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# Can reactivity to stress and family environment explain memory and executive function performance in early and middle childhood?

Reatividade ao estresse e ambiente familiar podem explicar o desempenho em memória e funções executivas na primeira infância e na idade escolar?

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## Abstract

**Introduction:** According to the literature, children's overall reactivity to stress is associated with their socioeconomic status and family environment. In turn, it has been shown that reactivity to stress is associated with cognitive performance. However, few studies have systematically tested these three constructs together.

**Objective:** To investigate the relationship between family environment, salivary cortisol measurements and children's memory and executive function performance.

**Method:** Salivary cortisol levels of 70 children aged 9 or 10 years were measured before and after performing tasks designed to assess memory and executive functions. Questionnaires on socioeconomic issues, family environment and maternal psychopathologies were administered to participants' families during the children's early childhood and again when they reached school age.

**Results:** Data were analyzed by calculating correlations between variables and conducting hierarchical regression. High cortisol levels were associated with poorer working memory and worse performance in tasks involving executive functions, and were also associated with high scores for maternal psychopathology (during early childhood and school age) and family dysfunction. Family environment variables and changes in cortisol levels explain around 20% of the variance in performance of cognitive tasks.

**Conclusion:** Family functioning and maternal psychopathology in early and middle childhood and children's stress levels were associated with children's working memory and executive functioning.

**Keywords:** Socioeconomic status, family environment, maternal psychopathology, cortisol, stress, neuropsychological assessment.

## Resumo

**Introdução:** De acordo com a literatura, o nível socioeconômico e o ambiente familiar estão associados à reatividade ao estresse na criança. Essa reatividade ao estresse, por sua vez, tem sido associada com desempenho cognitivo. No entanto, poucos estudos testaram sistematicamente esses três construtos ao mesmo tempo.

**Objetivo:** Investigar a relação entre ambiente familiar, medidas de cortisol salivar e desempenho em memória e funções executivas das crianças.

**Método:** Os níveis de cortisol salivar de 70 crianças com idade entre 9 e 10 anos foram medidos antes e depois de tarefas de memória e funções executivas. As famílias dos participantes completaram questionários sobre questões socioeconômicas, ambiente familiar e psicopatologia materna durante a primeira infância e a idade escolar da criança.

**Resultados:** Correlações e regressão hierárquica foram realizadas para análise de dados. Níveis de cortisol elevados, bem como alta psicopatologia materna (na primeira infância e em idade escolar) e disfunção familiar foram associados com baixo desempenho em tarefas de funções executivas e memória de trabalho. As variáveis ambiente familiar e alterações nos níveis de cortisol explicam cerca de 20% da variação no desempenho de tarefas cognitivas.

**Conclusão:** O funcionamento familiar e a psicopatologia materna no início e meio da infância, bem como os níveis de estresse das crianças, foram associados com a memória de trabalho e o funcionamento executivo das crianças.

**Descritores:** Nível socioeconômico, ambiente familiar, psicopatologia materna, cortisol, estresse, avaliação neuropsicológica.

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## Introduction

Theories have posited stress as a mechanism through which socioeconomic status (SES) and family environment exert their effects on cognition.<sup>1</sup> However, few studies have systematically tested these determinants together.<sup>2,3</sup> The main aim of this study was to address this gap in the literature by testing these variables in a single model that considers the direct effects of family environment on stress reactivity and on cognitive performance and investigates how stress is related to the results of cognitive assessments.

Children are exposed to vulnerabilities when their families cannot satisfactorily fulfill the basic tasks of socialization and provide them with adequate support in terms of nutrition, education and health care.<sup>4</sup> When family dysfunction occurs at key stages of development, such as during early childhood, children are at a higher risk of delayed development.<sup>5,6</sup> Parental care, in particular the discipline imposed by parents, verbal communication and parents' concern with the emotional needs of their children, appear to mediate (at least partially) the effects of socioeconomic status on children's emotional and cognitive development, especially at this stage of life.<sup>4,7,8</sup> Quality interactions between parents and children are associated with resilience in children living in stressful and impoverished environments.<sup>4</sup> In fact, clinical programs designed to improve parenting practices in poor families at high risk of vulnerabilities improve children's behavioral, cognitive and health indicators,<sup>9-11</sup> demonstrating that the quality of the environment in which children live is crucial to the quality of their development.

Adverse environmental conditions such as low SES can be related to higher levels of stress<sup>12</sup> and greater irritability, depression and anxiety in the parents, which impairs interactions between parents and children.<sup>13-15</sup> For example, maternal depression is associated with poorer cognitive performance in children,<sup>16-19</sup> especially deficits in working memory and executive functions.<sup>20,21</sup> Additionally, high levels of stress-related hormones have a direct effect on children's neurodevelopment.<sup>22</sup> For example, high levels of cortisol are associated with damage in the hypothalamus and prefrontal areas<sup>23</sup> and impaired memory and executive functioning.<sup>24</sup> The impact of SES on working memory during childhood development seems to be mediated by stress levels.<sup>25-28</sup>

Based on empirical studies, some authors<sup>29,30</sup> suggest multifactor models to explain the complex relationship between SES and children's cognitive development. These models include interactions between family environment and behavioral, cognitive and biological aspects of children's development. According to a model

proposed by Noble et al.,<sup>29</sup> family SES has a negative relationship with stress levels. It has been observed that the lower the SES, the higher the peripheral levels of proteins related to response to stress (cortisol and catecholamine).<sup>31</sup> In fact, interactions between parents and children and mothers' mental health can influence the physiology of children's response to stress, for example hypothalamic-pituitary-adrenal (HPA) axis activity.<sup>32,33</sup> There is therefore evidence that these stressors affect parenting practices and the linguistic environment. In families with low SES, parents can be less consistent in their parenting practices and less involved in their children's studies and activities, which, in turn, is associated with behavioral and cognitive problems in childhood.<sup>34,35</sup>

These multifactorial models seem to offer a very good explanation for how SES and family environment affect cognitive performance, but there is little empirical data to support these theories. The objective of this study was to investigate associations between variables related to the family environment (SES, maternal mental health, and family environment) during childhood, salivary cortisol measures and performance on measures of memory and executive functioning.

## Method

### Participants

The sample comprised 70 children and their parents, recruited from a low-income community in a city in southern Brazil by convenience at birth and followed to school age.<sup>34</sup> These families were assessed at two periods in the children's lives, (A) early childhood (mean [M] age = 2.05; standard deviation [SD] = 0.05 years) and (B) school age (M age = 9.87; SD = 0.41 years). Additionally, 51.4% (n = 36) of the children were girls, students in the 2nd to 5th grades at public schools. The families were predominantly classed as low SES. Table 1 lists descriptive data for the sample.

### Instruments and procedures

All guardians signed informed consent. The study was approved by the Research Ethics Committee at the Hospital de Clínicas de Porto Alegre (protocol no. 016/2009).

## **Sociodemographic and clinical evaluation**

Questionnaires covering several sociodemographic variables, including family income, were administered to the parents to enable assessment of family socioeconomic status. Family environment was assessed using the Global Assessment of Relational Functioning (GARF) scale, which has been validated for the Brazilian population.<sup>36</sup> This instrument measures the degree to which the family or the parents meet the emotional and operational needs of the family's members (5-point Likert scale).

Maternal mental health was assessed using the Self-Reporting Questionnaire (SRQ-20),<sup>37</sup> which evaluates emotional and physical symptoms associated with mental disorders. Significant psychiatric morbidity is associated with presence of eight or more of these symptoms, with sensitivity of 86.33% and specificity of 89.31%.<sup>37</sup> The Beck Depression Inventory (BDI)<sup>38</sup> was also used to evaluate depressive symptoms in mothers during their children's early childhood and the BDI for Primary Care (comprising seven items derived from the original BDI) was used when their children reached school age.<sup>39</sup>

## **Cognitive assessments**

Cognitive instruments were administered to each school-aged child, on an individual basis, in two sessions. In the first session, the Vocabulary and Matrix Reasoning subtests of the Wechsler Abbreviated Scale of Intelligence (WASI)<sup>40,41</sup> were administered. In the second session, the children performed cognitively challenging tasks intended to assess memory and executive functions.<sup>42</sup> According to Dickerson & Kemeny,<sup>43</sup> threats to one's social esteem or social status can be stressors. The magnitude of the stress response depends on the intensity of the challenge, its context, and the presence of factors of vulnerability and protection in the individual and social environment. This framework suggests that cognitive challenge may be a particularly informative method for investigating individuals' stress responses.<sup>44</sup>

The children were also assessed with the Child Brief Neuropsychological Assessment Battery (NEUPSILIN-INF)<sup>45</sup> consisting of: 1) working memory tasks, including forward and backward digit span, pseudowords span and a visual working memory task; 2) verbal memory, including immediate recall of a word list and figures; and 3) executive function, including inhibitory control tasks such as orthographic and semantic verbal fluency and auditory go/no-go tasks. Before the assessment, the examiner established a rapport with the child (approximately five minutes) in a quiet room. The battery

was structured in such a way that the tasks gradually increased in difficulty over 45 minutes.

## **Stress evaluation**

We collected salivary cortisol at two different time points (before and after cognitive testing with the NEUPSILIN-INF – 45 minute delay). The participant placed a cotton roll under the tongue for approximately 3 minutes, until it was completely saturated with saliva. The cotton roll was then removed from the mouth by the participant, returned to the examiner and placed into a 5 mL syringe without the plunger. The plunger was replaced in the syringe, and the saliva sample was collected into a labeled plastic tube. The minimum volume of saliva collected for each session was 0.5 mL.

After the collection protocol, all samples were centrifuged and stored at -80 °C until analysis. Samples were analyzed in duplicate by radioimmunoassay (Coat-A-Count® Cortisol Kit, Siemens Medical Solutions Diagnostics, Los Angeles, CA, USA). The sensitivity of this assay was estimated at 0.1 nM. The coefficients of intra and inter-assay variation were less than 10%. The results of each sample collection time were expressed in nmol/L. It is known that cortisol levels increase in the morning and decrease during the day,<sup>46</sup> so we decided to conduct the tests between 10:00 a.m. and 03:00 p.m. to minimize the effect of circadian phases.

## **Results**

The characteristics of the sample are listed in Table 1. Most families were from low SES backgrounds (91.2%), with SES characterized by family income. It was found that 19% of the mothers had symptoms of mental illness (SRQ-20) during their children's early childhood, rising to 32% when their children were school age. Additionally, 26% of mothers reported depressive symptoms at both stages of the study.

### **Family environment vs. cognitive performance**

Exploratory analyses were performed to test for correlations between measurements of family environment (family income, SRQ-20, BDI and GARF) assessed in early childhood and at school age, cortisol levels before and after cognitive testing and the children's performance in memory and executive function tasks at school age, using IQ as a control variable. This analysis showed that maternal psychopathology scores during the early years and school age of children were negatively

**Table 1** - Characteristics of the sample of children (n = 70). Age in years, years' schooling, IQ performance (WASI), cortisol levels (before and after cognitive testing), family income, maternal mental health (SRQ-20, BDI and BDI-PC), family environment (GARF) at early childhood and when child was school age and results of cognitive tasks.

	Min	Max	Mean	SD
Child variables				
Early childhood (age in years)	2	2.1	2.05	0.05
School age (in years)	9	10	9.87	0.41
Educational level (years of education)	2	5	3.56	0.65
IQ (WASI – percentile)	59	107	79.54	11.52
Cortisol level before cognitive testing (nmol/L)	1.30	18.35	4.34	0.19
Cortisol level after cognitive testing (nmol/L)	3.48	65.20	17.73	13.90
Family variables (early childhood)				
Family income (minimum wages)	0.80	8.05	3.77	1.67
Maternal psychopathology (SRQ-20)	0	16	4.67	3.54
Maternal depression (BDI)	0	34	8.41	8.26
Family environment (GARF)	15	90	69.12	16.35
Family variables (when child school age)				
Family income (minimum wages)	0.21	6.45	2.68	1.56
Maternal psychopathology (SRQ-20)	0	15	6.35	4.75
Maternal depression (BDI-PC)	0	17	4.21	4.86
Family environment (GARF)	20	90	66.19	18.73
Cognitive tasks (when child school age)				
Memory				
Immediate recall	1	8	4.89	1.45
Delayed recall	0	7	3.62	1.41
Forward digit span	7	24	17.86	3.54
Backward digit span	0	25	15.26	5.67
Pseudoword span	3	19	10.92	3.02
Visuospatial WM	4	28	17.62	7.37
Visuooverbal WM	3	9	5.85	1.36
Executive functions				
Orthographic verbal fluency	1	15	7.02	2.84
Semantic verbal fluency	4	23	12.95	3.73
Go/no-go task	34	60	54.27	4.49

BDI = Beck Depression Inventory; BDI-PC = Beck Depression Inventory for Primary Care; GARF = Global Assessment of Relational Functioning; IQ = intelligence quotient; Max = maximum; Min = minimum; SD = standard deviation; SRQ-20 = Self Reporting Questionnaire; WASI = Wechsler Abbreviated Scale of Intelligence; WM = working memory.

correlated with performance in a working memory task – forward digit span (SRQ-20 in early childhood:  $r = -0.41$ ;  $p = 0.022$ ) – and executive functions – go/no-go task (BDI at school age:  $r = -0.41$ ;  $p = 0.024$ ). Family functioning (GARF) at school age was positively correlated with performance in the go/no-go task ( $r = 0.39$ ;  $p = 0.03$ ) and income in early childhood was positively correlated with performance in executive functions – semantic verbal fluency ( $r = 0.32$ ;  $p = 0.03$ ) and go/no-go task ( $r = 0.32$ ;  $p = 0.034$ ).

### Family environment vs. stress

There was no significant difference between cortisol measures in the morning and the afternoon (cortisol pretest:  $t_{68} = 0.53$ ,  $p = 0.59$ ; cortisol posttest:  $t_{68} = 0.69$ ,

$p = 0.49$ ). Additionally, family environment variables correlated with final and initial cortisol measurements. Symptoms of maternal psychopathology in early childhood were positively correlated with cortisol levels before testing – SRQ-20 ( $r = 0.37$ ;  $p = 0.005$ ) and BDI ( $r = 0.28$ ;  $p = 0.033$ ). Results for the family functioning scale (GARF) assessed in early childhood correlated with cortisol measurement after cognitive testing ( $r = -0.44$ ;  $p = 0.015$ ) and the greater the degree of family dysfunction, the higher the level of stress after cognitive testing. Depressed mothers' children had less cortisol variation ( $t_{54} = -1.33$ ,  $p = 0.015$ ) and higher cortisol levels prior to neuropsychological testing ( $M = 5.48$ ,  $SD = 4.64$  vs.  $M = 3.85$ ,  $SD = 2.57$ ,  $t_{54} = 1.65$ ,  $p = 0.025$ ) than children with non-depressive mothers (as assessed by the BDI). The same was observed in relation to family

functioning. Children from families with a greater degree of dysfunction ( $n = 12$ ) had a higher initial cortisol level in relation to families with median ( $n = 36$ ) and low ( $n = 21$ ) dysfunction ( $F_{2,63} = 12.10$ ;  $p = 0.001$ ;  $\eta^2 = 0.76$ ) in early childhood and at school-age ( $F_{2,53} = 3.68$ ,  $p = 0.004$ ;  $\eta^2 = 0.12$ ).

### Stress vs. cognitive performance

We conducted an analysis of repeated measures to investigate the differences between cortisol levels measured before and after cognitive testing. Intra-subject ( $F_{1,66} = 117.78$ ;  $p < 0.001$ ;  $\eta^2 = 0.64$ ) and inter-subject ( $F_{1,66} = 1140.2$ ;  $p < 0.001$ ;  $\eta^2 = 0.94$ ) differences were detected. The post-neuropsychological testing cortisol level was more than twice the pre-test cortisol level ( $M = 0.55$ ,  $SD = 0.27$  vs.  $M = 1.13$ ,  $SD = 0.33$ ). This finding is to be expected in this situation because neuropsychological assessment can be seen as a cognitive challenge inducing a stress response. In the correlation analyses, post-test cortisol (but not pre-test cortisol) was negatively associated with performance in the tasks testing visuo-verbal memory ( $r = -0.32$ ;  $p = 0.012$ ), visuospatial working memory ( $r = -0.30$ ;  $p = 0.019$ ), forward digit span ( $r = -0.29$ ;  $p = 0.023$ ) and delayed episodic memory ( $r = -0.35$ ;  $p = 0.006$ ).

### Family environment, stress and cognitive performance models

Finally, a hierarchical multiple regression was performed, including environment variables assessed in early childhood (step 1) and at school age (step 2), change in child's cortisol levels (step 3) and IQ (step 4) as independent variables and treating performance in cognitive tasks as dependent variables. Table 2 only lists results that were statistically significant. As can be observed from this table, family income during early childhood contributed to performance in pseudoword span, in immediate episodic memory and in the go/no-go task. Mother's depression and mental health during early childhood were predictors of go/no-go task performance. Family income in early childhood and at school age contributed to forward digit span and visuo-verbal memory performance. Cortisol level after cognitive testing was a predictor of visuospatial working memory, delayed episodic memory, visuo-verbal memory and forward digit span performance. Performance in the other cognitive tasks was only explained by IQ.

## Discussion

This study related aspects of the family environment to a stress response mechanism in children. Cortisol levels were expected to increase in response to the stress caused by cognitive tasks (due to the progressive cognitive challenge).<sup>43</sup> We found that the higher the mother's psychopathology assessment score as tested during her child's early childhood, the higher the child's cortisol levels at school age before the cognitive challenge. Regarding the family environment, the higher the degree of family dysfunction, the higher the child's cortisol levels after cognitive testing, which suggest that children from maladaptive environments have differences in reactivity to stress. Cortisol levels are related to aspects of family environment,<sup>47,48</sup> since interactions between parents and children and mothers' mental health can influence the physiology of their children's response to stress<sup>28</sup> and, consequently, their health.<sup>15,49,50</sup> Some studies have associated parental support and maternal psychopathology in the child's first year of life – when the HPA axis is very labile – with prolonged activations of the HPA axis to respond to daily stressful events.<sup>32,51</sup> Although response to stress is considered an adaptive function,<sup>52</sup> chronic exposure to high concentrations of glucocorticoids contributes to development of physical diseases<sup>15,50,53,54</sup> and psychological and cognitive dysfunctions<sup>55</sup> that may persist into adulthood.<sup>26,56,57</sup>

Early exposure to maternal depressive symptoms also negatively affects children's development of executive functions and working memory.<sup>20,21,58</sup> A study by Hughes et al.,<sup>20</sup> for example, showed that maternal depression in the mothers of two-year old children was a predictor of performance in executive function tasks (inhibitory control) and working memory four years later, which is similar to the findings observed in the present study. Depressed mothers are less likely to respond to their children's stimuli (both by actions and vocalizations) or to get involved in interactive activities, which may impact their verbal skills.<sup>59</sup> Furthermore, early chronic stress and family dysfunction affect the child's development process, producing a cascading effect, in which child maladaptation to the hostile environment also contributes to family dysfunction and parents' psychopathology,<sup>60</sup> creating a cycle of maladaptation that is maintained (or gets worse) over time.<sup>61</sup>

The data from this study corroborate evidence from previous studies on the existence of a relationship between memory deficit and increased stress in children.<sup>62-65</sup> Stress affects skills that require a conscious effort in information processing, reducing cognitive efficiency.<sup>65</sup> With regard to acute stress, the reduced cognitive efficiency could be considered an adaptive

**Table 2** - Hierarchical linear regression model for cognitive performance

	<b>R<sup>2</sup></b>	<b>R<sup>2</sup><sub>adj</sub></b>	<b>F</b>	<b>df</b>	<b>B</b>	<b>p-value</b>
Verbal – immediate recall						
Step 1	0.08	0.02	1.34	4		
Income*					0.22	0.07
SRQ-20*					-0.03	0.87
BDI*					0.23	0.14
GARF*					0.04	0.78
Step 2	0.17	0.06	1.75	4		
Income†					-0.28‡	0.04
SRQ-20†					0.11	0.50
BDI†					-0.02	0.92
GARF†					0.26	0.11
Step 3	0.20	0.07	1.24	2		
Pre-test cortisol					-0.13	0.28
Post-test cortisol					-0.06	0.61
Step 4	0.33	0.20	10.90	1		
IQ					0.38‡	0.02
Verbal memory – delayed recall						
Step 1	0.06	0.01	1.10	4		
Income*					0.13	0.29
SRQ-20*					0.17	0.33
BDI*					0.03	0.85
GARF*					-0.01	0.95
Step 2	0.07	-0.05	0.16	4		
Income†					-0.03	0.85
SRQ-20†					-0.10	0.57
BDI†					0.07	0.68
GARF†					-0.01	0.94
Step 3	0.18	0.04	3.98	2		
Pre-test cortisol					-0.08	0.51
Post-test cortisol					-0.33‡	0.02
Step 4	0.22	0.07	2.94	1		
IQ					0.22‡	0.09
Visuoverbal memory						
Step 1	0.07	0.01	1.19	4		
Income*					0.15	0.21
SRQ-20*					-0.34	0.84
BDI*					0.05	0.74
GARF*					0.42‡	0.003
Step 2	0.09	-0.03	0.38	4		
Income†					0.02	0.91
SRQ-20†					0.07	0.67
BDI†					0.05	0.78
GARF†					-0.04	0.81
Step 3	0.28	0.16	7.69	2		
Pre-test cortisol					-0.03	0.80
Post-test cortisol					-0.47‡	0.001
Step 4	0.29	0.16	1.26	1		
IQ					0.13	0.27
Forward digit span						
Step 1	0.01	-0.05	0.23	4		
Income*					0.15	0.20
SRQ-20*					0.02	0.90
BDI*					0.05	0.75
GARF*					0.35‡	0.01
Step 2	0.18	0.07	2.97	4		
Income†					0.18	0.19

*Continued on next page*

SRQ-20†					0.17	0.28
BDI†					-0.02	0.91
GARF†					0.35‡	0.03
Step 3	0.31	0.19	5.83	2		
Pre-test cortisol					-0.08	0.49
Post-test cortisol					-0.38‡	0.01
Step 4	0.34	0.22	2.55	1		
IQ					0.18	0.12
Pseudoword span						
Step 1	0.10	0.04	1.73	4		
Income*					0.29‡	0.03
SRQ-20*					0.22	0.22
BDI*					-0.33‡	0.06
GARF*					-0.13	0.38
Step 2	0.11	-0.01	0.28	4		
Income†					0.06	0.67
SRQ-20†					0.05	0.80
BDI†					0.03	0.89
GARF†					0.10	0.57
Step 3	0.16	0.02	1.79	2		
Pre-test cortisol					0.13	0.32
Post-test cortisol					-0.18	0.21
Step 4	0.18	0.02	1.03	1		
IQ					0.13	0.31
Visuospatial WM						
Step 1	0.05	-0.01	0.84	4		
Income*					0.05	0.67
SRQ-20*					0.01	0.93
BDI*					-0.14	0.40
GARF*					-0.17	0.21
Step 2	0.08	-0.03	0.61	4		
Income†					0.14	0.34
SRQ-20†					0.19	0.26
BDI†					-0.15	0.39
GARF†					-0.19	0.91
Step 3	0.23	0.10	5.40	2		
Pre-test cortisol					-0.10	0.43
Post-test cortisol					-0.38‡	0.001
Step 4	0.27	0.13	3.18	1		
IQ					0.22	0.08
Go/no-go task						
Step 1	0.20	0.15	4.03	4		
Income*					0.30‡	0.01
SRQ-20*					-0.33‡	0.05
BDI*					-0.40‡	0.02
GARF*					0.10	0.49
Step 2	0.23	0.13	0.72	4		
Income†					0.02	0.89
SRQ-20†					0.22	0.19
BDI†					-0.22	0.22
GARF†					0.04	0.79
Step 3	0.24	0.11	0.06	2		
Pre-test cortisol					0.01	0.96
Post-test cortisol					-0.22	0.87
Step 4	0.24	0.10	0.60	1		
IQ					0.10	0.44

BDI = Beck Depression Inventory; df = degrees of freedom; GARF = Global Assessment of Relational Functioning; IQ = intelligence quotient; SRQ-20 = Self-Reporting Questionnaire; WM = working memory.

\* Early childhood; † school age.

‡ Significant to  $p < 0.05$ .



process to compensate for the increased automatic processing effectiveness when potentially negative and threatening events occur.<sup>66</sup> However, prolonged stress may cause overactivation of this mechanism, resulting in impairment of cognitive functioning.

Evidence from studies on explicit memory suggest that information retrieval processes are particularly susceptible to the adverse effects of stress and increased cortisol levels, while consolidation processes can be impaired by stress.<sup>67-69</sup> There is also evidence that stress has a direct effect on development of children's brains,<sup>52</sup> affecting their operation<sup>70</sup> and reaching prefrontal regions that are related to self-regulation and attention.<sup>71</sup> Inhibitory control, which concerns ability to inhibit competitive responses, is related to self-control (self-regulation) and is susceptible to environmental influences.<sup>20</sup> Low SES during childhood is linked with family dysfunction and, consequently, to poor self-control in adulthood, and is also associated with perceived stress.<sup>49</sup>

Another aspect that relates both to maternal mental health and to family environment is family income,<sup>34</sup> which was also a predictor of memory and executive function performance in this study. This indicator has been particularly associated with children's development of language and vocabulary<sup>72</sup> – which are essential for development of other cognitive functions<sup>73,74</sup> – for example, via the availability of books and other literature resources, computers and parental communication.<sup>14</sup> Furthermore, children living in deprived neighborhoods are more likely to have poor nutrition and are more prone to health problems, in addition to being exposed to pollutants and violence,<sup>15</sup> which have a direct impact on their cognitive development and general health.

Limitations of the study include the relatively small size of the sample and the particular characteristics of the participants. There is a degree of homogeneity to the sample in terms of SES (predominantly low SES) and the children assessed study at schools on the outskirts of city where there is a high incidence of psychopathologies among parents and children and this may have affected the results, since we do not have children from high SES families for comparison. Additionally, although widely used, cortisol levels measured in saliva, blood or urine can be highly variable because they are likely to be affected by several factors that may occur shortly before sampling.<sup>75</sup>

## Conclusion

As we report in this study, different factors of the family environment affect performance in certain

neuropsychological systems differently. We know that memory (episodic, working and semantic) and executive functions<sup>3,34,76</sup> are more susceptible to influence from the environment and stress due to their complexity and prolonged development.<sup>26,77</sup> We can assume that income is important because it limits the conditions for stimulation, nutrition and housing and access to better schools and to materials and activities that favor cognitive development.<sup>78</sup> Family functioning is relevant since it affects parenting style and how families deal with stressful situations.<sup>79</sup> Maternal mental health influences the way that mothers take care of their children and the extent to which they are able to get involved in their activities. All of these factors interact dynamically and it is not any one of them in isolation that can explain the effects on children's development, rather the sum of all of them produces a unique contribution in each case.<sup>61</sup>

The results of this study provide evidence for theorists who wish to attempt to explain the association between environment and performance in cognitive tasks, through mediation by family and stress factors.<sup>29,80</sup> This is a pioneering study in Brazil that has related early childhood factors with the results of memory and executive function assessments in school-age children. Knowledge in this field may support interventions in the public health system designed both to improve the quality of life of the population and to prevent cognitive deficits, through providing assistance to poor families, for example. Interventional studies have shown that improvement in the quality of family environment has a positive impact on people's health status, reducing inflammatory processes for example,<sup>49</sup> and improves their emotional and cognitive development.<sup>9-11</sup> Therefore, the present study provides information on the living conditions of a population that should benefit from improvements in the healthcare system of the community represented by this sample, based on the needs indicated by studying that sample.

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