

Socioeconomic Status, Urbanization and Executive Functions Development: Differences Between Urban and Rural Children*

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ABSTRACT – Socioeconomic Status (SES) has been linked to the development of Executive Functions (EF) usually by means of parental education and family income. Living conditions related to urbanization characteristics are rarely considered. This cross-sectional study investigated the performance in EF tasks of 99 Brazilian children aged 6 to 8 years residing in rural and urban regions. Results showed that children who lived in the rural area performed better than those who lived in the industrial city in the working memory and inhibitory tasks. Social interactions and urbanization conditions, such as parent occupations and social stratification, may explain these differences. Therefore, urbanization conditions of locations where families live should be considered in future studies concerning the influences of SES in EF development.

KEYWORDS: Executive Functions, socioeconomic status, child development

Status Socioeconômico, Urbanização e Desenvolvimento de Funções Executivas: Diferenças entre Crianças Urbanas e Rurais

RESUMO – O Status Socioeconômico (SES) tem sido vinculado ao desenvolvimento das Funções Executivas (FE), geralmente por meio da educação dos pais e da renda familiar. As condições de vida e a urbanização raramente são consideradas. Este estudo transversal investigou o desempenho em tarefas de FE de 99 crianças brasileiras de 6 a 8 anos residentes em regiões rurais e urbanas. Os resultados demonstram crianças residentes na zona rural obtendo desempenho superior às em cidade industrial em memória operacional e tarefas inibitórias. As interações sociais e as condições de urbanização, como ocupações dos pais e estratificação social, podem explicar essas diferenças. Portanto, as condições de urbanização devem ser consideradas em estudos futuros sobre as influências do SES no desenvolvimento do EF.

PALAVRAS-CHAVE: Funções Executivas, nível socioeconômico, desenvolvimento infantil

The concept of Executive Functions (EF) refers to a set of cognitive skills generally associated with intentional processing of stimuli and goal-directed behavior (Miyake et al., 2000). Three core components of EFs, *working memory*, *inhibitory control*, and *cognitive flexibility*, are crucial for the expression of fluid intelligence (Best & Miller, 2010; Diamond, 2013). *Working memory* (WM) is the ability to mentally sustain and manipulate information necessary to accomplish complex tasks (Baddeley, 2000). *Inhibitory control* (IC) allows an individual to inhibit an automatic

response to a specific task, or in a social situation that is rapidly interpreted as inappropriate (Nigg, 2001). This ability is also associated with selective attention, allowing the individual to discriminate relevant from irrelevant stimuli, and reducing demands on information processing (Gazzaniga et al., 2002). Verbal fluency skills are also associated with IC, due to the demand on working memory and inhibition in lexical access (Moura & Pereira, 2013; Seabra et al., 2014). Problems in IC are usually defined as impulsivity (Malloy-Diniz et al., 2008). *Cognitive Flexibility* (CF) refers to an

*The agreement with the Coordination for the Improvement of Higher Education Personnel (CAPES) and Violet Kozloff of Brain Organization for Language & Literacy Development (BOLD) Lab - University of Delaware.

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■ Submetido: 10/07/2020; Aceito: 12/02/2021.

individual's ability to promptly adapt responses according to changes in activities or situations (Craig et al., 2008).

There is much evidence that well-developed EFs are strongly associated with academic achievement (Blair & Razza, 2007; Duncan et al., 2007; Lan et al., 2011; Engel de Abreu et al., 2015) and behavioral regulation (Espy et al., 2011). These associations may be observed as early as the preschool years. For instance, in a sample of 3- to 5-year-old children, Blair and Diamond (2008) identified significant interactions between aspects of self-regulation and math and literacy outcomes, independent of general intelligence performance. More recently, Ribner et al. (2017) found that, among a large sample of low-income American children living in rural areas, performance in EF tasks at age 5 (before beginning elementary school) predicted academic achievement at 5th grade.

The development of EFs depends on prefrontal cortex (PFC) maturation, a long-term process determined by a complex interaction of neurobiological and environmental factors (Huizinga et al., 2006; Kolb et al., 2012). Consequently, the development of individual EF components differs by age range. While inhibitory control skills show greater development during the preschool period than in later years, working memory and cognitive flexibility develop more linearly throughout maturation (for a review see Best & Miller, 2010). The maturation of the neural circuitry that integrates frontal, limbic, and striatum structures consolidates near adolescence (Natale, 2007). At this age, individuals become progressively more able to assess the possibility of success or failure of actions directed toward established goals, to postpone decisions for a deeper analysis of a situation, and evaluate potential rewards (Casey et al., 2008). The slow maturation of the PFC allows increased opportunity for environmental influence on the development of EFs (Nelson & Guyer, 2011). The intrinsic connections between children's experiences and neurobiological maturation may explain why cognitive development changes constantly in both progressive and regressive ways (O'Hare & Sowell, 2008).

Extensive evidence demonstrates that the exposure of the developing brain to adaptive or aversive environmental events, such as sensory stimulation, stress, and parental interactions, affect neural structure and connectivity (Kolb et al., 2012). There is an increasing interest in the influence of Socioeconomic Status (SES) on the development of neurocognitive abilities, including EF, and on academic and social outcomes (Hackman & Farah, 2009; Hackman et al., 2010). SES is usually related to family conditions, such as income and parental education level, as well as to local community conditions such as access to public resources (Lederbogen et al., 2011).

The bioecological theory of development, proposed by Uriel Bronfenbrenner (1996), considers SES in a broad perspective that includes the complex relationships that a child establishes in a particular setting, such as school.

According to this theory, SES must also consider specific cultural, political, and social structures that affect quality of life, such as neighborhood and government institutions. These combined socioeconomic aspects, for instance, the availability of toys and books in the home, opportunities for family outings, and the nature of parental supervision of school activities, may influence the development of neurocognitive abilities (Marturano, 2006).

Socioeconomic vulnerability may cause maternal stress as early as the prenatal period and lead to a low quality parental care, affecting the development of EFs from the earliest years (Hackman et al., 2010; Sarsour et al., 2011). Working memory (Hackman, et al., 2014), verbal fluency (Ardila et al., 2005), language skills (Noble et al., 2007), attention and cognitive control (Stevens et al., 2009), and inhibitory control and cognitive flexibility (Sarsour et al., 2011) have been found to be particularly vulnerable. Andrade et al. (2005) investigated the association between quality of home life and cognitive development in a sample of 350 Brazilian children aged 17 to 42 months. The *Home Observation for Measurement of the Environment Scale* was used for the evaluation of SES. Results showed that children younger than 5 years old who had both parents in the home and mothers with higher educational levels presented the best cognitive development indices. Other studies revealed a greater effect of SES on the development of long-term memory, working memory, and language skills in children younger than 9 years old (Piccolo et al., 2016).

Low SES background frequently extends to school inequalities. In developing countries such as Brazil, children in private schools frequently show better performance on EF tasks than those in public schools, where there is often less investment in teacher training and lower parental educational levels (Shayer et al., 2015). Engel de Abreu et al. (2015) investigated the associations between different aspects of SES and the development of academic skills in the first years of school. Although they identified strong effects of both family income and school type (public or private), school type had the greatest influence.

It is important for studies in cognitive development, however, to consider SES in a broader perspective. There is evidence, for instance, that poor living conditions associated to uncontrolled urbanization affect health and wellbeing, and in some circumstances are even associated with higher incidence of psychiatric disorders (Vlahov & Galea, 2002; Lederbogen et al., 2011). Urbanization marked by higher population density and exposure to violence, commonly observed in large cities, may be more deleterious for child development than family income per se, since they contribute to parental stress levels. Furthermore, neighborhood conditions associated with urbanization constitute distal environmental variables, while home conditions, such as family income, constitute proximal environmental variables. Both may impact the developing brain, and have been associated with cognitive impairments and behavioral

dysregulation (Fishbein et al., 2019; Kohen et al., 2008). Noble et al. (2012) attribute this influence on exposure to environmental factors such as language stimulation at home and family stress. In a cohort of 1,099 children and adolescents aged 3 to 20 years, Noble et al. (2015) identified associations between volumetric brain characteristics, EFs, and family income. Results showed that the links between income and children's performance on some EF tasks are mediated by differences on brain surface areas.

Uncontrolled urbanization has impacted existing cultural differences between rural and urban populations. In recent decades, the agricultural sector in Brazil has undergone structural changes. The introduction of technological equipment has resulted in a new modernized agriculture. Thus, some cultural differences between rural and urban areas have been reduced (Bispo & Mendes, 2012). However, some remaining distinctions continue to differentiate between urban and rural zones and municipalities. Zimmerman (2012) proposed some criteria for this type of classification such as occupation of the inhabitants, social mobility, migration, intensity of social integration, and other environmental, demographic, social, cultural and economic characteristics.

By this account, in some contexts a rural area may be characterized by qualities such as lower population density, presence of agriculture, less social stratification and mobility, rural exodus, and greater intensity of social integration. On the other hand, an urban area may be marked by greater population density, more highly stratified society, greater social mobility, immigration from rural areas, less intensity of social integration, and heterogeneous functions and sectors of the economy.

Socioeconomic and socio-cultural differences related to urbanization lead us to expect that some aspects of children's cognitive performance and social behavior would differ between those living in rural, urban, and suburban areas. Few studies concerning EF development, however, have considered urbanization conditions when describing the sociodemographic characteristics of samples. The present study aims to contribute to the literature concerning socio-environmental influences on the development of EF skills. In particular, we investigate possible performance differences in inhibitory control, working memory, and verbal fluency tasks between children aged 6 to 8 years in urban and rural communities.

METHOD

Participants

A sample of 99 Brazilian children, aged 6 to 8 years old, of both genders, participated in this cross-sectional study (see Table 1). During this sensitive period for EF development, children also contend with the social challenges that come with entering elementary school (Kolb et al., 2012). All participants showed average intellectual performance, as assessed by the Brazilian version of the Raven's Coloured Progressive Matrices test (Pasquali et al., 2002), and none presented any signs of psychiatric disorders, as reported by teachers on the Brazilian version of the Strengths and Difficulties Questionnaire (Cury & Golfeto, 2003). All were first- or second-grade students in public schools. The Brazilian Research Ethics Committee of the Center for Health Sciences at the Universidade Federal de São Paulo approved this study (Protocol 945.321/2015). Parents and children signed authorized consent forms before data collection.

We sampled participants from three southern locations in the state of Minas Gerais: one from the rural region in Brazópolis municipality; a second group, 10 km away, from the urban area of Brazópolis; and a final group, 27 km away, from the urban municipality of Itajuba. We selected these municipalities for socioeconomic differences, including parental employment sectors, school characteristics, maternal educational level, and family social class. Despite their relative geographic proximity, the locations were characterized according to the Brazilian Institute of

Geography and Statistics (IBGE, 2015) criteria and the Human Development Index (HDI). The United Nations Development Program (UNDP, 2013) uses HDI to describe the ranges of human development, calculated as the geometric mean of life expectancy at birth, education index (which includes the average years of study and expected level of education) and income index. There are five development ranges: very low (0.000 to 0.499), low (0.500 to 0.599), medium (0.600 to 0.699), high (0.700 to 0.799), and very high (0.800 to 1,000).

Characterization of regions

Brazópolis is an agricultural hub in the Serra da Mantiqueira mountain region. The estimated population in 2015 was 14,889 inhabitants (6,770 living in the rural region), with a demographic density of 39.87 inhabitants / km² (Prefeitura de Brazópolis - MG, 2015). The Human Development Index (HDI) was 0.692. In the rural region, the main economic activity is the cultivation of bananas and coffee. The rural population is composed mainly of landowners and agricultural workers on small farms. Children attend the schools that are close to their home, and teachers are local residents who are sometimes relatives of their students. In the urban region of Brazópolis, the population is mainly composed of small tradesmen, retirees, and self-employed individuals. This region has only one elementary school.

Table 1
Sample Characteristics by Region.

Variables	RR (M-SD)	LC (M-SD)	IC (M-SD)	<i>p</i> (Kruskal-Wallis)
	(n = 30)	(n = 28)	(n = 40)	
	Male=17	Male=16	Male=18	
Age (months)	88.5 (8.5)	77.5 (3.2)	87.4 (7.5)	.00* ^{a,c}
Raven (percentile)	75.1 (16.2)	74.7 (24.8)	67.0 (24.7)	.16
SDQ	6.1 (4.5)	8.1 (3.5)	7.2 (4.9)	.17
ABEP score	18.7 (7.3)	23.9 (6.5)	21.9 (5.3)	.03* ^{a,c}
HERS domains				
Interaction with parents	14.9 (6.4)	14.4 (6.5)	13.7 (5.0)	.64
Material resources	14.0 (5.0)	12.6 (7.0)	12.3 (5.9)	.46
Parental support	52.8 (7.3)	51.0 (14.1)	47.4 (11.6)	0.07
Mother educational level	N = 28	N = 28	N = 33	-
Primary education (%/n)	42.8% (12)	17.8% (5)	42.4% (14)	-
Secondary education (%/n)	42.8% (12)	71.4% (20)	57.6% (19)	-
College (%/n)	14.4% (4)	10.8% (3)	0	-
School characteristics				
Number of students (n)	114	253	450	-
Number of teachers (n)	17	20	23	-
Students per teacher (n)	13	23.5	26.2	-

Note: For the first seven variables, values correspond to mean and standard deviation; a: RR ≠ LC $p < .05$; b: RR ≠ IC $p < .05$; c: LC ≠ IC $p < .05$. RR (Rural Region), LC (Local City) and IC (Industrial City); Primary education: grades 1 to 9; Secondary education: grades 10 to 12.

The city of Itajuba is a center for heavy industry with a federal university covering exact areas and five private colleges focused on humanities and health areas. Much of the workforce is composed of employees of the surrounding companies. The estimated population in 2015 was approximately 96,020 and covered 294,835 square kilometers, with a population density of 325.67 people per square kilometer. The HDI of this municipality was .787. Currently, there are five elementary and secondary private schools and 16 public schools (Brazilian Institute of Geography and Statistics [IBGE] 2015). Data were collected from an elementary school in the surrounding suburbs.

According to a classification proposed by IBGE (2015), the municipality of Itajuba is classified as a *Sub-Regional Center A*, regional provider of public goods and services. On the other hand, Brazopolis is not a major player in the region, classified as a *Local Center* with fewer than 10,000 inhabitants. Therefore, we grouped participants according to Rural Region (RR, rural Brazopolis), Local City (LC, urban Brazopolis), and Industrial City (IC, Itajuba).

Procedures

All data were collected at participants' schools, with authorization from each municipality's Education Secretary. Schools provided appropriate rooms for interviews with caretakers, as well for neuropsychological assessments. Children were assessed in a single individual session lasting

approximately 45 minutes. Tests were administered in the following order: Raven's Coloured Progressive Matrices, Corsi Block-Tapping test, Word Generation, Inhibition, and Digit Span.

The following section is a description of the instruments used to obtain the SES, behavioral, and cognitive measures.

Socioeconomic status characterization

Socioeconomic Status interviews assessed (a) maternal educational level, (b) family social class, defined according to the Brazilian Economic Classification Criteria (which provides an estimation of family purchasing power), and (c) family environmental resources, as measured by the Home Environment Resources Scale (HERS).

Marturano (2006) designed the HERS in accordance with Bronfenbrenner's bioecological theory of development. This measure assesses social support and material resources available at home which may contribute to a child's school achievement. During a semi-structured interview, caregivers respond to 10 questions about family resources. The questions fall under three categories. The first, *Interaction with Parents*, concerns family activities that may indicate stability in relationships, such as regular joint activities and child cooperation in daily domestic activities. The second, *Family Resources*, assesses exposure to learning experiences, the availability of books and intellectually stimulating toys, and opportunities for leisure activities such as family

outings or travel. The third category, *Parental Support*, includes questions about direct parental involvement in the child's school life. The inventory provides two scores, one raw and one relative for each topic (we calculated full score / maximum topic score x 10 to obtain the measures) (Marturano, 2006).

The Brazil Economic Classification Criteria scale (Associação Brasileira de Empresas de Pesquisa [ABEP], 2015) was used to estimate family purchasing power according to criteria such as primary earner education, household consumer goods, and domicile characteristics scored. Finally, households' incomes were classified according to one of the levels: A, B1; B2; C1; C2; D-E. A designation of A corresponds to "very high purchasing power" and D-E corresponds to "very low purchasing power". The present study used total score for all statistical analyses.

Emotional regulation skills

The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) answered by the teachers was used to identify mental health problems in children and adolescents aged 4 to 16 years (exclusion criteria). It asks about 25 attributes, including 10 typically considered strengths, 14 considered difficulties, and one which is neutral. The scale is divided into five subscales, each consisting of five items: emotional symptoms, conduct problems, hyperactivity, peer problems, and prosocial behavior. There are three versions, one for each of the parents, teachers, and children over the age of 11 years. The teacher version was used in this study. Each item is rated as false (zero points), more or less true (one point), or true (two points). Each subscale is scored from 0 to 10. A total difficulty score is calculated as the sum of the results of all subscales except for sociability, which is scored separately on a scale from 0 to 40 points. The cut-off for definition of behavioral problems in clinical levels was 16.

Intellectual and neuropsychological assessment.

a) Raven's Coloured Progressive Matrices. This instrument assesses non-verbal and fluid intelligence. The test is designed for children aged 5 to 11 years and was adapted for the Brazilian population by Angelini et al. (1999). Three series of 12 drawings organized as a matrix with one missing element are presented to participants, who must choose which one completes the matrix. Items increase progressively in complexity. One point is assigned to each correct answer, and the total is scored out of 36 points, then converted to a percentile ranking. The present study used percentile rank in statistical analyses.

b) NEPSY II – Neuropsychological Assessment of Development (Korkman et al., 1998), translated and adapted for Brazilian children to Argollo et al. (2009). This

neuropsychological battery is used for children aged 3 to 16 years old and contains 27 subtests. We used the Inhibition subtest, from the Attention and Executive Functioning content domain, and Word Generation, from the Language content domain.

Inhibition is a timed task based on the Stroop paradigm which does not involve reading. It assesses the ability to inhibit automatic responses in favor of new ones, as well as the ability to switch between responses according to rules. The child views a series of shapes and arrows and is asked to either name a quality (shape or direction) of the image or an alternate response that does not correspond to the image. The subtest has three conditions: Naming, Inhibition, and Switching. In this study, the Switching condition was not used because it is not intended for 6-year-old children. Performance was scored based on time spent on each task and number of errors.

The second subtest is a verbal fluency task and assesses lexical access according to initial letter prompts. Children were asked to name as many words as possible beginning with the letters S or F in 60 seconds. Children received a score corresponding to the number of correctly produced words for each letter. For both subtests, scores were converted to t-scores.

c) Digit Span. Verbal Digit Span is a subtest of the Wechsler Intelligence Scale for Children - III (WISC-III) indicated for people aged 6 to 16 years (Wechsler, 1997), Brazilian version by Nascimento & Figueiredo (2002). This subtest consists of sequences of 2 to 9 digits, orally presented by the examiner. The child is asked to repeat each sequence, sometimes forwards and sometimes backwards. These are classical measures of short-term memory (forward repetition) and working memory (backward repetition). The score used in this study was the digit span (maximum of digits recalled in the correct order).

d) Corsi Block-Tapping (Santos et al., 2005). This non-verbal task assesses visuospatial working memory using nine small blocks presented on a wooden board. Each block is printed on one side with numbers (1 to 9) which are visible only to the examiner for reference. The examiner taps blocks in progressively longer sequences, and the child is asked to tap the blocks in either the same order or the reverse order. In this study, performance was scored as the maximum number of blocks that could be tapped in reverse.

Statistical Analysis

Data were analyzed through descriptive and inferential statistics. The sampling distribution analysis was based on the Shapiro-Wilks test. Mann-Whitney and Kruskal-Wallis nonparametric tests were used to analyze age and region. Additionally, a Spearman's correlation analysis was performed. The level of significance for inferential and correlational analyses was set at 5% (p -value < .05). The Minitab Package was used for data analysis.

RESULTS

Main sociodemographic characteristics of the sample are illustrated in Table 1. Non-parametric analyses revealed that children from the Local City (LC) group were younger than those from the other two groups but did not differ in intellectual level or in behavioral problems as inferred by the SDQ scale. This group also had a higher family income.

Mean, minimum, and maximum performance on neuropsychological tests is summarized in Table 2 by age in years, collapsed across regional origin. Mean performance revealed increased performance by age on tasks that assess working memory and inhibitory control. We gained the most insight, however, from performance on the verbal fluency task. On average, 8-year-olds produced 1.2 more words than 7-year-olds, who in turn produced 1.5 more words than 6-year-olds. The difference in total number of words between ages 6 and 8 years was 2.7 words. As for the working memory tasks, the Digit Span Backward task showed a mean increase of 0.4 points per year. The highest mean Corsi Block test scores were observed among 8-year-olds. Average response time and number of errors on the Inhibition Test of NEPSY-II battery decreased with age. The biggest decrease in average number of errors occurred between the ages of 6 to 7 years, from 5.3 to 3.9 errors in the naming condition and from 12.1 to 10.3 errors in the inhibition condition. Average response time decreased by age, with lower scores from 7 to 8 years old.

When we transformed these data in t-scores, a non-parametric Kruskal-Wallis analysis showed significant age differences in verbal working memory ($p = 0.013$) and phonological verbal fluency tasks ($p = 0.028$): 6-year-old children differed from the 8-years-olds, but not from 7-year-olds. In the Corsi Task, not only did we see differences between 6- and 7-year-old children, but 7-year-olds also differed from 8-year-old children ($p < .01$). In the Inhibitory Control task, the 6-year-old children produced fewer errors in the naming condition ($p = .034$) and were faster in the inhibitory condition ($p < .01$) than children in the 7-year-old group.

Non-parametric analyses revealed that children from the LC group were younger than those from the other two

groups (see Table 1). Additionally, the LC group differed significantly from the other two regional groups in terms of SES. Therefore, we excluded this group from further regional analyses for an investigation of urbanization effects among a sample more homogenous in age and SES (see Table 3).

The Mann-Whitney test revealed some significant differences between the Rural Region (RR) and Industrial City (IC) groups. Children from the RR group showed better Digit Span ($p = 0.007$) and Corsi Block ($p = 0.02$) performance than those from the IC group. They also produced fewer errors and were faster at the naming condition of the NEPSY-II Inhibition Test. No group differences were detected in the inhibition condition.

We performed Spearman correlation analyses to identify possible associations between neuropsychological performance and family conditions, as assessed by the HERS scale, (see Table 4). Results showed weak but significant correlations between global HERS scores and the following measures: digit span ($\rho = .25$), phonological verbal fluency ($\rho = .31$), and time spent on the inhibitory condition of the NEPSY-II Inhibitory Test (IT) ($\rho = -.25$). The Family Resources factor of the HERS scale showed significant correlations with verbal fluency scores ($\rho = .20$) and time spent on the inhibitory condition of IT ($\rho = -.23$). Finally, the Parental Support factor was shown to correlate significantly with verbal fluency ($\rho = .23$) and digit span ($\rho = .26$) scores.

Further correlational analyses was performed to investigate possible associations between performance on executive function tasks and variables related to the presence of psychiatric symptoms (SDQ), intellectual performance (Raven's Coloured Progressive Matrices), and age. Significant correlations were detected among SDQ scores and the following measures: verbal fluency ($\rho = -.36$), number of errors ($\rho = -.35$) and completion time ($\rho = .29$) in the inhibitory condition of the IT. Raven's Coloured Progressive Matrices results revealed significant correlations with digit span ($\rho = .30$), Corsi Block ($\rho = .36$), number of errors ($\rho = -.33$), and completion time ($\rho = -.30$) in the inhibitory condition of IT. Finally, age only showed significant Spearman correlations with digit span ($\rho = .23$) and Corsi Block ($\rho = .38$) scores.

Table 2
Performance in neuropsychological tasks according to age groups.

Tasks	6 y.o	7 y.o	8 y.o
	Mean (Min.-Max) (n = 52)	Mean (Min.-Max) (n = 33)	Mean (Min.-Max) (n = 14)
Verbal Fluency	5.1 (0-16)	6.6 (0-14)	7.8 (1-14)
Digit Span	2.0 (0-4)	2.4 (0-3)	2.8 (0-4)
Corsi Block Tapping	2.5 (0-5)	2.8 (0-4)	3.9 (3-5)
Naming Errors	5.3 (0-17)	3.9 (0-12)	3.8 (0-10)
Naming Time (ms)	82.7 (30-128)	77.0 (52-121)	65.6 (52-92)
Inhibition Errors	12.1 (3-35)	10.3 (2-20)	9.6 (3-18)
Inhibition Time (ms)	115.3 (47-200)	112.0 (83-172)	91.8 (65-126)

Table 3
Performance differences in neuropsychological tasks between Rural Region (RR) and Industrial City (IC) groups.

Variables	RR (M-SD)	IC (M-SD)	p (Kruskal-Wallis)
	(n = 29)	(n = 40)	
Age (months)	88.5 (8.5)	87.4 (7.5)	.55
Phonological Fluency	7.93 (4.4)	6 (3.5)	.06
Digits Span	2.8 (0.5)	2.1 (1.1)	< .05*
Corsi Block Tapping	3.3 (0.9)	2.5 (1.2)	.02*
Naming Errors	50.4 (7.0)	56.4 (10.5)	.01*
Naming Time (ms)	46.3 (5.3)	49.7 (6.2)	.05*
Inhibition Errors	50.6 (6.9)	53.1 (8.3)	.21
Inhibition Time (ms)	48.2 (6.7)	49.7 (7.7)	.77

Note: Values correspond to mean and standard deviation. In Naming and Inhibition tests, performance was analyzed in *t*-scores. For the remaining, the raw scores were used.

* Indicates significant difference for $\leq .05$

Table 4
Correlations among participants measures of executive functions and socioeconomic, behavioral, intellectual and age variables.

	IP	MR	PS	HERS	ABEP	SDQ	RAVEN	Age
Digit Span	0.31*	0.14	0.26*	0.25*	-0.04	-0.17	0.30*	0.23*
Corsi Block Tapping	0.19	0.07	0.12	0.22	-0.10	-0.14	0.36*	0.38*
Verbal Fluency	0.23*	0.20*	0.23*	0.31*	0.12	-0.36*	0.13	0.13
Naming Errors	-0.10	0.15	0.05	-0.14	0.06	0.24*	-0.39*	0.02
Naming Time (ms)	-0.25*	-0.23*	-0.14	-0.35*	0.06	0.29*	-0.33*	-0.07
Inhibition Errors	-0.15	0.08	0.07	-0.12	0.08	-0.07	-0.30*	0.06
Inhibition Time (ms)	-0.16	-0.07	-0.06	-0.34*	-0.06	0.21	-0.11	0.18

IP = Interaction with parents index; MR = Material Resources index; PS = Parental Support index; HERS = Home Environment Resources Scale. * Indicates significant difference for $p \leq .05$.

DISCUSSION

The present study investigated whether children living in regions with different levels of urbanization considered as an SES variable differ in measures of Executive Functions (EF). The study focused on an age range of 6 to 8 years because it is a period of rapid EF development (Ellison & Semrud-Clikeman, 2007). Given the complexity of this cognitive domain, we used a combination of tasks predominantly associated with inhibitory control and working memory.

The analysis of the developmental profile showed an increase in overall task performance by age, but different patterns of cognitive improvement. In the tasks predominantly associated with verbal and visual spatial working memory (Digit Span and Corsi Block, respectively), a clear improvement was observed between the ages of 7 and 8. On the Inhibitory Control test of the NEPSY-II battery, on the other hand, we observed a linear increase with age, mainly in the scores on inhibitory tasks. Both conditions of this test (naming and inhibition) impose a low demand on working memory. The naming condition is the baseline task. The

decrease in number of errors produced by children in this condition was slower than that observed in the inhibition condition, in which the drop was higher between ages 6 and 8 than between 6 and 7. A similar developmental pattern was observed on the Word Generation subtest of the NEPSY-II battery.

Existing literature has discussed whether the improvement on inhibitory control tasks observed in older children is related to a true development of inhibitory control or to a basic enhancement of motor skills (Peterson et al., 2017). The NEPSY-II Inhibition test focuses on perceptual inhibitory control. Therefore, the comparisons between ages in this study exclusively reflect perceptual processing, as there is no motor component associated with the task. The analysis of the inhibitory control skill assessed by NEPSY-II's Inhibition Subtest revealed a bimodal distribution for errors and time, with a higher decline in the number of errors produced between the 6- and 7-year-old children in comparison to 8-year-olds, and a faster speed for 7- and

8-year-olds. A difference in completion time was observed only between ages 7 and 8 years, with a mean gain of 20 seconds in performance. In other words, the child increases the speed of execution only after decreasing the number of errors. This evidence suggests that children's motor speed did not influence their improvement on inhibitory control.

Other authors also proposed that there are different developmental pathways on different EFs between the ages 6 and 8. According to Petersen et al. (2016), for instance, perceptual inhibition develops earlier than motivational inhibition. Six-year-old children execute tasks involving verbal conflict accurately and in a flexible way, but not tasks involving nonverbal conflict. They also have difficulties inhibiting motor responses. At age 8, children execute both tasks correctly (Petersen et al., 2016) and successfully inhibit perseverative behaviors (Wolfe & Bell, 2004).

Results showed a linear increase in performance by age on the verbal working memory task (Digit Span), while an improvement in performance was detected on the nonverbal (Corsi Block Tapping) task in the 8-year-old group. In the inhibitory test, however, the improvement occurred at an earlier age. This suggests that perceptual inhibitory control develops before nonverbal (perceptual) working memory. Since both skills contribute to EFs, these results indicate that the development of perceptual working memory (visuospatial) is a precondition for the development of inhibition skills. It is quite possible that a developmental profile in which a higher control of perceived impulsive errors (at age 7) increased speed in task execution (at age 8), and improvement of working memory skills (at age 8) develop in sequence, but further studies are required to confirm this hypothesis. The same developmental trajectory was not observed in the verbal fluency task, a skill also associated with executive functioning.

The verbal fluency (Word Generation) task is a complex construct associated with systematic and strategic search, lexical access, cognitive flexibility, abstract reasoning, processing speed, working memory, and verbal ability (Moura & Pereira, 2013). As expected, our results showed a better performance along ages, with a largest difference between the lowest and highest ages from 6 to 8 years old. An increase of 2.7 words was observed from age 6 to age 8. Since verbal inhibition develops later in childhood, it may be necessary for verbal fluency to reach a specific threshold for both skills to develop. Verbal working memory is important for control of perseverative errors and intrusions in verbal fluency (Poarch & van Hell, 2012). In our study, results showed an increase in verbal working memory performance from ages 6 to 7, while in nonverbal working memory the increase was mainly between ages 7 and 8. This suggests a higher development of verbal inhibition and working memory when verbal fluency reaches its peak. Wolfe and Bell (2004) concluded, in a sample of children aged 4 years 6 months, that language and temperament predicted 90% of working memory and inhibitory control performance. Therefore, it

seems that working memory and inhibitory control skills preclude language abilities.

In summary, results showed different developmental trajectories in the three EF domains investigated. Cognitive flexibility associated with language (verbal fluency) was marked by a continuous improvement by age. In regard to working memory development, there was a peak from 6 to 7 years in the verbal domain (Digit Span) and another peak from 7 to 8 years in the nonverbal domain (Corsi Blocks). In brief, the developmental sequence that our results suggest for children ages 6 to 8 is: initial improvement in non-verbal inhibitory control and working memory tasks, followed by a progressive increase of verbal working memory and verbal fluency up to age 8.

With regard to performance differences by region, results showed that children from the rural region performed better in both working memory measures (Digit span and Corsi Blocks) than those from the industrial city. They also were faster and produced fewer errors in the naming condition of the inhibitory control task. It seems then that some regional conditions were more associated with performance differences in working memory skills and processing speed than were other socioeconomic variables, as maternal educational level, and family income was lower among families from the rural region. Notably, family resources as measured by the HERS scale showed no significant difference between rural and urban regions. Correlation analyses results for all children, independent of region, also suggest that family environmental resource variables, taken together, may be more predictive than family income. In the study developed by Tine (2014), however, both low-income rural and low-income urban children performed worse on working memory tasks than high-income counterparts.

Our results nevertheless suggest that living in a rural region in some circumstances may be more beneficial for the development of working memory and processing speed skills for 6- to 8-year-old children than living in an industrial city. Considering the characteristics of our samples, it is important to consider which aspects of regional living conditions might explain these differences. In the rural region the shorter distances between homes, schools, and farms, as well as the proximity of relatives, may constitute important conditions for children to exercise autonomy. In the industrial city, on the other hand, parents' jobs were further from home and the children were more likely to stay indoors for extended periods of time, usually with one relative, when they were not at school. It is possible, therefore, that children in the rural group had more opportunities for communicative interactions and learning social rules from their environment. It is well known that social interactions are particularly important for the development of EFs (Moriguchi, 2014). Additionally, the increased population density in urban regions was also more associated with social vulnerability conditions, such as higher levels of unemployment, poorer housing quality, and exposure to neighborhood violence. Ferguson et al. (2013)

also identified an impact of environmental risk factors, such as crowding, housing, and school and neighborhood quality, on cognitive and socioemotional development in childhood and adolescence.

There are several limitations to generalizing the study findings. Firstly, and most importantly, the rural zone in which the data were collected does not represent most rural conditions in Brazil. At national level, rural economies are dominated by large agricultural producers. In rural areas people usually experience high levels of illiteracy and alcohol abuse, and access to social infrastructure is frequently difficult. The differences seen in the Brazópolis rural zone, therefore, may be attributed to the fact that parents were small property owners, and the proximity of urban locations

facilitates access to health centers and educational facilities at the elementary school and middle school levels. Additionally, the region is in Southeastern Brazil, where the climate is especially favorable for agriculture, encouraging young farmers to stay in their communities. The small sample size, as well as the heterogeneous distribution of age ranges in the groups, also limits generalizations. Finally, the role of pedagogical variables in EF development, including the level of teacher training and quality of school facilities, were not explored thoroughly in the analysis of results.

Despite these limitations, we understand that our study takes a new approach to child development, considering a broader perspective on aspects of SES related to urbanization that may influence EF acquisition.

CONCLUSIONS

In sum, our results provide additional support for the effects of early social experiences on the development of skills dependent on the prefrontal cortex (Kolb et al. 2012). A particular emphasis was placed on the idea that social experiences are strongly influenced by urbanization levels in family living environments. Aspects such as urban concentration levels and neighborhood inequalities, among others, may have a more negative impact than poverty alone.

This impact may be in part explained by their limiting effects on children's daily social interactions and experiences of autonomy. Therefore, socioeconomic status must be considered more broadly for a better understanding of environmental influences on executive function development. This seems especially true for emergent countries with regional differences such as Brazil.

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