Psychology & Neuroscience
ISSN: 1984-3054
landeira@puc-rio.br
Pontifícia Universidade Católica do Rio de Janeiro
Brasil

Piccolo, Luciane da Rosa; Burges Sbicigo, Juliana; Grassi-Oliveira, Rodrigo; Fumagalli de Salles, Jerusa

Do socioeconomic status and stress reactivity really impact neurocognitive performance?

Psychology & Neuroscience, vol. 7, núm. 4, 2014, pp. 567-575
Pontifícia Universidade Católica do Rio de Janeiro
Rio de Janeiro, Brasil

PSYCHOLOGY & NEUROSCIENCE

Psychology & Neuroscience, 2014, 7, 4, 567-575
DOI: 10.3922/j.psns.2014.4.16

Do socioeconomic status and stress reactivity really impact neurocognitive performance?

Luciane da Rosa Piccolo[1], Juliana Burges Sbicigo[1], Rodrigo Grassi-Oliveira[2], and Jerusa Fumagalli de Salles[1]

1- Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil

2- Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, RS, Brazil

Abstract

Various discussions have centered on whether and how socioeconomic status and stress are associated with neurocognitive function in different stages of development. Reviews have been conducted focusing on only part of these relationships (SES and stress or SES and neurocognition). The aim of the present study was to review investigations that examined the relationship between socioeconomic status (SES), stress (assessed by cortisol levels and allostatic load), and neurocognitive performance (executive function, memory, language, and intelligence), including the three variables in the same study. A systematic review was conducted that evaluated articles published between 1990 and 2013 in the Web of Knowledge, PsycINFO, PubMed, SCOPUS, Embase, and BVS-Psi databases. Nine studies were analyzed based on inclusion criteria. Overall, SES, stress, and neurocognitive performance were independently related in the studies. Furthermore, early evidence suggest that stress is a mechanism that mediates the relationship between SES and neurocognitive performance, specifically in visuospatial working memory and executive function tasks in childhood. This evidence should be confirmed in future studies.
Keywords: socioeconomic status, cognition, neurocognitive performance, cortisol, stress.

Received 14 February 2014; received in revised form 17 July 2014; accepted 17 July 2014. Available online 16 December 2014.

Introduction

The literature has shown a relationship between socioeconomic status (SES) and neurocognitive task performance (Blair et al., 2011; Evans & Fuller-Rowell, 2013; Farah et al., 2006). One possible explanation for this relationship is mediation by stress (McEwen & Gianaros, 2010). Evidence indicates that reactivity to stress is related to neurocognitive performance on measures of intelligence and neurocognitive function (Evans & Schamberg, 2009; Noble, Korgaonkar, Grieve, & Brickman, 2013) and also related to SES (Noble, McCandliss, & Farah, 2007; Power, Li, & Hertzman, 2008).

With regard to general cognition, evidence suggests that the heritability of IQ changes according to SES (Nisbett et al., 2012; Turkheimer, Haley, Waldron, D'Onofrio, & Gottesman, 2003). In addition to IQ, some neurocognitive functions appear to be more sensitive to the effects of SES than others (Hackman, Farah, & Meaney, 2010). Specifically, language (Fluss, Ziegler, Warszawski, Ducot, Richard, & Billard, 2009; Lúcio, Pinheiro, & Nascimento, 2010), working memory (Engel, Santos, & Gathercole, 2008; Evans & Schamberg, 2009), and executive function (Filippetti & Filippetti, 2011; Sarsour, Sheridan, Jutte, Nuru-Jeter, Hinshaw, & Boyce, 2011) appear to be more influenced by this factor (Hackman et al., 2010). This fact may be explained by prolonged aging of these cognitive systems, which can lead to increased susceptibility to environmental influences (Noble, Tottenham, & Casey, 2005).

Stress has been mentioned as a mechanism by which SES exerts its effects on cognition. The stress response mechanism is characterized by activation of the autonomic nervous system and hypothalamic-pituitary-adrenal (HPA) axis, producing a cascade of neurobiological and neurochemical events such as the release of epinephrine and cortisol. Cortisol is a corticosteroid hormone family of steroids that is produced by the suprarenal glands and directly involved in the stress response (Graeff, 2007). Acute stress responses promote adaptation and survival through neural, cardiovascular, autonomic, immune, and metabolic system responses termed allostasis (McEwen & Stellar, 1993). In turn, chronic stress can cause and aggravate pathophysiology through these same systems

Luciane da Rosa Piccolo, Juliana Burges Sbicigo, and Jerusa Fumagalli de Salles, Instituto de Psicologia, Programa de Pós-Graduação em Psicologia, Universidade Federal do Rio Grande do Sul. Rodrigo Grassi-Oliveira, Programa de Pós-Graduação em Psicologia, Pontifícia Universidade Católica do Rio Grande do Sul. Correspondence regarding this article should be directed to: Luciane da Rosa Piccolo, Ramiro Barcelos, 2600, sala 114, Porto Alegre, RS, CEP 90035-003, Brasil. E-mail: lucianepiccolo@yahoo.com.br.

but in an unregulated way, producing allostatic load (McEwen, 2006). Some authors contend that social disadvantage related to socioeconomic factors appears to be associated with an increased stress response and, in turn, an increase in cortisol and the emergence of allostatic load in the body (Goodman, 1997; Lupien, King, Meaney, & McEwen, 2001).

Among the many factors that contribute to allostatic load are genes, early experiences, and learned behaviors that reflect lifestyle choices such as diet, exercise, and other habits. All of these factors influence the reactivity of the systems that produce physiological stress mediators (McEwen & Gianaros, 2010; McEwen, 1998). The adverse conditions under which families with low SES often live represent a stressor for its members (chronic stress), resulting in damage to overall health, including cognition.

The results of empirical studies have shown a relationship between low SES and poverty and increased allostatic load (Evans & Schamberg, 2009; Power et al., 2008), which in turn is related to lower neurocognitive performance (Blair, Granger, & Peters Razza, 2005; Sheridan, Sarsour, Jutte, D'Esposito, & Boyce, 2012). Hackman et al. (2010) reported a lack of studies that evaluated neurocognitive aspects in groups of children and adolescents who were subjected to stress, suggesting the need for further studies in this area. Recent systematic reviews analyzed studies that relate SES and neurocognitive performance, or SES and stress measures (Dowd, Simanek, & Aiello, 2009; Hackman et al., 2010; Oliveira et al., 2010), but we were interested in synthesizing the results of the studies that were looking for a relationship among those three constructs. Given the growing interest in this topic and its relevance, the present article reviews empirical studies that investigated the relationship between SES, measures of stress (i.e., cortisol and allostatic load) and neurocognitive performance.

Methods

A search of empirical articles published between 1990 and 2013 was performed in the following databases: Web of Knowledge, PsycINFO, SCOPUS, PubMed, Embase, and BVS-Psi. For this study, we consider stress as a physiological and behavioral response due to threatening events for the individual (McEwen & Wingfield, 2003; Selye, 1976). Cortisol, the primary stress hormone, have been widely used as a reliable measure of stress (Dowd et al., 2009). The concept of allostatic load as developed by McEwen (1998) refers to the sum of the wear that prolonged stress causes the organisms. SES is an individual's or group's position within a hierarchical social structure. SES depends on a combination of variables including occupation, education, income, wealth, and place of residence (APA, 2012). Neurocognitive performance is the result of assessments of cognitive functions (such as language, memory and executive functions) through tasks and/or instruments evaluated for this purpose.

The following sets of keywords that, combined, could cover the maximum number of articles of related research were used: socioeconomic status/factor/level/class, income, poverty, parental education, maternal education, cortisol, allostatic load, language, memory, executive functions, IQ, intelligence quotient, intelligence, cognit*, and neuropsycholog*. These words were obtained from the Terminology of Health Sciences Descriptors (DeCS)/ MeSH Terms and Thesaurus were used because they are related to the subject area. In the searches, we considered "all fields," with no specific selection by title or author. Combinations of words were formed according to the following criteria: (a) aspect of SES (socioeconomic status/factor/level/class, income, poverty, parental education, maternal education), (b) cortisol and allostatic load assessment (cortisol, allostatic load), and (c) neurocognitive assessment (language, memory, executive function, IQ, intelligence quotient, intelligence, cognit*, and neuropsycholog*). Combinations were performed one at a time so all words of all criteria were combined (a + b + c) in each database. For example, the following words were combined: "socioeconomic status" (a criteria), "cortisol" (b criteria), and "language" (c criteria), and so on. Descriptors of the participants' ages were not used (e.g., children or adults) because we intended to investigate studies of all age groups. Initially, articles were selected based on the abstracts by two independent researchers to identify studies that met the inclusion criteria and objectives of this review. The inclusion criteria were the following: (a) empirical article written in English, Spanish, or Portuguese, (b) answered the research question of this review, investigating the relationship between SES, assessment of cortisol/allostatic load, and performance on neurocognitive (language, memory, and executive function) or cognitive (intelligence) tasks, (c) use of instruments (tests) or experimental tasks that assessed neurocognitive function (language, memory, and executive function) or intelligence (IQ), and (d) study with human participants. Some of the articles left doubts about whether they met the inclusion criteria and were fully read but were discarded for not definitively meeting any of the criteria. After defining the final number of articles, they were fully read and tabulated by author, year, country, study type (transverse/longitudinal), sample, neurocognitive function, type of cortisol measure (salivary, urinary, or allostatic load), SES variables, and main results (Table 1). Subsequently, the items were characterized, and the methodological aspects and results were presented within the framework of the following topics: (1) relationships between SES, stress, and neurocognitive function, (2) profile of the samples and study design (3) cortisol measures, socioeconomic status indicators, and instruments for neurocognitive assessment.

Results and discussion

The search resulted in 1,095 articles, 1,086 of which were discarded in accordance with the selection criteria (Figure 1). After exclusion of articles repeated among databases, 299 articles remained. Of these,

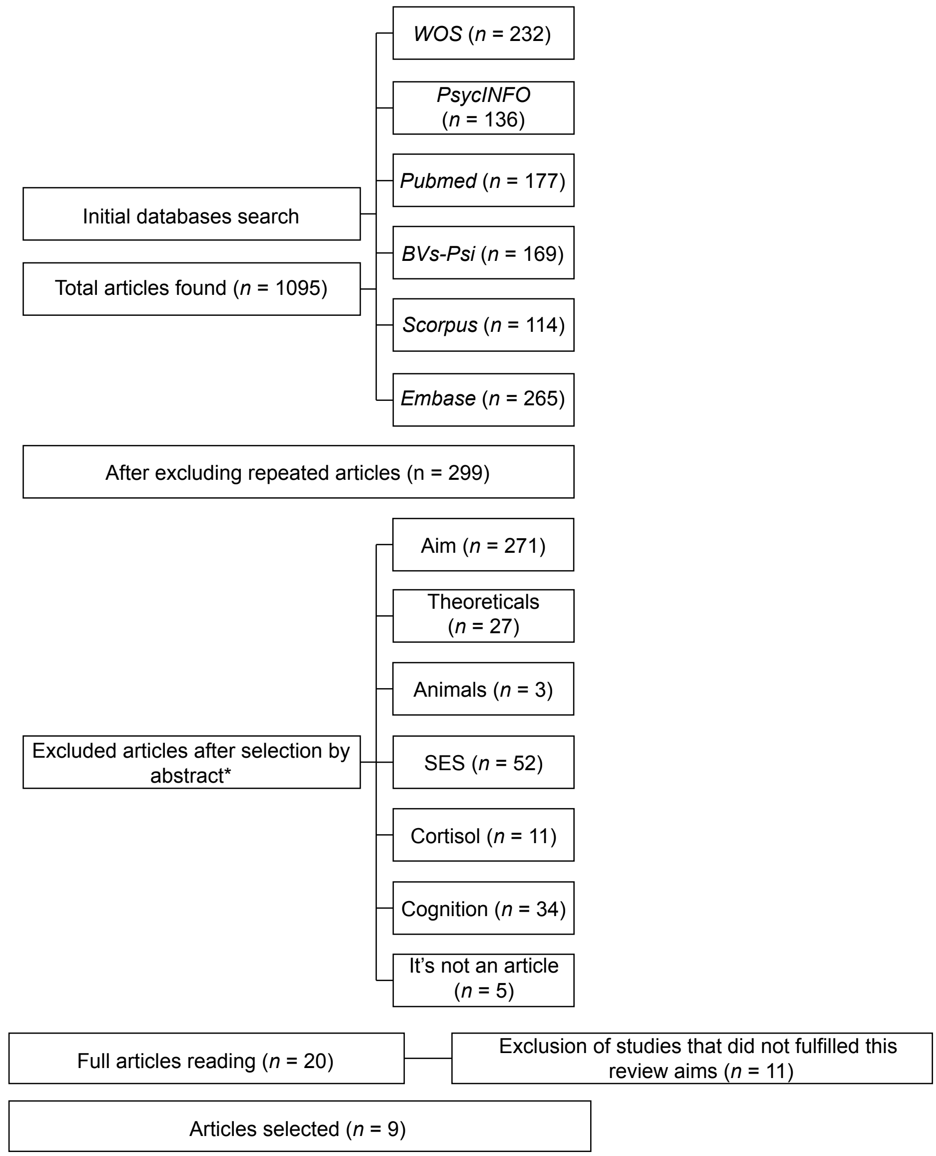

Figure 1. Flowchart of the study selection process. *Studies may fit into more than one category.

studies that did not have the aim to investigate the relationship between SES, cortisol/allostatic load, and performance on language, memory, executive function, and intelligence tasks (n = 271), theoretical studies (n = 27), studies with animals (n = 3), studies that did not evaluate SES (n = 52), cortisol (n = 11), or neurocognitive function (n = 34), and conference presentations (poster or oral communications) were excluded (n = 3). After reading the full articles, 11 were excluded because they did not meet the objectives of this review. Finally, nine articles met the inclusion criteria (Table 1) and were selected. Their results are presented below.

Relationship between socioeconomic status, stress, and neurocognitive function

Intelligence

In the analyzed studies, weak, moderate or no relations between SES, stress, and intelligence were found. Blair et al. (2011) used a structural equation model in which IQ was modeled as a latent variable using the cubes and vocabulary tasks. In this model, it was observed that in 3-year-old children, the measure of intelligence was marginally predicted by cortisol (β = -.15, p = .06), whereas the relationship between IQ and SES variables was not significant. In adults, Neupert et al. (2006) used multilevel modeling and found that older and more educated (higher SES) adults showed higher levels of reactivity to stress before performing cognitive tasks (measures of reasoning and intelligence). Older adults may perceive the tasks as more stressful because of age-related cognitive decline, but it is still unclear why higher SES was related to higher reactivity. Only correlations between reasoning and SES (schooling, r = .40, p < .01; income, r = .25, p < .05) and between WAIS-Vocabulary and SES (education, r = .55, p = .001; income, r = .25, p < .05) were reported, but these cognitive variables showed no bivariate relationship with cortisol.

Table 1. Articles that related socioeconomic status, cortisol and/or allostatic load, and general cognitive and neuropsychological function in children, adolescents, adults, and/or seniors.

Reference and country	Study design and sample	Neurocognitive function	Cortisol	Socioeconomic status	Main results
Child/adolescent studies					
Lupien et al. (2001) Canada	Cross-sectional *n* = 307 (% gender not specified) 6-16 years old	Declarative and non-declarative memory, selective attention, and language	Salivary (basal)	Parental education and family income	Low SES was related to increased levels of cortisol. Higher SES was associated with better selective attention performance.
Evans & Schamberg (2009) United States	Longitudinal (0-17 years old)* *n* = 195 (50% females) *M* = 17 years old	Working memory	Urinary (basal) (allostatic load)	Proportion of months living in poverty between 0 and 13 years old	Allostatic load mediated the (negative) relationship between childhood poverty and lower performance on working memory in late adolescence.
Blair et al. (2011) United States	Longitudinal (% gender not specified) *n* = 1,292, assessed at ages 7, 15, 24 and 36 months 0-3 years old	IQ and executive function	Salivary (basal)	Maternal education and family income	Cortisol was a mediator of the effects of maternal education on children's executive function.
Sheridan et al. (2012) United States	Cross-sectional *n* = 18 (1 boy) 8-12 years old	Executive function and language	Salivary (children pre- and post-fMRI scanning)	Parental education and family income	Change in cortisol was associated with low SES and lower executive function.
D'Angiulli et al. (2012) Canada	Cross-sectional *n* = 28 (11 female) 11-13 years old	Auditory selective attention	Salivary (collected six times, four times before and two times after the ERP experiment)	Parents' education and occupation, family income, and quality of residence	Higher SES was related to greater use of compensatory strategies in the attention task. Cortisol was not related to effect of SES on cognitive performance.
Evans & Fuller-Rowell (2013) United States	Longitudinal* *n* = 241(50% females) *M* = 17 years old (0-17 years old)*	Working memory and self-regulation	Urinary (basal) (allostatic load)	Proportion of months living in poverty between 0 and 13 years old	Poverty in childhood was a predictor of allostatic load which, in turn, was a predictor of working memory performance in late adolescence. Self-regulation moderated this prediction.
Adult/senior studies					
Neupert et al. (2006) United States	Cross-sectional *n* = 302 (35% females) 25-74 years old	Working memory, processing speed, vocabulary, and reasoning	Salivary (5-7 measures during the cognitives tasks)	Education	Higher SES was related to higher stress reactivity in older adults. SES was related to intelligence. Cognitive performance was not related to cortisol.
Fiocco et al. (2007) Canada	Cross-sectional *n* = 101 (22 males) 50-65 years old	Verbal fluency and working memory	Salivary (pre- and post-TSST)	Education	Lower SES was related to higher levels of cortisol and lower verbal fluency performance.
Pilgrim et al. (2010) Canada	Cross-sectional *n* = 25 (11 males) 8-35 years old	Selective attention	Salivary (nine salivary cortisol samples during cognitive testing)	Family income in childhood	Higher levels of cortisol were related to lower performance on a selective attention task. SES was not related to cognitive performance.

Note: SES, socioeconomic status; TSST, Trier Social Stress Test. *Those studies used the same sample.

Memory

Studies that investigated SES, stress, and memory reported, in most cases, a relationship among these three variables. Participants with higher SES had lower reactivity to stress/allostatic load and higher memory performance (Evans & Fuller-Rowell, 2013; Schamberg & Evans, 2009; Fiocco et al., 2007; Lupien et al., 2001). Evans and Schamberg (2009) observed a positive relationship between SES (years in which the child grew up in poverty) and allostatic load (β = .49, SE = .18, $p < .01$) and a negative relationship between SES and visuospatial working memory in early adulthood (β = -1.01, SE = .44, $p < .02$). However, this relationship between SES and visuospatial working memory became not significant (β = -0.77, SE = .45) when the measure of allostatic load was added in the regression equation. Therefore, allostatic load was found to be a mediator between SES and performance in this modality of working memory in early adulthood (β = -.47, SE = .16, $p < .01$).

The results of Evans and Schamberg (2009) were replicated in a structural model in Evans and Fuller-Rowell (2013) on the same sample. The years of exposure to poverty (SES) in childhood was a predictor of allostatic load (β = .168, SE = 0, 64, $p = .008$), which, in turn, was a negative predictor of visuospatial working memory in early adulthood (β = -.180, SE = .07, $p = .010$), with satisfactory adjustment indices (TLI = 1.684, CFI = 1.00, RMSEA = .000, SRMR = .013). Furthermore, the effect of SES on visuospatial working memory was moderated by self-regulation (β = .134, SE = .66, $p = .42$). Exposure to poverty had a less harmful influence on visuospatial working memory in early adulthood for individuals with higher self-regulatory capacity. This ability did not change the relationship between allostatic load and visuospatial working memory and exposure to poverty.

In Lupien et al. (2001), the results of an analysis of variance (ANOVA) showed a main effect of SES on cortisol level ($F_{1,307} = 6.62, p < .01$) in children between 6 and 10 years of age in which children from a lower SES had higher cortisol levels. The effects of SES on cortisol disappeared after the age of 10 years. Declarative and non-declarative memory were unaffected by SES at any age. Similarly, in two studies (Fiocco et al., 2007; Neupert et al., 2006), adults with different SES (education) did not differ in verbal working memory. However, in one study (Fiocco et al., 2007), the group with a lower SES showed greater reactivity to stress, whereas another study found no such relationship (Neupert et al., 2006).

Executive function and selective attention

SES indicators were related to executive function (Blair et al., 2011; Scheridan et al., 2012) and selective attention (D'Angiulli et al., 2012; Lupien et al., 2001). Evidence indicated that cortisol may be a mediator of the relationship between SES (maternal education) and executive function (Blair et al., 2011). In adults, only independent relations were observed between SES and cortisol and between SES and verbal fluency (Fiocco et al., 2007) as well between cortisol and selective attention (Pilgrim et al., 2010).

Scheridan et al. (2012) found a main effect of SES on executive function ($F = 4.44$, $p = .05$). Children with low SES presented more difficulties in cognitive task. This study also showed that the percent change in cortisol during functional magnetic resonance imaging in which the participant performed the task was related to lower income, lower task performance, and lower neural activation. The study, however, did not test a model with the three variables (SES, stress, and task performance) at the same time due to small sample size. This was accomplished by Blair et al. (2011). In their study, executive function was modeled using a single latent variable (including working memory, inhibitory control, and alternating attention), showing a direct deleterious effect of cortisol (β = -.42, $p < .0001$). SES (maternal education and family income) was not a direct predictor of executive function or cortisol. However, when parenting was inserted into the model, cortisol mediated the relationship between maternal education (but not income) and executive function (β = -.32, $p = .008$). In the study with adults (Fiocco et al., 2007), participants with lower SES (education) exhibited a greater response to stress ($F_{1,94} = 10.87$, $p = .001$). Participants with higher SES exhibited better performance in executive function tasks, including those that assessed phonological verbal fluency ($F_{1,101} = 8.56, p = .004$) and categorical fluency ($F_{1,101} = 7.86, p = .007$). However, the direct relationship between cortisol and verbal fluency was not investigated.

With regard to selective attention, Lupien et al. (2001) identified differences between children with low and high SES ($F_{5,306} = 3.8$, $p < .003$), whereas the second group had better scores. Moreover, low SES showed a main effect on increased stress reactivity ($F_{1,307} = 6.62$, $p < .01$) with an interaction between low SES and age ($F_{5,307} = 4.78$, $p < .001$). The effect of stress on SES was present only in children up to 10 years old. Children with a younger age and low SES exhibited lower cognitive performance compared with older children with a high SES when the children were 6 years old. At 16 years of age, however, the result was the opposite. Children with low SES exhibited better selective attention performance than children with high SES. These results, however, may have been influenced by the fact that each age group had few participants and the fact that children with low SES are more likely to leave school or refuse to participate in research because of their cognitive deficits. D'Angiulli et al. (2012) used electroencephalography and found that children with higher SES had greater differentiation of event-related potentials between relevant and irrelevant stimuli in a task of detecting sequences of tones compared with children with low SES who had hypoactivity in medial frontal regions. Reactivity to stress was not related to differences in SES (although relationships were found in the expected direction, but the effect may not have been detected because of the small sample size). In the regression model, SES (β = .71, SE = .21, p = .002) and stress reactivity (β = .19, SE = .07, p = .015) were related to activation of medial frontal regions. Pilgrim et al. (2010) found that elevated cortisol over time was negatively correlated with performance in a task that evaluated selective attention to stressful or neutral words (r = -.44, p = .03). SES did not differentiate the participants' performance on the attention task, but the relationship between SES and stress reactivity was not analyzed.

Language

One of the two studies (Lupien et al., 2001; Sheridan et al., 2012) that investigated the SES, stress and language relationship did not find effects of SES or stress on children's language performance (assessed by verbal fluency) (Lupien et al., 2001). In the study by Sheridan et al. (2012), the complexity of discursive language was assessed based on communication of the child in a family setting. SES was associated with salivary cortisol levels (β = -12.21, t_{13} = -2.86, p = .017), but not with discursive language of child. We discuss methodological characteristics of the studies below.

Sample profile and study design

The sample sizes varied between 18 and 1,292, and three studies included fewer than 30 participants (D'Angiulli et al., 2012; Pilgrim, Marin, & Lupien, 2010; Sheridan et al., 2012). The methods of sample selection included random stratification (Blair et al., 2011) and non-random sampling (D'Angiulli et al., 2012; Evans & Fuller-Rowell, 2013; Evans & Schamberg, 2009; Fiocco, Joober, Poirier, & Lupien, 2007; Lupien et al., 2001; Neupert, Miller, & Lachman, 2006; Pilgrim et al., 2010). Five studies were from the United States, and four were from Canada. These countries have the highest Human Development Index (HDI) in the world (the U.S. is third, and Canada is 11th; United Nations Program for Development, 2013). The HDI is a summary of long-term progress in three basic dimensions of human development: income, education, and health (United Nations Program for Development, 2013).

Of the 10 studies, six were conducted with children and adolescents (0-16 years old) for a total of 2,081 participants in this age group. Four studies were conducted with young and/or middle-age and/or elderly adults (18-74 years old), for a total of 1,155 adults surveyed. Six investigations were transverse, and four were longitudinal. Three studies investigated differences between boys and girls with regard to all of these variables. The author did not mention how many males and females were evaluated. They report that no differences were found between genders, at least for children (Blair et al., 2011; Lupien et al., 2001).

Cortisol measures, socioeconomic status indicators, and instruments for neurocognitive assessment

Cortisol measures

In eight studies, the form of cortisol assessment was salivary (Blair et al., 2011 ; D'Angiulli et al., 2012; Fiocco et al., 2007; Lupien et al., 2001; Neupert et al., 2006; Pilgrim et al., 2010; Sheridan et al., 2012). This form of cortisol measurement is widely used in research because saliva can be collected by untrained persons, and the collection method is more practical and noninvasive in naturalistic environments when repeated samples are required (Dowd, Simanek, & Aiello, 2009). The measurement of salivary cortisol is independent of the flow rate of saliva, and the samples are stable at room temperature for 1 week without any loss of cortisol activity. Thus, assessing the level of cortisol through saliva is a practical and reliable method for this analysis.

Although eight studies used salivary cortisol, differences were found in the experimental controls. One of the factors that can influence the level of cortisol is the time of day when it is collected (i.e., it is higher in the morning; Kirschbaum, Wolf, May, Wippich, & Hellhammer, 1996). In some studies, cortisol was collected during the same day shift for all of the participants (D'Angiulli et al., 2012; Fiocco et al, 2007; Lupien et al., 2001), whereas others measured cortisol on different days or at different times but statistically evaluated differences in those samples (Blair et al., 2011; Neupert et al., 2006; Pilgrim et al., 2012; Sheridan et al., 2012). The control over the time of the day that cortisol is measured avoids the misinterpretation that a higher basal level of cortisol is due to socioeconomic differences, for example, when individuals are assessed at different times.

Another difference in the measurements of salivary cortisol is that the researchers asked the participants to avoid consuming certain foods, smoking, and drinking alcohol a few hours before collection (Fiocco et al., 2007; Neupert et al., 2006) or requested a routine physical examination and blood screening (Fiocco et al., 2007). In the study by Pilgrim et al. (2012), the participants were selected in advance by telephone and excluded if they had a history of psychological disorders or other medical conditions that affect the functioning of the HPA axis or were smokers, but they did not control for substance consumption prior to testing. D'Angiulli et al. (2012) studied children and requested a diary in which they wrote down ingested foods, medications, physical activity, and other factors that may alter the HPA axis. In those studies (D'Angiulli et al., 2012; Pilgrim et al., 2012), the items that should not be consumed varied, whereas in other studies (Lupien et al., 2001; Sheridan et al., 2012), this control was not mentioned. Generally, different factors were considered to alter the function of the HPA axis, with both the presence and absence of controls, which may impact comparisons of the results of studies that evaluated cortisol.

Alternatively to cortisol evaluation, other studies (Evans & Schamberg, 2009; Evans & Fuller-Rowell, 2013) used a measure of allostatic load, calculated as the sum of the number of abnormal physiological parameters (systolic and diastolic blood pressure at rest, epinephrine, norepinephrine, and urinary cortisol levels, and body mass index) as a stress indicator. Because this consists of several factors, it seems to represent a consistent stress measure. However, cortisol is widely used as a reliable measure of stress (Dowd et al., 2009).

SES indicators

With regard to SES indicators, three studies used parent education and family income (Blair et al., 2011; Lupien et al, 2001; Sheridan et al., 2012). These measures can be considered substitutes for many other factors that systematically vary with SES and are likely to influence child development including physical health, family environment, early education, and the characteristics of the neighborhood where they live (Bornstein & Bradley, 2002). In two studies (Evans & Schamberg, 2009; Evans & Fuller-Rowell, 2013), poverty was evaluated based on an income-to-needs ratio ≤ 1, which is the official U.S. poverty line based on an annual income per capita adjusted index. The authors assessed poverty because the theory of allostasis emphasizes the duration of chronic environmental demands (such as living in poverty) as the main precipitating factor of body wear. Two other studies (D'Angiulli et al., 2012) used indices of SES. D'Angiulli et al. (2012) used an adaptation of the index of Hollingshead (1975), considering the education and occupation of the parents, family income, and quality of residence. Indices allow a more complete measurement of SES because they do not evaluate only one aspect, such as income (Pilgrim et al., 2010) or education (Fiocco et al., 2007; Neupert et al., 2006).

Instruments for Neurocognitive Assessment

The tasks that were used to assess neurocognitive functions were quite diverse. Some studies developed or adapted tasks (D'Angiulli et al., 2012; Pilgrim et al., 2010; Sheridan et al., 2012). Selective attention was assessed with a visual detection task (digit sequence of letters or numbers; Lupien et al., 2001), tone sequence detection task (D'Angiulli et al., 2012), and modified Posner's Spatial Orientation Paradigm task (positive, neutral, and social stress words as cues; Pilgrim et al., 2010). Alternated attention was assessed with a task of attention to item selection consisting of a modified version of the Flexible Item Selection Task (Blair et al., 2011) developed by Jacques and Zelazo (2001). Executive function was measured with a mapping task that was similar to the stimulus-response Dimensional Change Card Sorting Task (Sheridan et al., 2012). Processing speed was assessed by the Digit Symbol Substitution Test from the Wechsler Intelligence Scale (WAIS) and Letter Comparison Task (Neupert et al., 2006).

Other studies used instruments or classic tasks to assess executive function related to inhibitory control (Stroop test, Simon task, Go/No-Go task; Blair et al., 2011), verbal fluency (orthographic and semantic fluency; Fiocco et al., 2007), and self-regulation (standard protocol by Mischel, Shoda, & Rodriguez, 1989) with regard to delayed gratification (Evans & Fuller-Rowell, 2013). With regard to memory, declarative memory was assessed with the immediate and delayed recall of figure lists. Non-declarative memory was tested with the implicit retrieval of figures (Lupien et al., 2001). Visuospatial working memory was assessed with the Simon Game task (Evans & Schamberg, 2009; Evans & Fuller-Rowell, 2013) and the visuospatial span of figures and colors (Blair et al., 2011). Verbal working memory was assessed with the digit span test from the WAIS (Fiocco et al., 2007; Neupert et al., 2006) and inverse serial counting (Neupert et al., 2006). Language was assessed with a semantic verbal fluency task (considered a measure of language in young children; Lupien et al., 2001), and discursive language was assessed by evaluating family dinner situations (Sheridan et al., 2012). Intelligence was measured with the verbal skills and blocks subscales of the Wechsler Preschool and Primary Scales of Intelligence (WPPSI; Blair et al., 2011) and vocabulary subscale of the WAIS (Neupert et al., 2006). Raven's Coloured Progressive Matrices test and Schaie-Thurstone Letter Series were considered measures of reasoning (Neupert et al., 2006).

Discussion

The objective of this review was to analyze studies that investigated the relationship among the three variables—SES, stress and neurocognitive performance. In three studies, SES was associated with both cortisol and neurocognitive performance, whereas the latter two variables were unrelated (Fiocco et al. 2007; Lupien et al., 2001; Neupert et al. 2006). Other three studies corroborated the hypothesis that stress (cortisol or allostatic load) is a mediator of the effects of the SES on neurocognitive performance, specifically in visuospatial working memory (Evans & Fuller-Rowell, 2013; Evans & Schamberg, 2009) and executive functions (Blair et al., 2011). In the case of visuospatial working memory, the results of both multiple regression and structural equation analyses suggested that early life stress mediates the relationship between poverty in childhood and lower visuospatial working memory performance during late adolescence/early adulthood (Evans & Fuller-Rowell, 2013; Evans & Schamberg, 2009). In executive function, cortisol exercised mediating role when combined with parenting and family risk (Blair et al., 2011). Although higher cortisol has been associated with lower SES and lower neurocognitive performance, no mediation analyzes were not performed in Sheridan et al. (2012) due to small sample size. Together, these early results described herein support the theory of McEwen (1998) in which SES can influence neurocognitive development through a stress response mechanism. Low SES is related to cardiac and neuroendocrine markers of stress in various diseases in children and adults (Evans & Schamberg, 2009).

Other neurocognitive functions were independently associated with SES (D'Angiulli et al., 2012; Lupien et al., 2001; Neupert et al., 2006) and stress (Blair et al., 2011; Pilgrim et al., 2010). Intelligence was weakly negatively affected by cortisol in children (Blair et al., 2011), whereas intelligence was affected by SES in adults (Neupert et al., 2006). Selective attention performance was differentiated by SES in childhood (Lupien et al., 2001), whereas in adults both SES (D'Angiulli et al., 2012) and cortisol (Pilgrim et al., 2010) differentiated performance. Language in childhood suffered no effects of SES or stress in the two studies evaluated this function (Lupien et al., 2001; Sheridan et al., 2012). Because language is a very complex function, it is suggested that future researches use tasks that assess other aspects of language, such as reading or oral and written comprehension, for example.

Regarding the characteristics of the studies, future research should examine how SES, stress, and neurocognitive performance are related in other countries beyond Canada and U.S.A., especially in developing countries that have higher rates of poverty and where the impact of the environment on neurocognition may be greater. The diversity of instruments that were used to assess cognitive function and differences in the scope of the evaluated functions (i.e., some studies investigated only one function; Evans & Schamberg, 2009; Pilgrim et al., 2010) are factors that may help explain the conflicting results. With regard to the relationship between SES and stress, according to a review by Dowd et al. (2009), low SES is most consistently related to higher levels of measures of allostatic load, but discrepancies are still found in the literature in regard to the relationship only between SES and cortisol measures. However, among the articles presented in this review, the results of the studies that used measures of salivary cortisol and allostatic load were similar in which a relationship between low SES and higher levels of stress reactivity were found (Blair et al., 2011; Evans & Schamberg, 2009; Evans & Fuller-Rowell, 2013; Fiocco et al. 2007; Lupien et al., 2001; Neupert et al. 2006; Sheridan et al., 2012). Future studies should collect data on multiple indicators of stress physiology (Blair et al., 2011) such as in Evans and Schamberg (2009) and Evans and Fuller-Rowell (2013) and include measures of the sympathetic and parasympathetic systems. These measures are necessary to consistently establish relationships between early experience and stress physiology and their influence on neurocognitive development in children (Blair et al., 2001).

McEwen and Gianaros (2010) argued that although evidence indicates that differences in income, education, occupation, and other dimensions of SES are related to the causes of specific diseases and prevalence of risk factors for child development, health cannot be fully explained by material deprivation, illiteracy, or the shortage of qualified healthcare among those who occupy a lower socioeconomic position. The relationship between SES and health, not only concerning physical appearance but also concerning the psychological and cognitive domains of the individual, has been explained by exposure to stressful events in general (Lupien et al., 2001; Lupien, McEwen, Gunnar, & Heim, 2009; McEwen & Gianaros, 2010).

Conclusion

The present review found few studies that evaluated SES, stress, and neurocognition in the same investigation. The studies indicated a relationship among these three variables should be replicated in future studies to confirm and expand the results, including testing mediation models. Another noticeable aspect is that although the literature presents consistent hypotheses about the relationship between these variables (McEwen, 1998), the empirical data generally show weak relationships, and the mediating role of stress remains a hypothesis that needs to be tested.

Importantly, the studies reviewed herein have the following methodological limitations: (a) small samples, non-randomized samples, and samples limited to the U.S. and Canada, (b) the assessment of only a few cognitive functions, (c) a high diversity of neurocognitive assessment instruments, thus hindering direct comparisons of the results, (d) variability in the assessment of stress, in which some studies used only a measurement of cortisol (with consequently substantial variations in controls for obtaining cortisol), whereas others measured allostatic load and (e) the lack of testing all three variables in a single model.

Poverty or low SES in childhood and its deleterious effects should be considered from the perspective of cognitive development and biological manifestations. The mechanisms through which these effects operate or are inhibited should be considered (Noble & Farah, 2013). Stress has been considered a main mediating factor, although this is supported by little evidence. However, possibly stress does not act alone, which was demonstrated by the interaction of stress with parenting (Blair et al., 2011) and self-regulation (Evans & Fuller-Rowell, 2013) found in this review. Therefore, the interaction between stress and other variables that impact neurocognitive development should be investigated, such as maternal mental health, relationships with peers, and stressful events and experiences in other environments, such as in school and the community.

References

*Studies with an asterisk are part of the systematic review.

Arán Filippetti, V., & Filippetti, V. A. (2011). Funciones ejecutivas en niños escolarizados: efectos de la edad y del estrato socioeconómico. *Avances en Psicología Latinoamericana*, *29*(1), 98 – 113.

*Blair, C., Granger, D. A., Willoughby, M., Mills-Koonce, R., Cox, M., Greenberg, M. T., … FLP Investigators. (2011). Salivary cortisol mediates effects of poverty and parenting on executive functions in early childhood. *Child Development*, *82*(6), 1970–1984. doi:10.1111/j.1467-8624.2011.01643.x

Blair, C., Granger, D., & Peters Razza, R. (2005). Cortisol reactivity is positively related to executive function in preschool children attending head start. *Child Development*, *76*(3), 554–567. doi:10.1111/j.1467-8624.2005.00863.x

Bornstein, M. H., & Bradley, R. H. (2002). *Socioeconomic Status, Parenting, and Child Development*. Boca Raton, FL: Taylor & Francis.

*D'Angiulli, A., Van Roon, P. M., Weinberg, J., Oberlander, T. F., Grunau, R. E., Hertzman, C., & Maggi, S. (2012). Frontal EEG/ERP correlates of attentional processes, cortisol and motivational states in adolescents from lower and higher socioeconomic status. *Frontiers in Human Neuroscience*, *6*, 306. doi:10.3389/fnhum.2012.00306

Dowd, J. B., Simanek, A. M., & Aiello, A. E. (2009). Socio-economic status, cortisol and allostatic load: a review of the literature. *International Journal of Epidemiology*, *38*(5), 1297–1309.

Education & Socioeconomic Status Fact Sheet. ([s.d.]). *http://www.apa.org*. Recuperado 16 de junho de 2014, de http://www.apa.org/pi/ses/resources/publications/factsheet-education.aspx

Engel, P. M. J., Santos, F. H., & Gathercole, S. E. (2008). Are working memory measures free of socioeconomic influence? *Journal of Speech, Language, and Hearing Research: JSLHR*, *51*(6), 1580–1587. doi:10.1044/1092-4388(2008/07-0210)

*Evans, G. W., & Fuller-Rowell, T. E. (2013). Childhood poverty, chronic stress, and young adult working memory: the protective role of self-regulatory capacity. *Developmental Science*, *16*(5), 688–696. doi:10.1111/desc.12082

*Evans, G. W., & Schamberg, M. A. (2009). Childhood poverty, chronic stress, and adult working memory. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(16), 6545–6549. doi:10.1073/pnas.0811910106

Farah, M. J., Shera, D. M., Savage, J. H., Betancourt, L., Giannetta, J. M., Brodsky, N. L., … Hurt, H. (2006). Childhood poverty: specific associations with neurocognitive development. *Brain Research*, *1110*(1), 166–174. doi:10.1016/j.brainres.2006.06.072

*Fiocco, A. J., Joober, R., Poirier, J., & Lupien, S. (2007). Polymorphism of the 5-HT2A receptor gene: association with stress-related indices in healthy middle-aged adults. *Frontiers in Behavioral Neuroscience*, *1*. doi:10.3389/neuro.08.003.2007.

Franz, C. E., Spoon, K., Thompson, W., Hauger, R. L., Hellhammer, D. H., Jacobson, K. C., … Kremen, W. S. (2013). Adult cognitive ability and socioeconomic status as mediators of the effects of childhood disadvantage on salivary cortisol in aging adults. *Psychoneuroendocrinology*, *38*(10), 2127–2139. doi:10.1016/j.psyneuen.2013.04.001

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: A Research Note. *Journal of Child Psychology and Psychiatry*, *38*(5), 581–586. doi:10.1111/j.1469-7610.1997.tb01545.x

Graeff, F. G. (2007). Ansiedade, pânico e o eixo hipotálamo-pituitária-adrenal. *Revista Brasileira de Psiquiatria*, *29*, s3–s6. doi:10.1590/S1516-44462007000500002

Hackman, D. A., Farah, M. J., & Meaney, M. J. (2010). Socioeconomic status and the brain: mechanistic insights from human and animal research. *Nature Reviews. Neuroscience*, *11*(9), 651–659. doi:10.1038/nrn2897

Hollingshead, A. de B. (1975). *Four Factor Index of Social Status*. New Have, Yale University, Department of Sociology.

Jacques, S., & Zelazo, P. D. (2001). The Flexible Item Selection Task (FIST): a measure of executive function in preschoolers. *Developmental Neuropsychology*, *20*(3), 573–591. doi:10.1207/S15326942DN2003_2

Kirschbaum, C., Wolf, O. T., May, M., Wippich, W., & Hellhammer, D. H. (1996). Stress- and treatment-induced elevations of cortisol levels associated with impaired declarative memory in healthy adults. *Life Sciences*, *58*(17), 1475–1483. doi:10.1016/0024-3205(96)00118-X

Lúcio, P. S., Pinheiro, A. M. V., & Nascimento, E. do. (2010). A Influência de fatores sociais, individuais e lingüísticos no desempenho de crianças na leitura em voz alta de palavras isoladas. *Psicologia: Reflexão e Crítica*, *23*(3), 496–505. doi:10.1590/S0102-79722010000300010

*Lupien, S. J., King, S., Meaney, M. J., & McEwen, B. S. (2001). Can poverty get under your skin? Basal cortisol levels and cognitive function in children from low and high socioeconomic status. *Development and Psychopathology*, *13*(3), 653–676.

Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature Reviews Neuroscience*, *10*(6), 434–445. doi:10.1038/nrn2639

McEwen, B. S. (1998). Protective and damaging effects of stress mediators. *New England Journal of Medicine*, *338*(3), 171–179. doi:10.1056/NEJM199801153380307

McEwen, B. S. (2006). Protective and damaging effects of stress mediators: central role of the brain. *Dialogues in Clinical Neuroscience*, *8*(4), 367–381.

McEwen, B. S., & Gianaros, P. J. (2010). Central role of the brain in stress and adaptation: links to socioeconomic status, health, and disease. *Annals of the New York Academy of Sciences*, *1186*, 190–222. doi:10.1111/j.1749-6632.2009.05331.x

McEwen, B. S., & Stellar, E. (1993). Stress and the individual. Mechanisms leading to disease. *Archives of Internal Medicine*, *153*(18), 2093–2101.

Mischel, W., Shoda, Y., & Rodriguez, M. I. (1989). Delay of gratification in children. *Science*, *244*(4907), 933–938. doi:10.1126/science.2658056

*Neupert, S. D., Miller, L. M. S., & Lachman, M. E. (2006). Physiological reactivity to cognitive stressors: variations by age and socioeconomic status. *International Journal of Aging & Human Development*, *62*(3), 221–235.

Nisbett, R. E., Aronson, J., Blair, C., Dickens, W., Flynn, J., Halpern, D. F., & Turkheimer, E. (2012). Intelligence: new findings and theoretical developments. *The American Psychologist*, *67*(2), 130–159. doi:10.1037/a0026699

Noble, K. G., Korgaonkar, M. S., Grieve, S. M., & Brickman, A. M. (2013). Higher education is an age-independent predictor of white matter integrity and cognitive control in late adolescence. *Developmental Science*, *16*(5), 653–664. doi:10.1111/desc.12077

Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science*, *10*(4), 464–480. doi:10.1111/j.1467-7687.2007.00600.x

Noble, K. G., Tottenham, N., & Casey, B. J. (2005). Neuroscience perspectives on disparities in school readiness and cognitive achievement. *The Future of Children/Center for the Future of Children, the David and Lucile Packard Foundation*, *15*(1), 71–89.

*Pilgrim, K., Marin, M.-F., & Lupien, S. J. (2010). Attentional orienting toward social stress stimuli predicts increased cortisol responsivity to psychosocial stress irrespective of the early socioeconomic status. *Psychoneuroendocrinology*, *35*(4), 588–595. doi:10.1016/j.psyneuen.2009.09.015

Power, C., Li, L., & Hertzman, C. (2008). Cognitive development and cortisol patterns in mid-life: findings from a British birth cohort. *Psychoneuroendocrinology*, *33*(4), 530–539. doi:10.1016/j.psyneuen.2008.01.017

Sarsour, K., Sheridan, M., Jutte, D., Nuru-Jeter, A., Hinshaw, S., & Boyce, W. T. (2011). Family socioeconomic status and child executive functions: the roles of language, home environment, and single parenthood. *Journal of the International Neuropsychological Society: JINS*, *17*(1), 120–132. doi:10.1017/S1355617710001335

*Sheridan, M. A., Sarsour, K., Jutte, D., D'Esposito, M., & Boyce, W. T. (2012). The impact of social disparity on prefrontal function in childhood. *PloS One*, *7*(4), e35744. doi:10.1371/journal.pone.0035744

Turkheimer, E., Haley, A., Waldron, M., D'Onofrio, B., & Gottesman, I. I. (2003). Socioeconomic status modifies heritability of IQ in young children. *Psychological Science*, *14*(6), 623–628.

United Nations Program for Development—UNPD. (2013). *Development Report 2013—The Rise of the South: Human Progress in a Diverse World*. New York, UNPD.