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School performance and poverty: the mediating role of executive functions

Korzeniowski, C.[1], Cupani, M.[2], Ison, M.[3] & Difabio, H[4].

[1] Institute of Human, Social and Environmental Sciences (INCIHUSA-CONICET). Scientific-Technological Center (CCT Mendoza - CONICET), Argentina.
[2] Personality Psychology Laboratory - CIPSI - Group linked to the Culture and Society Research and Study Center (CIECS) – CONICET. School of Psychology, National University of Cordoba, Argentina.
[3] Institute of Human, Social and Environmental Sciences (INCIHUSA-CONICET). Scientific-Technological Center (CCT Mendoza - CONICET), Argentina.
[4] Cuyo Research Institute (CIC) - CONICET - Mendoza, Argentina.

Argentina

Correspondence: Celina Korzeniowski. Av. Ruiz Leal s/n (CP 5500), Parque General San Martín, Mendoza. Argentina. E-mail: ckorzeniowski@mendoza-conicet.gob.ar

Abstract

Introduction. This study aims at analyzing whether EFs may predict the SP of children from different low socioeconomic strata, having controlled the effects of age and socioeconomic status (SES).

Method. The sample included 178 Argentine children of both genders (52% boys), between 6 and 10 years of age, belonging to the upper-low SES (41%), lower-low SES (39%) and marginal SES (20%). The children were evaluated by means of a battery of neuropsychological EF and school achievement tests.

Results. The proposed model accounted for 69% of the SP of the children. EFs were the most significant direct predictor and, in addition, mediated the relationship between SES and SP.

Conclusion. In line with previous findings, these results indicate that the impoverishment of family material and sociocultural conditions is associated with a lower EF performance among children, which negatively impacts their SP.

Keywords: school performance, executive functions, socioeconomic status, poverty, Argentine children

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Resumen

Introducción. El presente trabajo tiene como objetivo analizar si las funciones ejecutivas (FE) predicen el rendimiento escolar (RE) de niños pertenecientes a diferentes estratos socioeconómicos bajos, controlando el efecto de la edad y del nivel socioeconómico (NSE).

Método. La muestra estuvo compuesta por 178 niños argentinos de ambos sexos (52% varones), de 6 a 10 años de edad, pertenecientes a NSE Bajo Superior (41%), Bajo Inferior (39%) y Marginal (20%). Los niños fueron evaluados con una batería de tests neuropsicológicos de FE y con tests de aprovechamiento escolar.

Resultados. El modelo propuesto explicó el 69% del RE de los niños. Las FE fueron el predictor directo más significativo y, además, mediaron las relaciones entre NSE y RE.

Conclusión. El empobrecimiento de las condiciones materiales y socioculturales de la familia, se asocia con un menor desempeño de las FE en los niños, lo que repercute negativamente en su RE.

Palabras Clave: rendimiento escolar, funciones ejecutivas, nivel socioeconómico, pobreza, niños argentinos.

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Introduction

School performance (SP) is a complex process involving multiple personal and contextual factors. The persistent educational gap between socioeconomically advantaged and disadvantaged children, which plays a central role in the intergenerational transmission of poverty (Crook & Evans, 2014; Fitzpatrick, McKinnon, Blair & Willoughby, 2014; Hackman, Farah & Meaney, 2010), is an issue of constant concern. The probability of never attending school is four times higher among the poorest children in the world than among the wealthiest ones, and that of completing primary school without achieving basic competencies is five times higher (United Nations Organization for Education, Science and Culture [UNESCO], 2015). Latin America is one of the regions with the highest rates of educational inequality in the world: poor children who live in rural areas have a higher probability than their urban counterparts from affluent households of repeating a primary school grade and abandoning elementary education (Regional Bureau for Education in Latin America and the Caribbean [OREALC/UNESCO], 2015).

This situation is worsened by the existence of different schooling circuits, depending on the social origin of pupils, resulting in poorer school performance by low socioeconomic strata children compared to children from medium or high socioeconomic strata (National Board of Information on and Assessment of Education Quality [DiNIECE], 2013; Enríquez, 2011; Krüger, 2013; OREALC/UNESCO, 2015). These educational inequalities emerge early during childhood and become more robust across primary and secondary school, leading to less successful educational achievements and a lower income in adulthood (Blair & Raver, 2014; Diamond & Lee, 2011). Consequently, understanding how poverty conditions cause an early academic and long-lasting risk in children is of utmost importance (Fitzpatrick et al., 2014).

A possible line of study is the analysis of the effects of poverty upon cognitive development, specifically upon executive functions (EFs), as these are considered to be one of the cognitive systems that are most sensitive to environmental influence (Hackman et al., 2010; Noble, MacCandliss & Farah, 2007). EFs involve a set of high order cognitive functions that control and regulate behaviors, emotions and cognitions necessary to reach goals and solve problems (Diamond, 2013). Different studies reveal that EFs are one of the

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most significant SP predictors from preschool age to adulthood (Best, Miller & Naglieri, 2011; Checa & Rueda, 2011; Diamond, 2013; Welsh et al., 2010), which is largely grounded on to the fact that the suitable development of EFs helps children keep focused on relevant task information, control distractors, plan, organize and monitor their learning process, develop strategies to reach a goal, detect mistakes, consider different problem solutions, and reflect upon thoughts and actions (Blair & Raver, 2014).

During school age, children attain great progress in EFs and school competencies simultaneously, which suggests an overlapping of development processes (Fuhs, Nesbitt, Farran & Dong, 2014). In fact, the first school grades reveal a peak in the strength of correlations between EFs and SP (Best et al., 2011; Welsh et al.; 2010). Therefore, the intense development of cognitive control functions that is reported from 6 to 8 years of age, and from 10 to 12 years of age (Flores-Lázaro, Castillo-Preciado & Jiménez-Miramonte, 2014; Hughes, 2011), could be considered a potential factor that may facilitate learning and child performance in the classroom.

However, the relationships between EFs and SP are mediated by multiple factors, one of them being the quality of the cognitive stimulation received at early childhood. It has been reported that poverty-stricken children at social risk show poorer performance in terms of attention, working memory, planning, inhibitory control, verbal fluency, cognitive flexibility, organization, metacognition and monitoring (Arán Filippetti & Richaud de Minzi, 2012; Hackman et al., 2010; Ison, Greco, Korzeniowski & Morelato, 2015; Lipina et al., 2011; Musso, 2010; Noble et al., 2007). This cognitive development alteration is associated with behavior problems, school failure, problematic social bonds, all of which impact learning during childhood and predict a poorer educational level (Diamond & Lee, 2011).

This is largely due to the fact that the atmosphere where disadvantaged children are raised is frequently characterized by chronic stress situations and the absence of stimulating experiences that boost EFs (Fitzpatrick et al., 2014). It has been documented that parents who achieved a lower educational level do not read much to their children, have poorer dialogue abilities, use a less complex discourse and a more limited vocabulary while interacting with their sons and daughters, which is associated with poorer linguistic and cognitive resources on the part of children (Ardila, Rosselli, Matute & Guajardo, 2005; Hoff, 2003). All these factors

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together decrease the quality of cognitive stimulation, in addition to making households deficient in material resources and tools available to stimulate learning (Bradley & Corwyn, 2002).

In sum, poverty impacts school performance by means of multiple mechanisms, and EFs can be a mediating factor in that impact. In fact, some studies (Fitzpatrick et al., 2014; Nesbitt, Baker-Ward & Willoughby, 2013) in US preschoolers have shown that cognitive control functions in children mediated the relationship between socioeconomic status (SES) and school performance in math and reading tasks. Another study performed in US children of different ethnical origin evidenced that household SES measured at early childhood (1 to 24 months of age) predicted the children’s math and reading abilities in later school grades (grade 5), and that this relationship was mediated by planning abilities (Crook & Evans, 2014). Therefore, based on prior results and assuming that, as poverty conditions worsen, the academic risk of children increases, the objective of this paper is to analyze whether EFs mediate the relationships between poverty gradients and school performance in Argentine 6- to 10-year olds.

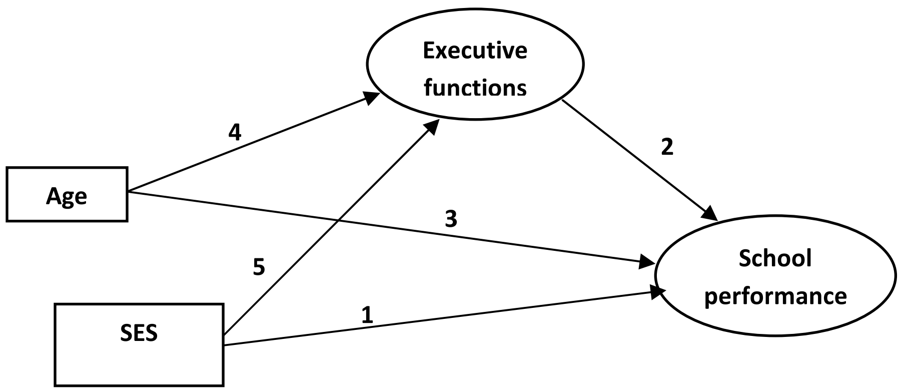

Figure 1. Predictors of school performance in children. *Note*: SES reports poverty gradients.

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Figure 1 shows a graphic representation of an academic performance model. According to prior studies (i.e. Checa & Rueda, 2011; Crook & Evans, 2014; Davidson, Amsoa, Anderson & Diamond, 2006; Diamond, 2013; Fuhs et al., 2014; Hackman et al., 2010; Lipina et al., 2011; Noble et al., 2007; DiNIECE, 2013; Welsh et al., 2010), we posit that SES (*path* 1), EFs (*path* 2) and Age (*path* 3) have a direct and positive incidence on SP. In addition, EFs are considered to modulate SP in primary schoolers, after controlling the effect of age (*path* 4) and the child's socioeconomic strata (*path* 5).

Objectives and hypothesis

The *specific objectives* of our study were:

1. Analyze whether executive functions predict school performance in Argentine children, after controlling the effect of age and the child's socioeconomic stratum.
2. Explore whether executive functions mediate the relationships between poverty gradients and school performance in the children included in the study.

Work hypotheses were based on the proposed theoretical model (Figure 1) and were the following:

1. School performance is predicted by the children's age, their family socioeconomic status and executive functions.
2. Executive functions partially account for the socioeconomic differences observed in children's school performance.

Method

Participants

We used a non-probabilistic intentional sample composed of 178 Argentine 6- to 10-year old school boys and girls (52% boys), (M = 7.24, SD = 1.17), from Upper Low (41%), Lower Low (39%) and Marginal (20%) SES. These children attended from 1st to 3rd primary school grades in two public, urban, marginal schools in Mendoza (Argentina). In order to participate in the study, children had to be authorized by their parents or legal guardians under

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a written consent. Children who a) presented neurological, psychological or psychiatric disorders; b) had previously been diagnosed with learning disorders; and c) were two or more years older than the regular age for the school grade were excluded from the study.

Instruments

Escala Magallanes de Atención Visual [Magellan visual attention scale] (EMAV, for its initials in Spanish, García-Pérez & Magaz-Lago, 2000). This is a continuous execution visual test in which participants have to recognize figures that match a target from among a set of different shapes. It evaluates focused and sustained attention. This instrument has been adapted for Argentine 6- to 12-year old school children (Carrada, 2011). The reliability index estimated with the halving method was high (*rho* = .89). The reliability index for the sample under study was satisfactory (*rho* = .87).

Porteus Maze Test [PMT] (Porteus, 2006). This test measures planning abilities and inhibitory control. It consists of ten mazes ordered by increasing difficulty. Participants must solve the task taking into account three rules: not to lift the pencil while they trace their way through the maze, not to cross lines and avoid blind alleys. The PMT has a moderately high internal consistency (α = 0.80, Krikorian & Bartok, 1998). Our research study used the Porteus Quality Index (Marino, Fernández & Alderete, 2001) to rate planning abilities and the adaptation of Q scores (Korzeniowski, 2015) to rate the inhibitory control function. In this sample, the internal consistency indices for the planning scores (α = 0.81) were satisfactory. Similarly, the inter-examiner reliability for the nine items that make up the Q score was acceptable (the Intraclass Matching Ratio [IMR] ranged between .79 to .99).

Concept Formation of the Woodcock-Muñoz Tests of Cognitive Ability (Muñoz-Sandoval, Woodcock, Mc Grez & Mather, 2005). This test assesses categorical reasoning and flexibility in thinking. It is administered to individual subjects, who have to perform a controlled learning task where a rule or a concept needs to be identified from among a set of visual stimuli presented. The reliability of this instrument for the age range from 5 to 19 years old is *rho* = .94 (Muñoz-Sandoval et al., 2005). The reliability obtained with the study sample was satisfactory (*rho* = .80).

A metacognitive interview for children (Lucangeli & Cornoldi, 1997). This is a semi-structured interview consisting of 8 questions, 4 of which are open, while the other 4 have a Likert format to assess the child's metastrategic knowledge relative to a categorization task and flexibility in thinking. The interview is divided into two parts. The first part rates prediction and planning abilities, so it is administered before the subject carries out the proposed task. The second part of the interview measures monitoring and evaluation abilities and is administered immediately after the task is completed. For the open questions, the level of agreement among examiners was estimated (IMR from .86 to .95), while for the four Likert items, internal consistency was estimated ($\alpha = 0.52$).

Woodcock-Muñoz Achievement Tests (Woodcock & Muñoz-Sandoval, 1996). In this study, three subtests that form part of this battery and can be used individually from 3 years of age until adulthood were administered. *Letter-Word Identification.* This test measures reading skills to identify a letter or a word accurately and quickly. Items increase in difficulty: vowels, consonants, frequent words and unusual words. This test has a high average internal consistency (*rho* = .92). For the study sample, an excellent reliability ratio was obtained (*rho* = .98). *Dictation***.** This test is administered as a traditional dictation test and measures basic writing skills (letter drawing, punctuation and word spelling). Items increase in difficulty. The reliability of this instrument is *rho* = .91. For the study sample, *rho* = .92. *Applied problems***.** This test measures the ability to analyze and solve practical math problems. It consists of 59 verbal problems with graphic or written support arranged by increasing difficulty. Reliability is *rho* = .91. The reliability obtained for the study sample was satisfactory (*rho* = .81).

Socioeconomic status (SES) (Comisión de Enlace Institucional, 2006). This index rates the socioeconomic status of a household through indirect variables, excluding income level. It has two main variables: level of employment and level of education of the main household provider. It also has secondary variables, such as access to health care systems. For this study, the two main variables were used to assess family SES.

Procedure

An authorization from the General School Authority in Mendoza province was obtained, as well as from the principals of each participating school. Parents were asked to sign an informed consent to their children's participation in the study. Authorized children

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were explained the characteristics of the tasks that would be conducted, were invited to participate on their own free will and were informed of their rights as study subjects. Children were evaluated by the main author of this paper in four 30-minute sessions. Evaluations were performed in a well-aerated and well-illuminated classroom selected by the school for this purpose. In the first session, EMAV was administered to the whole group. Over the three remaining sessions, the EF and school achievement tests were administered individually. The procedure was developed in accordance with international ethical standards (American Psychological Association, 2002) and was accepted by the Ethics Committee of the Institute of Human, Social and Environmental Sciences from CONICET-Argentina.

Data analysis

Three steps were implemented to develop the data for the proposed analyses. First, missing value patterns were evaluated to identify whether they presented a random distribution by using the SPSS 19 missing value analysis routine. The second step identified univariate atypical cases by applying standard score calculation to each variable. Cases with a z score higher than 3.29 (two-tailed test, $p<0.001$) were considered atypical. Before discarding any value, the Mahalanobis distance test was performed with $p<0.001$ to detect multivariate atypical cases (Tabachnick & Fidell, 2001). As a third step, the assumptions of normality for the study sample were corroborated by an analysis of asymmetry and kurtosis of each variable. As a criterion to evaluate asymmetry and kurtosis indices, values comprised from +1.00 to -1.00 were rated as excellent, while values below +2.00 and -2.00 were rated as acceptable (George & Mallery, 2011). Our last analysis diagnosed multicollinearity to estimate the existence of highly correlated or redundant variables ($r \geq 0.90$).

The AMOS 19.0 software (Arbuckle & Wothke, 1999) was used to evaluate the Structural Equation Modeling, including the Maximum Probability approach as the estimation method. Model adjustment was evaluated by the chi-square statistic, the relationship between chi-square and the degrees of freedom (CMIN/DF), the comparative fit index (CFI), the goodness-of-fit index (GFI), the root mean square error of approximation (RMSEA) and the standardized root mean square residual (SRMR). For this study, the following criteria were applied to the goodness-of-fit: the relationship between chi-square and the degrees of freedom with values lower than 3.0 (Kline, 2011); CFI and GFI indices with values from 0.90 to 0.95 or higher (considered as an acceptable to excellent fit) and, finally, for RMSEA and SRMR, values from 0.05 to 0.08 (Hu & Bentler, 1995). Last, the indirect and total effects of the model variables were analyzed by bootstrapping (Efron, 1979). Different data simulation research studies (MacKinnon, Lockwoo & Williams, 2004) revealed that this procedure enables a stricter control of Type I Error and that it is advisable to use this method instead of the Sobel test. The Monte Carlo parametric bootstrapping approach was used to apply this method, estimating the 95% confidence intervals (BC, bias corrected) and 1,000 randomly selected samples were generated on the basis of data.

Results

Data preparation

Missing values did not exceed 5%, so they were accounted for using the Expectation-Maximization algorithm. Nine univariate atypical cases were then discarded (4.8%), which gave us a sample of 178 children. Asymmetry and kurtosis indices ranged from -2.00 to +2.00 to be considered acceptable for the proposed parametric analyses (George & Mallery, 2011). The multicollinearity analysis showed a high correlation, with a value of 0.89, between two achievement tests, while the remaining correlations were moderate. Table 1 shows the inter-correlations among the studied variables in participant children.

Table 1. *Descriptive statistics and bivariate correlations between cognitive, school performance, age and SES variables in school children (n=178)*

	M	*SD*	1	2	3	4	5	6	7	8	9	10
1. Attention	0.25	0.14										
2. Cognitive flexibility	13.11	4.82	0.35**	-								
3. Planning	4.26	1.93	0.41**	0.45**	-							
4. Inhibitory control	8.07	4.09	-0.22**	-0.14	-0.21**	-						
5. Metacognition	6.80	2.63	0.13	0.52**	0.24**	-0.02	-					
6. Word identification	23.00	15.4	0.53**	0.41**	0.40**	-0.30**	0.19*	-				
7. Practical problems	19.79	3.72	0.55**	0.59**	0.37**	-0.20**	0.33*	0.67**	-			
8. Dictation	17.55	7.31	0.51**	0.42**	0.39**	-0.27**	0.22**	0.89**	0.70**	-		
9. Age	7.24	1.17	0.43**	0.19**	0.36**	-0.24**	0.03	0.60**	0.52**	0.59**	-	
10. SES			0.08	0.21**	0.11	-0.16*	0.12	0.09	0.07	0.13	0.04	-

Note: ** $p < 0.01$ (bilateral). * $p < 0.05$ (bilateral). SES = socioeconomic status. [a] Correlations between SES and the other variables were calculated with the Spearman's Rho statistic.

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Evaluation of the proposed model

A two-stage estimation was applied to the structural equation model (Kline, 2011). First, the measurement model was evaluated to examine the latent structure underlying the different measurements and, then, the structural model was evaluated to observe the fit and the variance between variables.

Measurement model. A measurement model was evaluated composed of two latent variables and 8 indicators as observable variables with their respective measurement errors. The quantity of indicators per latent factor ranged from 3 to 5. Obtained statistics suggest that this model did not achieve an acceptable fit to data (GFI = 0.89; CFI = 0.88; RMSEA = 0.14). An examination of the modification indices seemed to evidence content overlapping between two indicators (*flexibility* and *metacognition*). Therefore, the covariance parameter was included among the errors in the model and the model then became acceptable (CFI = 0.93, GFI = 0.94, RMSEA= 0.11). Standardized regression weights ($p \leq 0.05$) in the Executive Functions factor ranged from 0.28 to 0.68, and from 0.75 to 0.94 in the School Performance factor.

Structural model. The structural model is shown in Figure 2, where the standardized *path* ratios and the determination ratios can be observed (R^2). Results show an acceptable model fit to the data ($X^2_{(31, 178)} = 83.43$, $p<0.001$, CFI = 0.93, GFI = 0.93, RMSEA = 0.09 and CMIN/DF = 2.69) and accounted for 69% of school performance.

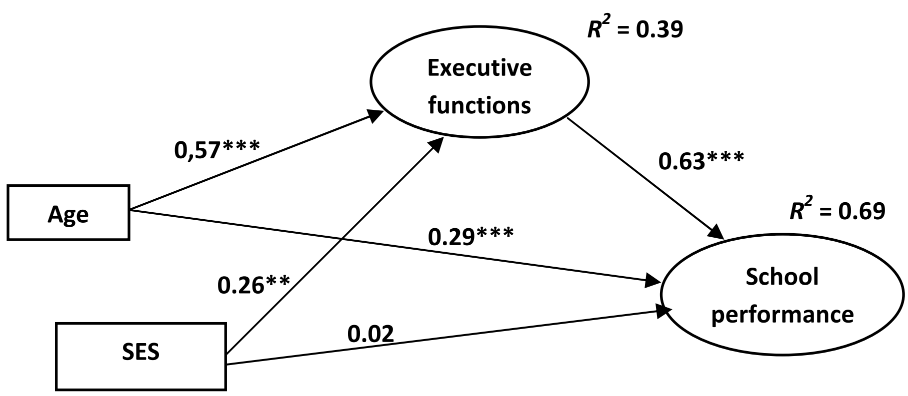

Figure 2. Structural equation model testing the impact of age, poverty and executive functions on school performance in children. *** $p<0.001$, ** $p<0.01$.

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Direct, indirect and total effects were analyzed to determine whether data actually accounted for the proposed relationships. As proposed (*path* 2 and *path* 3), the variables EF (β = 0.63) and age (β = 0.26) presented a statistically significant standardized *path* ratio and in a positive direction in terms of academic performance. Contrary to what was described (*path* 1), SES (β = 0.02) did not have a direct or significant contribution to performance. The model accounted for 39% of the variance of the EF variable. As proposed in the model (*path* 4 and *path* 5), age (β = 0.57) and SES (β = 0.26) presented a statistically significant standardized *path* ratio and in a positive direction in terms of EF, showing that as children grew older or belonged to a less disadvantaged socioeconomic stratum, their EF increased.

Analysis of indirect and total effects

EFs were observed to mediate significantly the age-SP ratio (β = 0.36), showing that as children grew older, their cognitive control functions improved, which was associated with significantly better school competencies. The total effect of the age variable on SP (β = 0.62) was statistically significant. Finally, EFs were observed to mediate significantly the relationship between SES and SP (β = 0.16), showing that as children belonged to a less poor socioeconomic stratum, their EFs improved and so did school performance. In summary, these findings suggest that cognitive control functions were the most significant direct predictor of SP in participant children and that, in addition, they mediated the relationships between poverty and SP, and between age and SP.

Discussion

Poverty impacts school performance through multiple ways, one of them being child cognitive development. This study conducted in Argentine primary schoolers supports this assumption. Our results show that, based on controlled effects of age and SES, SP was actually predicted by cognitive control functions in children from low socioeconomic strata. These data strengthen and expand prior studies that corroborated the critical role of EFs in school performance (Best et al., 2011; Diamond, 2013; Welsh et al., 2010).

An important difference between this and earlier studies is the integration into the EF construct of a set of rarely used indicators, such as planning and metacognition. The EF latent

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variable usually includes working memory, inhibitory/attentional control and flexibility (Nesbitt et al., 2013). However, cognitive demands increase as children progress along their school paths, which requires from them more and more abilities to plan tasks, solve problems and monitor their own thought processes and actions; hence the importance of spiking the latent variable with complex EFs.

Another interesting difference is to have found evidence about the mediating role of EFs in the relationship to poverty conditions and school performance in a sample of Latin American children. Earlier studies tested these relationships by comparing low- and high-socioeconomic strata US children (Crook & Evans, 2014; Fitzpatrick et al., 2014; Nesbitt et al., 2013). Our reported results are enhanced by the fact that SES did not modulate directly the SP of these schoolers, consistently with prior studies reporting that the SES evaluated as a construct is not normally a sensitive predictor of school performance differences (Crook & Evans, 2014; Nesbitt et al., 2013). However, this study showed that sociocultural conditions in the household predicted the children's cognitive performance, thus also impacting their school competencies.

Another remarkable aspect is the incorporation of the *age* variable into the model to control its effect on cognitive and school performance. On the one hand, results show that as children grow older, school performance improves significantly. Although this is in line with the gradual nature of education in Argentina, it is indeed an interesting finding because it contradicts the assumptions that posit a cumulative effect of *poverties* (Krüger, 2013) to the detriment of the school performance of children at social risk. In our study, older children evidenced higher reading, writing and problem resolution competencies than their younger counterparts. This is actually encouraging and supports earlier studies considering urban marginal schools as institutions that can promote practices and conditions to soften the children's original sociocultural differences in favor of quality learning (Enríquez, 2011).

In addition, results show that the evolutionary development of EFs helps improve children's proficiency at school competencies, in line with prior research reporting the importance of strengthening and improving EFs as a way to boost school learning (Best et al., 2011; Blair & Raver, 2014; Diamond & Lee, 2011; Welsh et al., 2011).

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However, this study is not free from *limitations*, one of them being the fact that the SES measure we used did not have predictive value regarding the school performance of participants. Even though this difficulty is likely to be associated with a lower sample variability, as participants belonged to a socially vulnerable population, there could be an alternative explanation: the index applied to capture sociocultural differences associated with different poverty strata was one of limited capacity. It may have been necessary to factor in, for example, overcrowding, collection of state subsidies, availability of material resources and utilities, cultural capital, access to health care systems. Therefore, it is suggested that future studies use an SES construct that can identify the poorest households' sociocultural variations that modulate SP more precisely.

Not using a longitudinal design or including in the model variables such as CI, processing speed, language development, curriculum design, reported in earlier studies as significant predictors of SP (Arán Filippetti & Richaud de Minzi, 2012; Blair & Raver, 2014; Crook & Evans, 2014; Nesbitt et al., 2013) was a second limitation of our work. New research studies should test our findings by adding the referred to control variables. Finally, our reported results need to be looked at from a contextualized perspective, as they apply to primary schoolers from socially vulnerable areas in Argentina, so they cannot be generalized to children from other regions or socioeconomic statuses. It would be interesting to test the proposed model with different Latin American populations encompassing a larger socioeconomic heterogeneity.

In brief, this study provides continuity to recent work reporting that EFs partly account for school performance differences caused by the effect of sociocultural disparities in the family (Crook & Evans, 2014; Fitzpatrick et al., 2014; Nesbitt et al., 2013). Its major contribution is to have observed a pattern of transitive relations between poverty gradients, EFs and SP. To our knowledge, this is one of the first studies to have inspected these relations in a sample of Argentine primary schoolers.

Conclusion

Poverty creates an early and long-lasting academic risk in children. Therefore, identifying children's characteristics that can contribute to reducing this risk is a necessary link to narrow the persistent economic and sociocultural gap associated with extreme poverty. This study strengthens prior evidence describing EFs as a cognitive system that is sensitive to the environmental experience, as it documents that EFs can partially account for SP differences among children, associated to the multiple sociocultural configurations found among the poorest socioeconomic statuses. Our results highlight the importance of implementing cognitive stimulation programs or curriculum designs oriented to strengthening cognitive control functions in socioeconomically challenged children with a view to succeeding in school performance.

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