group. On average, parents from UBN homes had completed primary education level and were employed as skilled workers. In contrast, the SBN parents reached at least incomplete secondary education and were employed in administrative positions. Families from UBN homes lived in households with less desirable conditions and higher rates of overcrowding. In addition, children in the UBN group evidenced (a) almost one more year of preschool attendance, (b) fewer books at home, (c) less reading frequency, and (d) a lesser use of computer and the Internet than children in the SBN group. UBN mothers also evidenced higher depression and anxiety indicators than mothers in the SBN group. Regarding the health history of children and their scores on the effortful control dimension, no differences were found between groups (Table 3).

Correlations between the dependent variables were also low (Table 4). As expected, performance comparisons between socioeconomic groups showed that the UBN group obtained significantly lower efficacy levels and scores in Stroop, ANT, Self-ordered, TOL, Corsi, and K-BIT matrices tasks (Figure 1 and Table 5). Regarding reaction time variables, the UBN group took more time in Congruent and Incongruent Stroop blocks. No other differences were found between groups in either the Stroop mixed condition or the ANT (see comparisons with data in Table 3 and with z-scores in Figure 2).

Mediation analysis showed significant indirect effects of *Literacy activities* on the working memory (Corsi blocks) and fluid processing (K-BITM) domains, and significant effects of *Computer resources* on the fluid processing domain (Figures 2 and 3, Table 6).

Marginal indirect effects of *Computer resources* on attentional control and working memory (Corsi blocks)

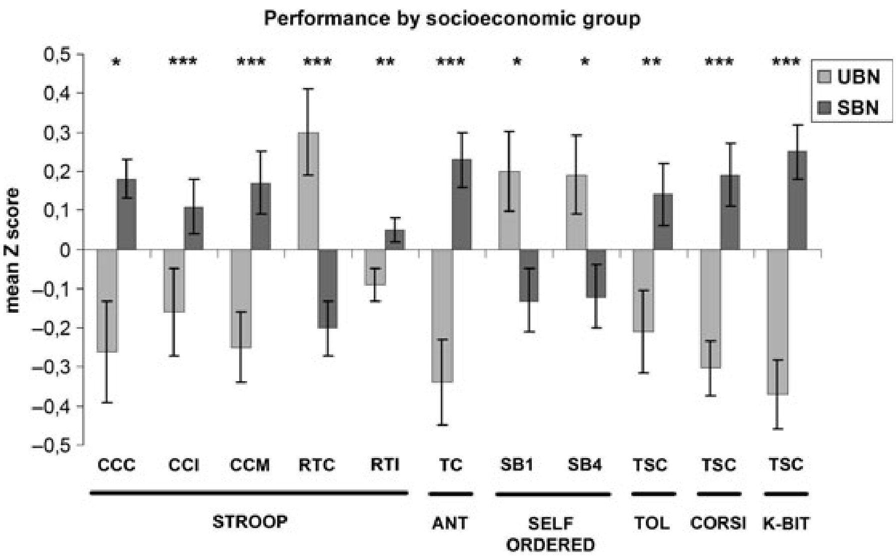

Figure 1 *Performance of children from UBN and SBN groups by task and dependent variable expressed in standardized z-scores. Note: CCC: Consecutive correct congruent; CCI: consecutive correct incongruent; CCM: consecutive correct mixt; RTC: reaction time congruent; RTI: reaction time incongruent; TC: total correct; SB1: selections in block 1; SB4: selections in block 4; TSC: total score; * p < .05; ** p < .01; *** p < .0001.*

domains have been verified (Figures 3 and 4). No mediation effects were found for temperament or for maternal mental health variables (Table 6).

Discussion

Results of this study showed first that children from UBN homes had lower efficacy on cognitive tasks related to the prefrontal/executive neurocognitive subsystem, as has been found in other DCN studies on childhood poverty during the last decade (D'Angiulli, Herdman, Stapells & Hertzman, 2008; Farah *et al*., 2006, 2008; Kishiyama, Boyce, Jimenez, Perry & Knight, 2009; Lipina, Martelli, Vuelta, Injoque Ricle & Colombo, 2004; Lipina *et al*., 2005; Mezzacappa, 2004; Noble, Norman & Farah, 2005; Noble, Farah & McCandliss, 2006a; Noble, Wolmetz, Ochs, Farah & McCandliss, 2006b; Noble, McCandliss & Farah, 2007; Raizada, Richards, Meltzoff & Kuhl, 2008; Rao, Betancourt, Gianetta, Brodsky, Korczykowski, Avants, Gee, Wang, Hurt, Detre & Farah, 2010; Stevens, Fanning, Coch, Sanders & Neville, 2008; Stevens, Lauinger & Neville, 2009).

No differences between socioeconomic groups were verified in Stroop and ANT reaction times, in contrast to previous findings which showed an impact of SES on ANT reaction time (Mezzacappa, 2004). Finding variations in the impact of socioeconomic status in some aspects of performance while not in others, even within the same age group, could be related to the specific operationalization of poverty (Lipina *et al*., 2011), or to cultural traits and differences (Roselli and Ardilla, 2003).

This performance pattern could also imply that the impact of childhood poverty on prefrontal/executive function in healthy children is likely to vary in terms of neural and computational resources from different networks or network nodes involved in the processing tasks of different paradigms. In this sense, the hypothesis of the socioeconomic modulation on interactive specialization (Tomalski & Johnson, 2010) suggests the importance of using different paradigms in neural activation studies with fMRI and EEG techniques, both in laboratory and other contexts, to the extent that the neuroimaging technologies are likely to allow (e.g. Fekete, Rubin, Carlson & Mujica-Parodi, 2011). In this discussion, the context of the behavioral findings should be reviewed after implementing neural approaches aimed at identifying variations in efficiency within a problem-solving performance context of analysis. Such an endeavor, integrating the discussion on the cognitive models involved, would help enrich the building of appropriate epistemological bridges between levels of analysis (Crone & Ridderinkhof, 2011). This should include the differentiation of specific (executive control) and general (fluid processing) paradigms, inasmuch as results at the behavioral level still suggest overlapping processing (Duncan & Owen, 2000).

After analyzing sociodemographic differences between UBN and SBN groups, the expected differences were

Table 5 *Performance by task, dependent variable, and socioeconomic group*

Task	Dependent Variable	SBN			UBN					
		n	*M (SD)*	95 % CI	*n*	*M (SD)*	95 % CI	*df*	*F*	Sig.
Stroop	Consecutive Correct Congruent	145	9.96 (2.79)	[10.42, 10.15]	98	8.89 (3.73)	[8.51, 10.07]	1,128	5.19	.024
	Consecutive Correct Incongruent	142	7.20 (3.82)	[6.93, 8.09]	95	6.23 (3.79)	[6.03, 7.64]	1,128	22.55	.000
	Consecutive Correct Mixt	145	7.36 (5.54)	[6,61, 8,48]	98	5.44 (4.78)	[4.66, 6.94]	1,128	24.93	.000
	Reaction Time Congruent	145	944.58 (280.85)	[877.58, 969.89]	97	1104.81 (343.16)	[1000.04, 1137.46]	1,128	25.38	.000
	Reaction Time Incongruent	138	1204.46 (33.61)	[1143.01, 1253.83]	92	1247.14 (346.93)	[1174.93, 1322.11]	1,128	5.85	.016
	Reaction Time Mixt	145	1374.89 (291.91)	[1349.48, 1451.37]	97	1369.93 (339.63)	[1306.95, 1457.78]	1,128	3.77	.053
ANT	Total Correct	147	79.27 (16.01)	[78.53, 83.74]	98	68.50 (20.31)	[65.91, 74.74]	1,144	62.74	.000
	Reaction Time Alert	147	35.42 (193.13)	[18.93, 80.73]	97	32.32 (229.97)	[−19.99, 84.88]	1,144	.46	.501
	Reaction Time Orientation	147	14.95 (197.28)	[10.06, 59.02]	98	44.70 (251.16)	[4.34, 102.31]	1,144	1.59	.208
	Reaction Time Control	147	102.05 (163.51)	[78.55, 132.76]	98	70.60 (229.65)	[18.44, 118.17]	1,144	.39	.534
Self-ordered	Selections Block 1	143	4.31 (1.06)	[4.09, 4.48]	94	4.67 (1.07)	[4.48, 4.94]	1,237	6.19	.014
	Selections Block 2	143	4.01 (1.03)	[3.88, 4.25]	94	4.13 (1.10)	[3.95, 4.45]	1,237	.49	.490
	Selections Block 3	143	5.80 (1.11)	[5.65, 6.04]	94	5.94 (1.30)	[5.68, 6.27]	1,237	.53	.466
	Selections Block 4	143	5.00 (1.21)	[4.78, 5.20]	94	5.38 (1.18)	[5.21, 5.75]	1,237	5.45	.019
TOL	Total Score	138	23,50 (13,71)	[21.50, 26.37]	92	18.56 (14.23)	[16.43, 23.04]	1,230	9.53	.002
Corsi	Total Score	146	11.62 (6.37)	[10.51, 13.57]	92	7.80 (3.83)	[6.82, 9.56]	1,238	19.11	.000
K-BITM	Total Score	146	13.45 (4.12)	[13.12, 14.44]	98	10.72 (4.03)	[10.25, 12.02]	1,244	29.71	.000

Note: SBN: Satisfied Basic Needs; UBN: Unsatisfied Basic Needs. All analyses were adjusted for age and gender.

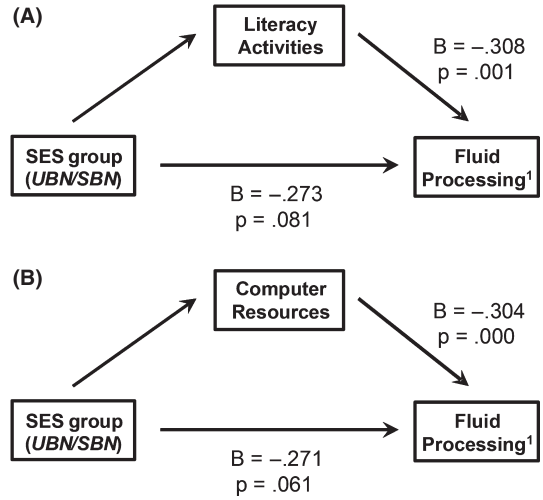

Figure 2 *Model testing the mediating effect of Literacy Activities (A) and Computer Resources (B) on the relationship between socioeconomic condition (UBN/SBN) and Fluid Processing. Note: [1]Corresponding to performance on K-BIT matrices.*

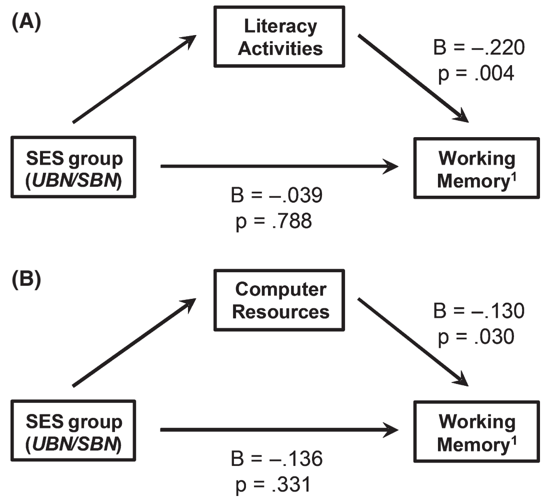

Figure 3 *Model testing the mediating effect of Literacy Activities (A) and Computer Resources (B) on the relationship between socioeconomic condition (UBN/SBN) and Working Memory. Note: [1]Spatial working memory corresponding to performance on Corsi Blocks.*

observed regarding classic approaches to absolute poverty (i.e. parental education and occupation, dwelling and overcrowding). In addition, this study proposes the inclusion of other factors considered as potential mediators in developmental psychology (Bradley & Corwyn, 2002), economics (Gordon *et al*., 2003; Minujin *et al*., 2006) and, more recently, by DCN (Hackman *et al*., 2010), such as preschool attendance, number of books in

Table 6 *Mediation model with dependent variables regressed on mediator and independent variables*

Cognitive domain (task)	DV	IV	MV	Direct effect				Indirect effect				% M
				Coef.	*SE*	Z	Sig	Sobel Coef.	*SE*	Z	Sig	
Attentional control[1]	Efficiency	SES group	Computer Resources	−.137	.116	−1.182	.237	−.112	.052	−2.140	.032	.450
Working memory[1]	Score	SES group	Literacy Activities	−.039	.148	−.268	.788	−.220	.080	−2.727	.004	.846
(Corsi)			Computer Resources	−.136	.140	−.971	.331	−.130	.060	−2.160	.030	.488
Fluid processing[2]	Score	SES group	Literacy Activities	−.273	.157	−1.739	.081	−.308	.094	−3,264	.001	.530
(K-BITM)			Computer Resources	−.271	.145	−1.869	.061	−.304	.079	−3,806	.000	.528

Note: DV: dependent variable; IV: Independent variable; MV: Mediator variable; %M: Proportion of total effect that is mediated. [1]Analysis was adjusted for age, gender and fluid intelligence. [2]Analysis was adjusted for age and gender.

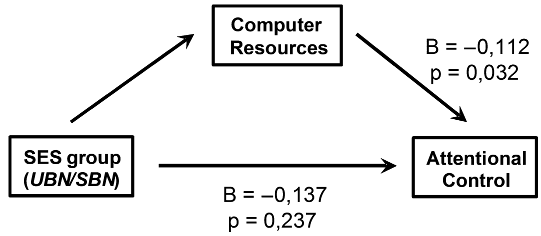

Figure 4 *Model testing the mediating effect of Computer Resources on the relationship between socioeconomic condition (UBN/SBN) and Attentional Control.*

households, frequency of reading to children, and use of computers and the Internet.

With the exception of preschool attendance, UBN children had been exposed to greater deprivation than SBN children in all domains. Regarding preschool attendance, UBN children had on average one more year of preschool experience than SBN children. Considering that preschool attendance is a valuable factor for development (Duncan, Ludwig & Magnuson, 2007), it is necessary to analyze the quality of cognitive stimulation within different developmental contexts (i.e. home, school) to understand why a potentially valuable factor could be associated with poverty. The mediation analysis that included these variables allowed the verification of significant and marginally indirect effects. The composite of *Literacy activities* was a mediator of SES effects on performance in tasks demanding spatial working memory and fluid processing, but not in attentional control, object working memory (i.e. Self-ordered) or planning. Moreover, *Computer resources* was a significant mediator for fluid processing and a marginal mediator in attentional control, but not in spatial and object working memory or planning. These different mediation effects are consistent with the hypothesis that no single environmental factor is likely to explain all socioeconomic effects, and that it is probable that specific factors mediate specific aspects of neurocognitive development (Duncan & Magnuson, 2012; Hackman *et al*., 2010). Healthcare access and cognitive stimulation are among the most important environmental factors proposed as mediators of the socioeconomic impact on cognitive development. Results in this study showed that children from UBN and SBN groups only differed in mediators related to the latter factor, such as books, frequency of reading, and computer and Internet use. Thus, not all the proposed mediators had indirect effects on the relationship between SES and cognitive performance, suggesting the importance of further explorations of other potential mediators associated with the experience of poverty from a child's perspective (Duncan & Magnuson, 2012; Lipina *et al*., 2011) and more recent indicators of child deprivation such as access to information (Gordon *et al*., 2003; Minujin *et al*., 2006).

From a neurocognitive perspective, these results contribute to the notion that cognitive control competences requiring a greater integration of basic processes (e.g. planning, attentional control, inhibitory control, and different working memory processes; Luciana & Nelson, 2002) will respond differently to deprivation. It is reasonable to consider the possibility that specific aspects of childhood poverty could be related to alterations in certain networks and not others, even within the same cognitive control domain. It would be fruitful to explore these hypotheses at the neural level of analysis with the use of neuroimaging techniques, such as the plasticity of the networks involved, as has been carried out in studies of neural mechanisms on the diffusion and focalization of cortical activities in learning processes by Durston and colleagues (Durston, Davidson, Tottenham, Galvan, Spicer, Fossella & Casey, 2006).

The use of computers and the Internet could mediate the relationship between socioeconomic status and cognitive performance demanding attentional control and working memory processes due to the specific demands of different software, games and search activities (e.g. Goldin, Segretin, Hermida, Paz, Lipina & Sigman, 2013; Green & Bavelier, 2012). In this sense, findings suggest the importance of exploring such processes in future studies at a neural level of analysis, to improve understanding of their plasticity (i.e. poverty effects and interventions). An analysis of these factors is also a valid example of how the inclusion of factors related specifically to the experience of poverty can be transferred to the realm of DCN.

Finding differences between disparate socioeconomic groups in some factors, but not all, mediating the relationship between SES and cognitive performance also suggests that the impact of poverty on control systems might not be uniform even within the same age group. This also implies the need to explore the hypothesis that the presence of deprivation does not necessarily mean the verification of impacts, thus implying that more factors should be analyzed. In this sense, this endeavor would contribute to overcoming major constraints in designing and implementing longitudinal studies at the neural level of analysis, to contribute to the exploration of the plasticity phenomena involved (i.e. interactive specialization). In addition, there is also a need to implement different types of mediation analyses (e.g. SEM), which could contribute to the identification of relationships between mediators and mediating mechanisms.

In contrast to expectations based on previous studies (Walker, Wachs, Gardner, Lozoff, Wasserman, Pollit, Carter & International Child Development Steering Group, 2007), this study has not verified any indirect effect of maternal mental health (despite the fact that UBN mothers evidenced significantly higher levels of anxiety and depression indicators) or of the temperamental dimension of effortful control. It is notable that children from both groups obtained similar scores. Both results suggest that there is a need to continue analyzing such factors as potential mediators, including diagnostic tools rather than screenings, while increasing sample sizes so that more variations among individuals are included.

In conclusion, the findings of this study allow us to advance the exploration of the social determinants and inequalities of child poverty in connection with executive control performance, suggesting the exploration of paths based on the integration of concepts of child poverty with more specificity in terms of how children experience different forms of deprivation. The findings also demonstrate the value of the behavioral approach in the context of DCN, building potential theoretical and methodological bridges between neuroscience and the social sciences (Lipina & Farah, 2011). Finally, this study has resulted in the creation of a Latin American preschool executive performance database, which could be used either in intervention programs or to test theoretical issues regarding control executive components and sub-processes.

Acknowledgements

This study was supported by the Fondo para la Investigación Científica y Tecnológica (FONCYT) (Grant: PICT-2005 Nro. 38202), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Centro de Educación Médica e Investigación Clínica 'Norberto Quirno' (CEMIC), Fundación Conectar, Ministery of Education of the City of Buenos Aires. The authors thank the communities from Schools 1, 3 (School Districts 8 and 11), NEA-2000 (School District 12), and Cayce Hook for her editing of the manuscript.

References

Boltvinik, J. (1995). *Poverty measurement methods: An overview*. Washington, DC: PNUD.

Bradley, R.H., & Corwyn, R.F. (2002). Socioeconomic status and child development. *Annual Review of Psychology*, **53**, 371–399.

Buss, C., Davis, E.P., Hobel, C.J., & Sandman, C.A. (2011). Maternal pregnancy-specific anxiety is associated with child executive function at 6–9 years age. *Stress*, **14**, 665–676.

Crone, E.A., & Ridderinkhof, K.R. (2011). The developing brain: from theory to neuroimaging and back. *Developmental Cognitive Neuroscience*, **1**, 101–109.

D'Angiulli, A., Herdman, A., Stapells, D., & Hertzman, C. (2008). Children's event related potentials of auditory selective attention vary with their socioeconomic status. *Neuropsychology*, **22**, 293–300.

Davidson, M.C., Amso, D., Anderson, L.C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, **44**, 2037–2078.

Duncan, G.J., Ludwig, J., & Magnuson, K.A. (2007). Reducing poverty through preschool interventions. *The Future of the Children*, **17**, 143–160.

Duncan, G.J., & Magnuson, K. (2012). Socioeconomic status and cognitive functioning: moving from correlation to causation. *WIREs Cognitive Science*, **3**, 377–386.

Duncan, J., & Owen, A.M. (2000). Common regions of the human frontal lobe recruited by diverse cognitive demands. *Trends in Neurosciences*, **23**, 475–483.

Durston, S., Davidson, M.C., Tottenham, N., Galvan, A., Spicer, J., Fossella, J.A., & Casey, B.J. (2006). A shift from diffuse to focal cortical activity with development. *Developmental Science*, **9**, 1–20.

Eviatar, Z. (2000). Culture and brain organization. *Brain and Cognition*, **42**, 50–52.

Farah, M.J., Betancourt, L., Shera, D.M., Savage, J.H., Giannetta, J.M., Brodsky, N.L., Malmud, E.K., & Hurt, H. (2008). Environmental stimulation, parental nurturance and cognitive development in humans. *Developmental Science*, **11**, 793–801.

Farah, M.J., Shera, D.M., Savage, J.H., Betancourt, L., Giannetta, J.M., Brodsky, N.L., Malmud, E.K., & Hurt, H. (2006). Childhood poverty: specific associations with neurocognitive development. *Brain Research*, **1110**, 166–174.

Fekete, T., Rubin, D., Carlson, J.M., & Mujica-Parodi, L.R. (2011). A stand-alone method for anatomical localization of NIRS measurements. *NeuroImage*, **56**, 2080–2088.

Gianaros, P.J., & Manuck, S.B. (2010). Neurobiological pathways linking socioeconomic position and health. *Psychosomatic Medicine*, **72**, 450–461.

Goldin, A.P., Segretin, M.S., Hermida, M.J., Paz, L., Lipina, S.J., & Sigman, M. (2013). Training planning and working memory in third graders. *Mind, Brain & Education*, **7**, 136–146.

Gordon, D., Nandy, S., Pantazis, C., Pemberton, S., & Townsend, P. (2003). *Child poverty in the developing world*. Bristol: Policy Press.

Green, C.S., & Bavelier, D. (2012). Learning, attentional control, and action review video games. *Current Biology*, **22**, 197–206.

Guo, G., & Mullan-Harris, M.K. (2000). The mechanisms mediating the effects of poverty on children's intellectual development. *Demography*, **37**, 431–447.

Hackman, D.A., & Farah, M.J. (2009). Socioeconomic status and the developing brain. *Trends in Cognitive Sciences*, **13**, 65–73.

Hackman, D.A., Farah, M.J., & Meany, M.J. (2010). Socioeconomic status and the brain: mechanistic insights from human and animal research. *Nature Reviews Neuroscience*, **11**, 651–659.

Hamilton, M. (1959). The assessment of anxiety states by rating. *British Journal of Medical Psychology*, **32**, 50–55.

Kishiyama, M.M., Boyce, W.T., Jimenez, A.M., Perry, L.M., & Knight, R.T. (2009). Socioeconomic disparities affect prefrontal function in children. *Journal of Cognitive Neuroscience*, **10**, 1–10.

Lipina, S.J., & Colombo, J.A. (2009). *Poverty and brain development during childhood*. Washington, DC: American Psychological Association.

Lipina, S.J., & Farah, M.J. (2011). Child poverty under the lens of cognitive neuroscience. *CROP Brief Series*, **6**, 1–3.

Lipina S.J., Martelli, M.I., Vuelta, B.L., & Colombo, J.A. (2005). Performance on the A-not-B task of Argentinean infants from unsatisfied and satisfied basic needs homes. *Interamerican Journal of Psychology*, **39**, 49–60.

Lipina, S.J., Martelli, M.I., Vuelta, B., Injoque Ricle, I., & Colombo, J.A. (2004). Pobreza y desempeño ejecutivo en alumnos preescolares de la ciudad de Buenos Aires (Argentina). [Poverty and executive performance in preschooler from the City of Buenos Aires (Argentina)]. *Interdisciplinaria*, **21**, 153–193.

Lipina, S.J., & Posner, M.I. (2012). The impact of poverty on the development of brain networks. *Frontiers in Human Neuroscience*, **6**, 238.

Lipina, S.J., Simonds, J., & Segretin, M.S. (2011). Recognizing the child in child poverty. *Vulnerable Children and Youth Studies*, **6**, 8–17.

Luciana M., & Nelson, C.A. (2002). Assessment of neuropsychological function through use of the Cambridge Neuropsychological Testing Automated Battery: performance in 4- to 12-year-old children. *Developmental Neuropsychology*, **22**, 595–624.

Mezzacappa, E. (2004). Alerting, orienting, and executive attention: developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Development*, **75**, 1373–1386.

Minujin, A., Delamonica, E., Davidziuk, A., & González, E.D. (2006). The definition of child poverty: a discussion of concepts and measurements. *Environment & Urbanization*, **18**, 481–500.

Noble, K.G., Farah, M.J., & McCandliss, B.D. (2006a). Socioeconomic background modulates cognition achievement relationships in reading. *Cognitive Development*, **21**, 349–368.

Noble, K.G., McCandliss, B.D., & Farah, M.J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science*, **10**, 464–480.

Noble, K.G., Norman, M.F., & Farah, M.J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science*, **8**, 74–87.

Noble, K.G., Wolmetz, M.E., Ochs, L.G., Farah, M.J., & McCandliss, B.D. (2006b). Brain–behavior relationships in reading acquisition are modulated by socioeconomic factors. *Developmental Science*, **9**, 642–654.

Pickering, S.J. (2001). The development of visuo-spatial working memory. *Memory*, **9**, 423–432.
Posner, M.I., & Raichle, M.E. (1994). *Images of mind*. Washington, DC: American Psychological Association.
Raizada, R.D., & Kishiyama, M.M. (2010). Effects of socioeconomic status on brain development and how cognitive neuroscience may contribute to leveling the playing field. *Frontiers in Human Neuroscience*, **5**, 1–26.
Raizada, R.D.S., Richards, T.L., Meltzoff, A., & Kuhl, P.K. (2008). Socioeconomic status predicts hemispheric specialization of the left inferior frontal gyrus in young children. *NeuroImage*, **40**, 1392–1401.
Rao, H., Betancourt, L., Giannetta, J.M., Brodsky, N.L., Korczykowski, M., Avants, B.B., Gee, J.C., Wang, J., Hurt, H., Detre, J.A., & Farah, M.J. (2010). Early parental care is important for hippocampal maturation: evidence from brain morphology in humans. *NeuroImage*, **49**, 1144–1150.
Roselli, M., & Ardilla, A. (2003). The impact of culture and education on non-verbal neuropsychological measurement: a critical review. *Brain and Cognition*, **52**, 326–333.
Rueda, M.R., Rothbart, M.K., McCandliss, B.D., Saccomanno, L., & Posner, M.I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences, USA*, **102**, 14931–14936.
Sarsour, K., Sheridan, M., Jutte, D., Nuru-Jeter, A., Hinshaw, S., & Boyce, W.T. (2011). Family socioeconomic status and child executive functions: the roles of language, home environment, and single parenthood. *Journal of International Neuropsychology Society*, **17**, 120–132.
Shallice, T. (1982). Specific impairments of planning. *Philosophical Transcripts of the Royal Society of London*, **298**, 199–209.
Sperber, D., & Hirschfeld, L.A. (2004). The cognitive foundations of cultural stability and diversity. *Trends in Cognitive Sciences*, **8**, 40–46.
Stevens, C., Fanning, J., Coch, D., Sanders, L., & Neville, H.J. (2008). Neural mechanisms of selective auditory attention are enhanced by computerized training: electrophysiological evidence from language-impaired and typically developing children. *Brain Research*, **1205**, 55–69.
Stevens, C., Lauinger, B., & Neville, H. (2009). Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: an event-related brain potential study. *Developmental Science*, **12**, 634–646.
Tomalski, P., & Johnson, M.H. (2010). The effects of early adveristy on the adult and developing brain. *Current Opinion in Psychiatry*, **23**, 233–238.
Walker, S.P., Wachs, T.D., Gardner, J.M., Lozoff, B., Wasserman, G.A., Pollit, E., & Carter, J.A., & International Child Development Steering Group (2007). Child development: risk factors for adverse outcomes in developing countries. *Lancet*, **369**, 145–157.

Received: 11 April 2013
Accepted: 12 April 2013