Développement des fonctions exécutives chez l'enfant du nord-est du Brésil

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THE BRAZILIAN VERSION OF THE CHILD EXECUTIVE FUNCTIONS BATTERY (CEF-B): PSYCHOMETRIC PROPERTIES AND EXECUTIVE DEVELOPMENT PROFILE OF CHILDREN FROM THE NORTHEAST OF BRAZIL

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Abstract

Currently, the neuropsychological assessment of executive functions (EF) has been the object of increasing research interest. In Brazil, the number of publications regarding both EF neuropsychological tests and scientific productions, has increased substantially. Despite advances, there is still remarkable dissatisfaction with the validation and standardization of available EF measures, as well as a lack of specific batteries for the evaluation of EF in the pediatric population in Brazil. This limitation hinders the characterization of the typical development of EF in Brazilian children and limits the knowledge about the semiology of EF disorders in children. Considering this scenario, this thesis aims to provide Brazilian researchers and professionals with a battery of psychometric tests developed in France and simultaneously adapted to different cultures, namely, Lebanon, Morocco, Tunisia, Ecuador and Brazil: the Child Executive Functions Battery (CEF-B). This study consisted of a continuation of the translation and adaptation process initiated at the master's level. The main objectives of the thesis were designed through three complementary perspectives: developmental, cultural and clinical. From a clinical perspective, we aimed to analyze the psychometric properties of the Brazilian version of the CEF-B and to characterize the development profile of EF in children in the Northeast of Brazil. In addition, we performed a critical analysis of the instruments available for clinical evaluation of EF in the Brazilian pediatric population. Regarding cultural and development objectives, this study also aimed to analyze the impact of socio-demographic factors (such as gender and type of school) on EF development. To achieve the proposed objectives, this study was carried out with children from 7 to 12 years old with typical development of three cities in Rio Grande do Norte. The sample was divided into six age groups and each group was composed of approximately 40 children, homogeneously distributed by sex and type of school. A global effect of age was found for most of the EF measures evaluated. Gender effect was mostly non-significant, except for 4 of the 12 tasks. There was a significant effect of socioeconomic status on 8 tasks, all in favor of private school children. Exploratory factorial and correlation analysis showed a 4-factor EF structure, corroborating the theoretical distribution considered in the French CEF-B. Regarding the psychometric properties, a satisfactory retest and internal consistency reliability coefficients were found. In addition, data on the effect of age suggested good developmental validity of the battery. Although normative data are still lacking for other regions of Brazil, we believe that the next steps of this research will allow the clinical use of the CEF-B. These future investigations will provide clinical neuropsychologists with an improved theoretical basis for child executive development and tools for better identifying executive disorders in the pediatric population.

Keywords: executive functions, normative data, child neuropsychological assessment, child development

Resumo

Atualmente, a avaliação neuropsicológica das funções executivas (FE) tem sido objeto de interesse crescente de pesquisas. No Brasil, o número de publicações relativas tanto aos testes neuropsicológicos de FE como às produções científicas, aumentou substancialmente Apesar dos esforços em âmbito nacional na produção e adaptação de testes que avaliam FE na infância, ainda se evidencia notável insatisfação em relação à validação e normatização dos testes disponíveis, bem como escassez de baterias específicas para a avaliação das FE em população pediátrica no Brasil. . Esta limitação dificulta a caracterização do desenvolvimento típico das FE em crianças brasileiras e limita o conhecimento sobre a semiologia dos transtornos executivos infantis. Nesse cenário, essa tese pretendeu disponibilizar para os pesquisadores e profissionais neuropsicólogos brasileiros uma bateria de testes psicométricos desenvolvida na França e adaptada simultaneamente para diferentes culturas, a saber, Líbano, Marrocos, Tunísia, Equador e Brasil: o protocolo Funções Executivas em Crianças (FEC). Este estudo consistiu na continuação do processo de tradução e adaptação iniciado ao nível do mestrado. Os principais objetivos da tese foram delineados em torno de três perspectivas complementares: de desenvolvimento, cultural e clínica. Do ponto de vista clínico, pretendeu-se analisar as propriedades psicométricas da versão brasileira da FEC e caracterizar o perfil de desenvolvimento das FE em crianças do nordeste do Brasil. Além disso, realizámos uma análise crítica dos instrumentos disponíveis para avaliação clínica das FE na população pediátrica brasileira. No que diz respeito aos objetivos cultural e de desenvolvimento, este estudo visou analisar o impacto de fatores sociodemográficos (tais como sexo e tipo de escola) no desenvolvimento executivo. Para alcançar os objetivos propostos, este estudo foi realizado com 230 crianças com desenvolvimento típico entre sete e 12 anos de idade de três cidades do Rio Grande do Norte. A amostra foi dividida em seis grupos etários. Cada grupo foi composto por aproximadamente 40 crianças, distribuídas homogeneamente por sexo e tipo de escola. Foi encontrado um efeito global da idade para a maioria das medidas executivas avaliadas. O efeito do gênero não foi significativo para a maior parte das tarefas, exceto para 4 das 12. Houve um efeito significativo do nível socioeconômico em 8 tarefas, todos a favor de crianças de escolas privadas. A análise fatorial exploratória e de correlação revelou uma estrutura de 4 fatores, corroborando a repartição teórica considerada na FEC. Em relação às propriedades psicométricas, foram encontrados bons indicadores de fidedignidade teste-reteste e de coeficientes de consistência interna. Além disso, os dados sobre o efeito da idade, sugeriam uma boa validade de desenvolvimento da bateria. Embora ainda faltem dados normativos para outras regiões do Brasil, acreditamos que os próximos passos desta investigação permitirão a utilização clínica da CEF-B. Estas investigações futuras proporcionarão aos neuropsicólogos clínicos uma base teórica mais sólida para a compreensão das FE, assim como ferramentas mais adaptadas para uma melhor identificação dos distúrbios executivos na população pediátrica.

Palavras-chave: funções executivas; dados normativos; avaliação neuropsicológica infantil; desenvolvimento infantil.

Résumé

L'évaluation neuropsychologique des fonctions exécutives (FE) fait l'objet d'un intérêt croissant au niveau de la recherche. Au Brésil, le nombre de publications concernant à la fois les tests neuropsychologiques des EF et les productions scientifiques, a considérablement augmenté. Malgré les efforts nationaux dans l'élaboration et l'adaptation des tests qui évaluent les FE chez l'enfant, il existe encore une insatisfaction remarquable quant à la validation et la standardisation des tests disponibles, ainsi qu'un manque de batteries spécifiques pour l'évaluation des FE dans la population pédiatrique au Brésil. Cette limitation fait obstacle à la connaissance de la sémiologie des troubles de FE chez les enfants et limite l'évaluation et la recherche sur le développement typique des enfants brésiliens. Cette étude vise à fournir aux chercheurs et aux professionnels brésiliens une batterie de tests psychométriques développés en France et adaptés simultanément à différentes cultures, à savoir, le Liban, le Maroc, la Tunisie, l'Equateur et le Brésil : la batterie des fonctions exécutives de l'enfant (FÉE). Cette étude a consisté en une poursuite du processus de traduction et d'adaptation initié au niveau du master. Les principaux objectifs de la thèse ont été conçus à travers trois perspectives complémentaires : développementale, culturelle et clinique. D'un point de vue clinique, nous avons cherché à analyser les propriétés psychométriques de la version brésilienne de la CEF-B et à caractériser le profil de développement des FE chez les enfants du Nord-Est du Brésil. De plus, nous avons effectué une analyse critique des outils disponibles pour l'évaluation clinique des FE dans la population pédiatrique brésilienne. En ce qui concerne les objectifs culturels et de développement, cette étude visait également à analyser l'impact des facteurs socio-démographiques (tels que le genre et le type d'école) sur le développement exécutif. Pour atteindre les objectifs proposés, cette étude a été menée auprès de 230 enfants de 7 à 12 ans présentant un développement typique recrutés dans trois villes du Rio Grande do Norte. L'échantillon a été divisé en six groupes d'âge et chaque groupe était composé d'environ 40 enfants, répartis de manière homogène par sexe et par type d'école. Un effet global de l'âge a été constaté pour la plupart des mesures des FE. L'effet du sexe était significatif pour seulement 4 des 12 tâches. Un effet significatif du niveau socio-économique a été constaté pour 8 tâches, toutes en faveur des enfants des écoles privées. Une analyse factorielle exploratoire et une étude des corrélations a montré une structure à 4 facteurs, corroborant la distribution théorique considérée dans la version française de la FÉE. En ce qui concerne les propriétés psychométriques, les coefficients de fidélité étaient satisfaisants. De plus, les données sur l'effet de l'âge suggèrent une bonne validité de développement de la batterie. Bien que les données normatives manquent encore pour d'autres régions du Brésil, les prolongements de cette recherche auront pour ambition l'utilisation clinique de la FEE auprès de différents contextes pédiatriques. L'enjeu est de fournir aux neuropsychologues cliniciens des stratégies d'examen théoriquement guidées et méthodologiquement structurées pour la compréhension du développement typique et perturbé des FE chez l'enfant brésilien.

Mots clés : fonctions exécutives, données normatives, évaluation neuropsychologique de l'enfant, développement de l'enfant

Resumen

La evaluación neuropsicológica de las funciones ejecutivas (FE) es objeto de un creciente interés de investigación. En Brasil, el número de publicaciones tanto de pruebas neuropsicológicas de FE como de producciones científicas ha aumentado sustancialmente. A pesar de los esfuerzos nacionales en el desarrollo y la adaptación de pruebas que evalúan las FE en los niños, sigue habiendo una gran insatisfacción con la validación y la estandarización de las pruebas disponibles, así como una falta de baterías específicas para la evaluación de las FE en la población pediátrica brasileña. Esta limitación dificulta el conocimiento de la semiología de los desórdenes ejecutivas en los niños y restringe la evaluación e investigación del desarrollo típico de los niños brasileños. En este escenario, esta tesis objetivó proporcionar a los investigadores y profesionales brasileños una batería de pruebas psicométricas desarrolladas en Francia y adaptadas simultáneamente a diferentes culturas, a saber, el Líbano, Marruecos, Túnez, Ecuador y el Brasil: la batería Funciones Executivas en Niños (FEN). Este estudio consistió en la continuación del proceso de traducción y adaptación iniciado a nivel de maestría. Los principales objetivos de la tesis se esbozaron en torno a tres perspectivas complementarias: la del desarrollo, la cultural y la clínica. Desde el punto de vista clínico, se pretendió analizar las propiedades psicométricas de la versión brasileña de la FEN y caracterizar el perfil de desarrollo de la FEN en los niños del nordeste de Brasil. Además, realizamos un análisis crítico de los instrumentos disponibles para la evaluación clínica de las FE en la población pediátrica brasileña. En lo que respecta a los objetivos culturales y de desarrollo, este estudio tenía por objeto analizar la repercusión de los factores sociodemográficos (como el género y el tipo de escuela) en el desarrollo ejecutivo. Para lograr los objetivos propuestos, este estudio se realizó con 230 niños de 7 a 12 años de edad con un desarrollo típico en tres ciudades de Río Grande do Norte. La muestra se dividió en seis grupos de edad y cada grupo estaba compuesto por aproximadamente 40 niños, distribuidos homogéneamente por género y tipo de escuela. Se encontró un efecto general de la edad en la mayoría de las medidas de FE evaluadas. El efecto de género fue mayormente insignificante, excepto para 4 de las 12 tareas. Se encontró un efecto significativo del nivel socioeconómico en ocho tareas, todas ellas a favor de los niños de escuelas privadas. Un análisis exploratorio factorial y de correlación demostró una estructura de 4 factores, corroborando la distribución teórica considerada en la FEN. Con respecto a las propiedades psicométricas, se encontraron coeficientes satisfactorios de fiabilidad de retest y de consistencia interna. Además, los datos sobre el efecto de la edad sugieren una buena validez de desarrollo de la batería. Aunque todavía faltan datos normativos para otras regiones del Brasil, los próximos pasos de esta investigación permitirán el uso clínico de la FEN. Estas futuras investigaciones proporcionarán a los neuropsicólogos clínicos una base teórica más sólida para el desarrollo ejecutivo infantil y herramientas para identificar mejor los trastornos ejecutivos en la población pediátrica.

Palabras clave: funciones ejecutivas, datos normativos, evaluación neuropsicológica infantil, desarrollo infantil

Summary

“Toda criança do mundo
Deve ser bem protegida
Contra os rigores do tempo
Contra os rigores da vida”

Agradecimentos

Elaborar uma tese pode ser uma tarefa de natureza essencialmente individual, mas nunca solitária. Os encontros que fazem esse percurso ecoam nessas páginas e transbordam a crença de que a ciência feita à muitas mãos é necessária para transformar realidades. A sorte de contar com diversas vozes, culturas e contextos na construção desse trabalho traz também o desafio da síntese de palavras e emoções nessa seção de agradecimentos. Na esperança de que essas palavras registradas nos acervos da UFRN e Université d'Angers possam ser sempre registro da minha gratidão, eu mergulho na viagem ao tempo dos quatro anos que levaram a esse momento.

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1. Initial considerations

Executive functions (EF) are among the most studied and debated processes in the current neuropsychological literature. These high-level processes allow the subject to engage in goal-oriented behaviors, to organize the control of actions in a broad sense and to deal with new situations or circumstances that require adjustment, adaptation or flexibility of behavior (Elliott, 2003; Gazzaniga et al., 2006; Huizinga et al., 2006).

In both children and adults, EF are essential for guiding and regulating intellectual, emotional and social capacities (Diamond, 2013; Zelazo, 2012). It is noteworthy that, especially in children, these skills have been identified as predictors of academic success, with performance in executive tests more correlated with school success than performance in intelligence tests during the early years of the literacy cycle (Alloway & Alloway, 2010; Follmer, 2017; Shaul & Schwartz, 2014). Given the importance of EF for quality of life, research around this topic has become central to neuropsychological evaluation, especially in clinical settings (Malloy-Diniz et al., 2010).

Neuropsychological assessment of children allows the identification of early changes in cognitive and/or behavioral development, which may be associated with dysexecutive symptoms (Dajani et al., 2016). In view of the prolonged neurobiological maturation of the fronto-subcortical networks, the influence of social and cultural factors in the emergence of EF in children has been increasingly recognized, given the vulnerability of executive development (Farah, 2017; Hackman et al., 2015; Lawson et al., 2017; Sbicigo et al., 2013). These aspects suggest that the development of assessment methods should consider the cultural aspects of the country and region in which they will be used (Fernandez & Marcopulos, 2008).

In Brazil, this aspect is particularly important given the remarkable cultural variability and socioeconomic inequality of the country (Piccolo et al., 2016). For example, the Northeast region is ranked last in the National Human Development Index. Specifically, the State of Rio Grande do Norte ranks third from the last in the country's performance in reading, writing, and mathematics. Given the role of EF in learning, it is important to understand the development paths of these functions in contexts of vulnerability and risk, using appropriate tools for these populations.

Despite national efforts in the production and adaptation of executive tests for children, there are still plenty of shortcomings regarding the available standardized psychological tests. There is also a shortage of batteries based on specific theoretical models for executive assessment in the pediatric population. In addition, most of the tasks commonly used are built for adults, and therefore not necessarily adapted to children (Natale et al., 2008). These limitations impose obstacles to the construction of knowledge about the typical development of EF in Brazil, as well as about the semiology of executive disorders in childhood (i.e. neurodevelopmental disorders, early brain injuries, psychopathology; Barros & Hazin, 2013).

In this context, in 2015, the *Laboratório de Pesquisa e Extensão em Neuropsicologia* of the *Universidade Federal do Rio Grande do Norte* (LAPEN-UFRN) established an international collaboration with the *Laboratoire de Psychologie des Pays de la Loire* (LPPL) of the *University of Angers* – France in order to search for alternatives to minimize the aforementioned shortcomings. Among the activities that led to the collaboration between the institutions was the cross-cultural adaptation and validation of the Child Executive Functions Battery – CEF-B (Roy et al., 2020. This battery aimed to assess EF in children and adolescents aged six to 16 years. This partnership was officialized with the submission and approval of a joint research project proposal to the Human Sciences Call for Projects of the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq), and, later to the MCTI/CNPQ Nº 01/2016 – Universal Call for Projects of the same funding agency.

This initial collaboration resulted in the development of my master's dissertation, which consisted of the translation and adaptation of the CEF-B (Guerra, 2016). The master’s project was promoted to a PhD thesis (based on Decree n°77 of 15 August 2006 regarding the promotion of a master’s level project to the PhD level) which was developed as a co-tutorship supported by the international agreement previously signed between the UFRN and the *Université d'Angers*. In accordance with the co-tutorship agreement, an international doctoral scholarship was granted by the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES) to carry out the interchange period at the French university in 2019. It should be noted that other similar studies are being developed with the CEF-B in other countries, including France, Tunisia, Morocco, Lebanon and Ecuador, which grants the study cross-cultural elements for the analysis and discussion of data.

Some results from my master's dissertation, as well as the considerations raised in the context of my doctoral studies, have been published/submitted or are submitted/under revision to scientific journals. These are listed as follows:

- Guerra, A., Guerra, Y., Silvestre I., Rezende, M., Le Gall, D., Roy, A., & Hazin, I. (In press). Transcultural adaptation of the Childhood Executive Functions Battery (CEF-B) for brazilian Portuguese. *Avaliação Psicológica.* (Annex 1)

- Guerra, A., Lodenos, V., Bellouard-Masson, S., Le Gall, D., Hazin, I., & Roy, A. (2019). Les fonctions exécutives chez l'enfant: Quels liens avec les apprentissages et comment penser leur évaluation ? *Rééducation Orthophonique*, 278, 27-48.

- Guerra, A, Combes, C., Hazin, I., Le Gall, D., & Roy, A. (2020) L’émergence et le développement des fonctions exécutives chez l’enfant : réflexions sur l'impact des aspects contextuels, culturels et de l'environnement numérique. *ANAE : Approche Neuropsychologique Des Apprentissages Chez l'Enfant*. 167, 375-382.

- Charbonier, V., Guerra, A. (2020). Intérêt de l'inventaire d'évaluation comportementale des fonctions exécutives dans le bilan neuropsychologique de l'enfant : à propos d'une étude de cas. *ANAE : Approche Neuropsychologique Des Apprentissages Chez l'Enfant*. 167, 403-412.

- Siebra, C., Guerra, A., Roy, A., Hazin, I., & Salgado-Azoni, C. (In press). Developmental dyslexia and executive functions: Evidence on main evaluation methods. *Estudos de Psicologia.*

- Er-Rafiqi, M., Guerra, A., Le Gall, D., & Roy, A. (under review). Development of cognitive flexibility and planning skills in school-age Moroccan children.

- Er-Rafiqi, M., Guerra, A., Le Gall, D., & Roy, A. (under review). Development of inhibition and working memory in school-age Moroccan children.

- Roukoz, C., Guerra, A., Le Gall, D., & Roy, A. (Considered for publication). Development of Executive Functions in Lebanese Children.

The present thesis is a continuation of the study initiated at the master's level. It ccomprises one theoretical article and three empirical articles that were structured as follows:

1. General Introduction

2. Objectives

3. General Method

4. Results and Discussions: composed of a theoretical article and two empirical articles

5. General Conclusion.

All studies were written in English as a strategy to broaden the reach of the studies and strengthen the international cooperation that supports this thesis. It should be noted that the empirical studies were analyzed jointly with the other countries that compose the CEF-B project, which allowed discussions on the adaptation and cross-cultural validity of the protocol tasks. In the next sections, each of the studies will be presented independently.

2. General introduction

Although widely debated and studied, EF still represent a very challenge construct to circumscribe due to the various and divergent ideas regarding it. Given the difficulty of reaching consensus on EF definitions, a recent review highlighted conceptual and operational points of convergence (Baggetta & Alexander, 2016). According to the authors, researchers agree that EF (1) guides action and behaviors that are essential to learning and carrying out everyday tasks; (2) contributes to the regulation and monitoring of tasks; (3) concerns not only the cognitive domain, but also socioemotional and behavioral aspects; and also (4) consists of a multidimensional construct in its essence with more than one individual component or function (Baggetta & Alexander, 2016)

As a multidimensional construct, EF encompasses cognitive, behavioral and emotional processes, which are theoretically and clinically dissociable. Cognitive skills (or "cool" components, according to some authors eg. Zelazo & Carlson, 2012) mainly require logical reasoning resources without emotional state and are usually associated with lateral prefrontal cortex (Happaney et al., 2004; Zelazo & Muller, 2002). These skills include several processes such as attention, abstraction, organization, planning, mental flexibility, self-regulation, working memory (WM), verbal fluency, among others (Gazzaniga et al., 2006; Lezak et al., 2004). Despite the different classifications, classical studies recognize that inhibition, WM and cognitive flexibility are the basic components of EF (e.g., Diamond, 2013; Friedman & Miyake, 2017; Lehto et al., 2003; Miyake et al., 2000). Furthermore, planning, abstract reasoning and problem solving are recognized as a higher-level executive process (Diamond, 2013), although there is no scientific consensus on the nature and organization of this type of component. In general, cognitive components (basic and complex) are defined as independent, although they are strongly interconnected regarding the execution of complex tasks (Diamond, 2013; Lehto et al., 2003; Miyake et al., 2000).

Although less studied than cognitive components and often disregarded in classic models, emotional and behavioral factors (or "hot" components according to some authors, i.e. Zelazo, 2015) play an essential role in the regulation of emotional states or in making appropriate decisions. They seem to depend on orbitofrontal cortex and other medial regions (see Happaney et al., 2004, for a review) and are related, for example, to behavioral self-regulatory skills, emotional decision-making and social cognition. Thus, deficits in these components can result in inadequate social behavior, difficulties in decision-making and/or judgment, and impairments in initiating, continuing, changing and/or organizing action plans (Zelazo et al., 2010).

Given the importance of EF in global psychological development (Diamond, 2013), the assessment of these functions in children is essential. In addition, executive dysfunctions are central symptoms in different neurological, developmental and context-related conditions, given the characteristics of the development of the prefrontal networks and their connections. In fact, the issue of early vulnerability of EF is relatively consensual in clinical neuropsychology. During childhood, the prefrontal cortex and the networks connecting it to the rest of the brain could be affected by brain damage, resulting in a high risk of dysexecutive symptoms (Anderson et al., 2010; Dennis, 2006). However, executive dysfunction is not necessarily associated with prefrontal injury. Given the systemic nature of the brain, these dysfunctions may be related, for example, to disconnections between neural networks caused by white matter lesions or structural deficits in other regions of the brain (Anderson et al., 2010). However, several medical conditions may present a high risk of impairing the developmental dynamics inherent to the prefrontal cortex and its multiple interconnections. This risk mostly concerns acquired neurological pathologies in children who may have suffered early brain damage during fetal life, the perinatal period, or even during childhood. These lesions usually refer to cases of head trauma (including shaken babies), epilepsy, prematurity and cerebral palsy, brain tumors, stroke or fetal alcohol syndrome (see, for example, Anderson et al., 2011).

Neurodevelopmental disorders represent another clinical risk which can lead to executive disorders. These conditions are associated with neurobiological changes and, consequently, with atypical development of the brain, particularly frontal networks. Neurodevelopmental disorders include specific alterations in language, learning or motor development, attention deficit hyperactivity disorder (ADHD), autism spectrum disorder, intellectual disability, as well as neurogenetic diseases such as neurofibromatosis type 1, phenylketonuria or 22Q11.2 (Dajani et al., 2016; Elliott, 2003). Furthermore, it should be noted that executive dysfunctions may be related to psychological developmental disorders in the broadest sense, including psychopathologies commonly reported in child psychiatry, for example depression and anxiety (Micco et al., 2009; Zelazo, 2020).

Although the pediatric dysexecutive syndrome is reported in several medical and neurodevelopmental conditions, the description of the symptoms differs from one etiological diagnosis to the other. This variable symptomatology leads to a partial description of the dysexecutive syndrome in children, even raising questions regarding its existence and repercussion on the medical, social and educational environment (Roy et al., 2017). Nevertheless, a theoretical proposition was elaborated to describe its main characteristics (Roy, 2015; Roy et al., 2017). According to this proposal, the empirical data collected in the last thirty years converge to the idea that executive disorders in children 1) are relatively frequent; 2) are variable in their expression, with possible clinical dissociation; 3) are chronic, or even likely to worsen when the demands for autonomy are greater (possible late onset of symptoms); and 4) usually have a serious impact on integration and academic, social and professional success (Garcia-Barrera, 2019; Zelazo, 2020). Despite the absence of precise diagnostic criteria, impairment of executive functioning is at the core of a broad spectrum of clinical contexts. Therefore, appropriate EF investigation methods are needed in order to better understand the typical and atypical executive development in children.

Assessing EF in children is a challenging endeavor. In fact, this procedure comprises several particularities in comparison to the investigation of other cognitive functions. It requires the consideration of a specific theoretical-methodological framework that minimizes possible biases and that enable the evaluation of different executive components. In this framework, the neurobiological maturation (in typical and atypical conditions) of these higher-level functions should be taken into consideration, as well as the adequacy of measures to the level of child development and the role of contextual and cultural variables in executive functioning and development. However, these recommendations are confronted with methodological difficulties that are now well identified and which will be discussed in the following paragraphs.

2.1. Classic biases of EF measurement and its transposition into child assessment

The assessment of complex functions often requires the use of complex tests. Although the simulation of such tasks allows the evaluation of how EF operate in their execution, the intricacy of these higher-level functions and the tasks themselves can lead to measurement errors. These biases are frequently described in the assessment of EF in adults and are not only associated with their complex nature and dependence on lower-level functions, but also with their multifactorial and interdependent nature (Chan, 2008). In children, as previously described, these issues are amplified by the developmental characteristics of this stage of life (Hughes & Graham, 2002).

The theoretical dissociation between different executive processes seems, in fact, to be particularly complex. The plurality and interdependence of EF hampers the elaboration of tasks that allow the specific assessment of individual executive components. Furthermore, each executive process can be classified in several ways and classic complex tests (e.g., Wisconsin Card Sorting Test – WSCT, Hanoi Tower, London Tower and Rey–Osterrieth complex figure - ROCF) can be used to evaluate a wide range of functions, according to the interest of clinicians and researchers. The WCST, for example, has been used by different scientists as a measure of "inhibition", "flexibility", "problem solving" and "categorization". While this classification may seem reasonable on an intuitive level, no empirical evidence can prove the construct evaluated by the task (Miyake et al., 2000). The use of tasks designed to be difficult and complex and the lack of consensus on the evaluated construct may hinder the understanding of what is really expected at each stage of the child's executive development.

Another major methodological barrier is the choice of the type of tool used to assess EF in pediatric population. The majority of tasks commonly used for children are originally designed for adults and therefore are not necessarily adapted to this population. In addition to the inherent challenges of assessing EF, the high level of difficulty of adult tasks, which is adequate for the evaluation of fully developed functions, is in fact inappropriate for assessing processes that are still under development. Therefore, the continued use of adult-centered tests without considering their sensitivity to children may compromise the understanding of typical and atypical development of EF (Hughes & Graham, 2002).

In addition to errors associated with the multifactorial and interdependent nature of EF, these processes are necessarily mediated by lower-level functions (Denckla, 1996). In order to discuss which processes are associated with poor performance in executive tasks, it is essential to dissociate, through a hypothetical-deductive logic, basic processes from the more complex ones. To this end, it is suggested to add complementary steps to the complex tasks. A good example is the ROCF, which is widely used by neuropsychologists as a measure of visuo-construction and visual-spatial skills and planning abilities. However, the use of this test to assess specific skills may be compromised if its application does not include dissociation strategies. More precisely, the result of spontaneous copy does not provide a clear overview of the underlying mechanisms involved in the failure. In fact, the use of the ROCF as a planning measure without verifying the development of more basic functions (mediators of the performance of the task) can lead to erroneous analysis. To differentiate the two main cognitive domains accessed by the ROCF, researchers have proposed a complementary step to the test in which the engagement of planning strategies is reduced. This step allows the disassociation between planning/organizational difficulties (lack of engagement of EF) and gestual disorders (reaching lower-level processes) (see Roy et al., 2010 for a description of the task). This type of strategy aids in making executive measures more precise and in minimizing the biases of the assessment of high-level functions in children.

Moreover, considering the multidimensional nature of EF, current literature recommends that assessment strategies must be based on several indicators and evaluation sources (Toplak et al., 2013). The investigation process must associate/confront 1) the interview and clinical observations, 2) the results obtained through performance-based measures and 3) the results obtained through measures that are described as more "ecological" or more representative of daily life. The performance-based approach comprises standardized procedures and the presence of an examiner. The excessively formal (or even artificial) nature of the usual testing situation may lack sensitivity and has led to the development of different approaches that are referred to as "ecological assessment" (Anderson, 2002). These approaches include questionnaires for parents and teachers, as well as tests that more closely resemble everyday life situations regarding their design and materials. Although some neuropsychological performance-based tests are sensitive for the detection of executive dysfunction, their ecological validity for the measurement of EF has been contested. When used alone, neuropsychological tests do not consistently discriminate between clinical and control groups (Barkley, 1997; Mahone et al., 2002) nor predict executive functioning in everyday activities (Wilson, 1997). In this context, it is necessary to examine EF in children by using multiple data sources and to assess children's behaviors outside the testing environment through questionnaires for parents and teachers (rating scales), as well as tasks that are designed to simulate everyday life situations.

This perspective is particularly important because even highly dysfunctional children can obtain normal scores on neuropsychological performance-based tests. However, a child might perform as well as expected in everyday life situations, but present low performance in executive tests. For this reason and in order to systematically compare clinical observations with real-world observations, it is essential that parents and teachers are given the opportunity to describe child's issues in everyday life. Furthermore, studies that confronted these two types of EF assessment have shown relatively weak agreement between subjects with and without pathologies (both children and adults) suggesting that these two approaches are different and complementary in assessing diverse aspects of executive functioning (Toplak et al., 2013). Through this logic, it seems essential to combine these two types of indicators to the elements resulting from clinical interview and observation (Roy et al., 2017). Also, both performance-based and rating measures need to be adapted to the reality of each stage of child development, as well as to the culture and context in which they live.

2.2. Typical and atypical development of EF and its repercussions on children's neuropsychological assessment

The maturation of the human brain is progressively established throughout childhood and adolescence. Based on the logic of caudo-rostral maturation (going "forward"), the frontal structures and the connections that link them to other cortical and subcortical regions would be the last to reach the peak of their development. This premise would drive the myelinization and late synaptic elimination of prefrontal areas, which would characterize the early but prolonged development of this region compared to other brain areas (Dennis, 2006; Lenroot & Giedd, 2006).

Datasets from developmental studies in infants and children, lesion studies in macaques and clinical cases (with adults and children) reported in neuropsychology literature suggest that the EF maturation timeline would be associated with that of prefrontal networks (Alvarez & Emory, 2006; Stuss & Alexander, 2000). Thus, by analogy with prefrontal development, EF would start operating since the first years of life but would follow a long developmental trajectory and reach a late functional maturity. This maturation would reach its peak, at best, around 25 or 30 years of age (Lebel et al., 2008; Tamnes et al., 2010): It should be noted, however, that the development of these functions is not limited to the maturation of the prefrontal cortex, because higher levels of human functioning are not restricted to specific areas of the brain and also depend on the development of more basic functions. In this perspective, the location of higher mental processes would not be static, but systemic, encompassing various brain structures and organizing itself according to the stages of child development (Bodrova et al., 2011).

Inhibitory control and WM would be the first processes to be differentiated and would constitute the necessary common basis for the progressive development of mental flexibility skills (Anderson et al., 2010; Diamond, 2013). Once these three core processes have reached a first state of maturity, the higher-level EF, such as planning, would begin to differentiate as independent processes (Diamond, 2013). Similarly, lower-level skills (such as those required in an activity that demands selective attention) would require less time to develop compared to more complex skills (such as those needed in tasks that demand the hierarchization of action sequences) (Davidson, 2006; Dias, 2009; Huizinga et al., 2006) . Therefore, executive development seems to be a non-linear and asynchronous process, characterized by spurts or peaks in development (Anderson, 2002).

In this perspective, an appropriate instrument for the evaluation of EF in the pediatric population should take into consideration the specificities and trajectories of their ontogenic development. This implies that the test material should be adapted to the level of development of the child and should allow the possibility of mediation during the execution of the task. The use of mediation strategies in tasks (for example, to repeat the task instructions after a certain number of errors or to allow the possibility of questioning/correcting the child's response) is particularly important in case of errors in the execution of the task. The level of mediation (quantity and quality) required to perform the task allows a better understanding of the level of development of the assessed function (acquired/undergoing/unacquired) and helps identify potential executive deficits in children (Tzuriel, 2001).

2.2.1. The search for a theoretical model for children

In the context of the hypothetical-deductive reasoning that drives the clinical approach in neuropsychology, it is necessary to rely on theoretical models to guide the assessment and the potential choice of remediation. Given that the development of the expertise on EF in children is still recent, the transposition of knowledge acquired from adult neuropsychology (theoretical modeling and the use of tests created specifically for this population) is still performed in this domain (Roy, 2015). Although adult-centered models can be a compelling source for comprehending executive deficits in children, it should be noted that these models consider a mature state as reference, which does not allow explaining the dynamic and progressive characteristic of executive development (Zesiger & Hirsbrunner, 2000). Therefore, given that the child brain is in full development, the theoretical modeling and forms of EF assessment in childhood should follow the particularities of this stage of the life cycle.

In contrast to the adult-centered perspective, the neuropsychological analysis of children should be confronted with the specificity of the interactions between cognitive/affective development and neurobiological maturation. It should be emphasized that this maturation permeates several factors such as genetic predispositions, brain specialization, plasticity, the so-called 'critical periods' and also the context and culture where development occurs. In view of these variables, the classic neuropsychological relationships established in adults are hypothetical in children and should be considered with caution, limiting the use of theoretical models and methods of assessment designed for adults (Henry & Bettenay, 2010; Isquith et al., 2005).

In the absence of a well-developed heuristic theoretical model for childhood, factorial studies offer another perspective for analyzing the structure and organization of EF. The number of this type of study increased since the 1990s, and they helped complement the theoretical approach to EF by leading the debate on the identification of the main executive components. Despite advances provided by this type of analysis, findings about the type and quantity of the components are inconsistent in the literature (Table 1).

Table 1. Summary of the main factorial studies on EF in children

Study	Sample	Analysis	Factors and tasks	Findings
Levin & al. (1991)	7-15 (n=52)	Principal component analysis	Semantic association/concept formation : CVLT, VF, TQT, FF Freedom from perseveration: Go/No-Go, WCST, FF Planning/Strategy: TOL	3 factors
Welsh & al. (1991)	3-12 (n=100)	Principal component analysis	Speeded responding: VF, visual search, motor sequencing, and recognition memory. Set maintenance: MFFT, WCST Planning: TOH	3 factors
Sevino (1998)	8-12 (n=170)	Principal component analysis	Factor 1 : TMT, Stroop Factor 2 : VF Factor 3 : Multiple classifications Factor 4 : FF et TOH Factor 5 : ROCF	5 factors

Klenberg & al.(2001)	3-12 (n=400)	Factor analysis with orthogonal rotation	Fluency: FF, VF. Selective visual attention: Visual Search subtest. Auditory attention: Auditory attention and auditory response set. Simple inhibitory functions: Statue subtest	4 factors
Anderson & al. (2001)	11-17 (n=138)	Principal component analysis	Attentional control–processing speed: Codes, CNT Cognitive flexibility–monitoring: digit span, VF Goal setting: TOL Online monitoring–planning: ROCF Accuracy: VF, CNT, ROCF	4 factors
Lehto & al. (2003)	8-13 (n=108)	Exploratory and confirmatory analysis	WM : Labyrinthes (WISC-III), WM spatial, spatial span, auditory attention and response set (NEPSY), TOL Inhibition: MFFT, TOL Shifting: VF, TMT B, TOL	3 factors
Brocki & Bohlin (2004)	6-13 (n=92)	Orthogonal and oblique rotation	Disinhibition: Go/No-go, CPT (false alarms) Speed/Arousal: Go/No-go, CPT (reaction time and omissions) WM/Fluency: digit span, VF, hand movements task(K-ABC), Stroop- like task, Time reproduction task	4 factors
Huizinga et al. (2006)	7,11,15,21 (n=384)	Confirmatory factor analysis	WM: Tic Tac Toe, Mental Counters, Running Memory Inhibition: Stop Signal, Flankers, Stroop Shifting: Local–Global, Dots–Triangles, Smiling Faces	2 factors
van der Sluis et al. (2007)	9-12 (n=172)	Confirmatory factor analysis	Updating: Keep Track, Letter Memory, Digit Memory Inhibition: Quantity Stroop, Object Inhibition, Stroop,Numerical Size Shifting: Object Shift, Symbol, Place, Making Trails	2 factors
Wiebe et al. (2008)	2-3 4-6 (n=243)	Confirmatory factor analysis	WM: Six Boxes, Delayed Alternation, Digit Span Inhibition: Delayed Response, Whisper, Statue, Visual Attention, Shape School, Tower of Hanoi, Continuous Performance Test	Single factor
Agostino et al. (2010)	8-13 (n=155)	Structural equation modeling	M-capacity: Mental Attention Memory, Direction Following, Figural Intersection Inhibition: Antisaccade, Color Stroop, Number Stroop Updating: Letter Memory, n-back Shifting: Contingency Naming, Trails	4 factors
McAuley and White (2011)	6–8 9–12 13–17 18–24 (n=147)	Latent variables approach	Working memory: Digit Span Forward/Backward,Recognition Span (shape/location), 2-back (location/letter) Inhibition: Stimulus Response Compatibility Processing Speed: Simple Reaction Time, Stimulus Response Compatibility—compatible trials, Go/No-Go go trials	2 factors (excluding speed)
Wu et al. (2011)	7–14 (n= 185)	Structural equation modeling	WM: Code Transmission Inhibition: Sky Search Attention, Stroop Shifting: Creature Counting, Contingency Naming, Opposite World	3 factors
Rose et al. (2011)	11 (n=134)	Confirmatory factor analysis	WM: Spatial WM, Listening Span, Counting Span Inhibition: Go/No-Go, Rapid Visual Information Processing Shifting: TMT, Dimensional Shift	3 factors
Fuhs and Day (2011)	3-5 (n=132)	Confirmatory factor analysis	Inhibition: Head/Feet, Day/Night, BRIEF-P (inhibition) Shifting: Flexible Item Selection, Spatial Reversal, BRIEF-P (Shift)	Single factor

Wiebe et al. (2011)	3 (n=228)	Confirmatory factor analysis	WM: Nine Boxes, Nebraska Barnyard, Delayed Alternation Inhibition: Big Little Stroop, Go/No-Go, Shape School, Snack Delay	Single factor
Van der Ven et al. (2012)	7-8 (n=211)	Confirmatory factor analysis	WM: Digit Span Backwards, Odd One Out & Keep Track Inhibition: Animal Stroop, Local Global & Simon Shift: Animal Shifting, Trail Making Test in Colours & Sorting Task	2 factors
Miller et al. (2012)	3-5 (n=219)	Confirmatory factor analyses	WM: Backward Digit & Word Span, Boxes, Continuous Performance task: omissions Inhibition: Dimensional Change Card Sort, Go/No-Go: hit Set shift: Continuous Performance Task: commissions, Boy–Girl Stroop, Tower of Hanoi, Go/No-Go: commissions	2 factors
Willoughby, Wirth, et al. (2012)	3–5 (n=1123)	Confirmatory factor analyses	WM: WM Span, Pick the Picture Inhibition: Spatial Conflict, Silly Sounds Stroop, Spatial Conflict Arrows, Animal Go/No-Go	Single factor
Lee, Bull, and Ho (2013)	6-15 (n = 688)	Confirmatory factor analyses	Updating and working memory: Listening Recall task, Mister X task. pictorial updating task. Inhibition and switching: Flanker task, Simon task, Picture–Symbol task, Mickey Task.	2 factors in early childhood 3 factors in the teenage years
Monette et al. (2015)	5 n = 272	Confirmatory factor analysis	Inhibition: Fruit Stroop, Day–night test WM-flexibility: Backward word span, Backward block span, Trails-P, Verbal fluidity shift, Face sort.	2 factors

Notes. CVLT=California Verbal Learning Test ; VF= Verbal fluency ; TQT=Twenty Question Test ; FF= Figural Fluency; WCST= Wisconsin Card Sorting Test"; TOL= Tower of London ; MFFT=Matching Familiar Figure Test ; TOH=Tower of Hanoi ; TMT= Trail Making Test ; ROCF= Rey–Osterrieth complex figure; CNT= Contingency Naming Test ;CPT= Continuous Performance Test; WM= Working Memory.

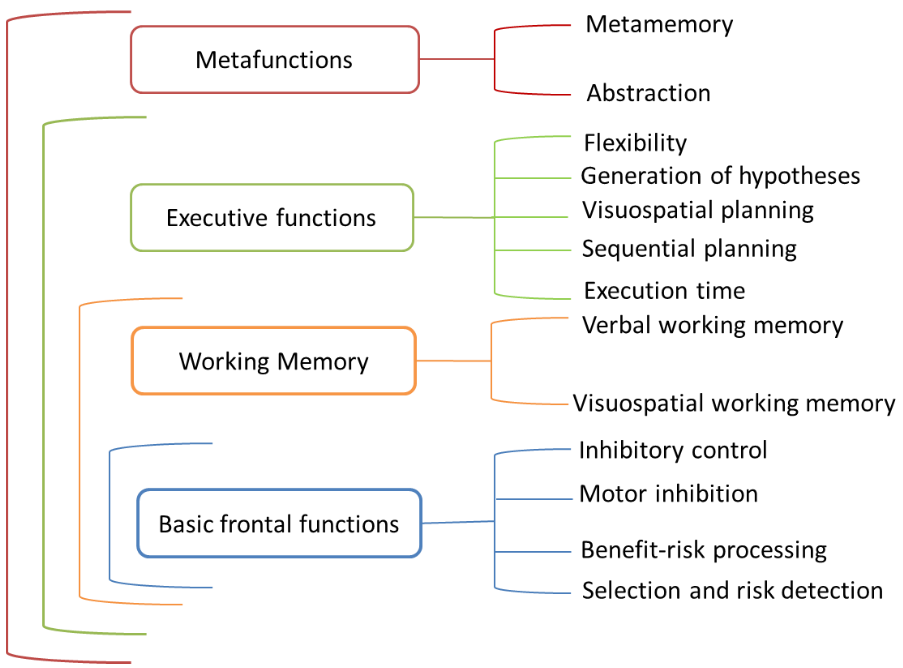
Several methodological parameters can be analyzed to explain the absence of a consensual factorial structure. First, there is a great heterogeneity between studies in terms of the tools used, measurements and age ranges and divisions (Table 1). Moreover, the choice of measures is rarely argued. In the cases where not all the variables initially selected are included in the analysis, the selection criteria are generally not explained. Discussion on the adopted criteria is especially important when carrying out factorial analysis because the dimensions obtained are influenced by the chosen variables. The diversity of results is therefore at least partially related to the fact that studies differ in several aspects, complicating the comparison between obtained factors. Furthermore, there is variability in statistical procedures and the names given to the factors, sometimes even for tests grouped identically. It is also important to consider that the number of subjects in the studied groups is often considerably low per age group, which could compromise the results found. Finally, the effect of age and socio-cultural level is rarely controlled, and basic cognitive processes are usually not taken into consideration.

Despite controversies, the use of factorial analysis to evaluate the structure of executive components throughout the development has evidenced that EF appear to be relatively undifferentiated until approximately 5 years of age, which means that the structure of these functions in this age group is almost unitary. In fact, studies conducted with 3-year-olds have been remarkably consistent. All studies conducted with children in these age group have shown an EF structure with a single latent variable (Wiebe et al., 2008; Wiebe et al., 2011; Willoughby et al., 2010; Willoughby et al., 2012). Studies carried out with slightly older preschoolers (4 and 5 years old) support both a unitary model (Fuhs & Day, 2011; Shing et al.,2010; Wiebe et al., 2008) and a two-factor model (Lee et al., 2013; Miller et al., 2012; Usai et al., 2014; van der Ven et al., 2013). It would be only after the age of 6 that EF would gradually specialize, approaching a multifactorial structure similar to adults (Brocki & Bohlin, 2004; Huizinga et al., 2006).

In addition to models based on factorial studies, theoretical-conceptual models of EF in children are also widely discussed. Among them, the models proposed by Dennis (2006), Florez-Lazaro et al. (2012) and Diamond (2013) are particularly noteworthy. Dennis (2006) proposed a model both for the typical and atypical development of the prefrontal cortex, including the concept of EF. According to this model, the prefrontal cortex would function as to integrate information from the five senses, allowing the development of interrelated representations by using processing resources (WM and inhibitory control) that would depend on the dorso-lateral regions. On the other hand, there are also representations that would depend on orbital and ventromedial regions, providing temporal links between past and future (evoking planning), "thought" links between the self and the other (referring to metacognition and theory of mind), and emotional links between affectivity and thought (allowing affective decision-making, emotion regulation and the transmission of socio-affective messages).

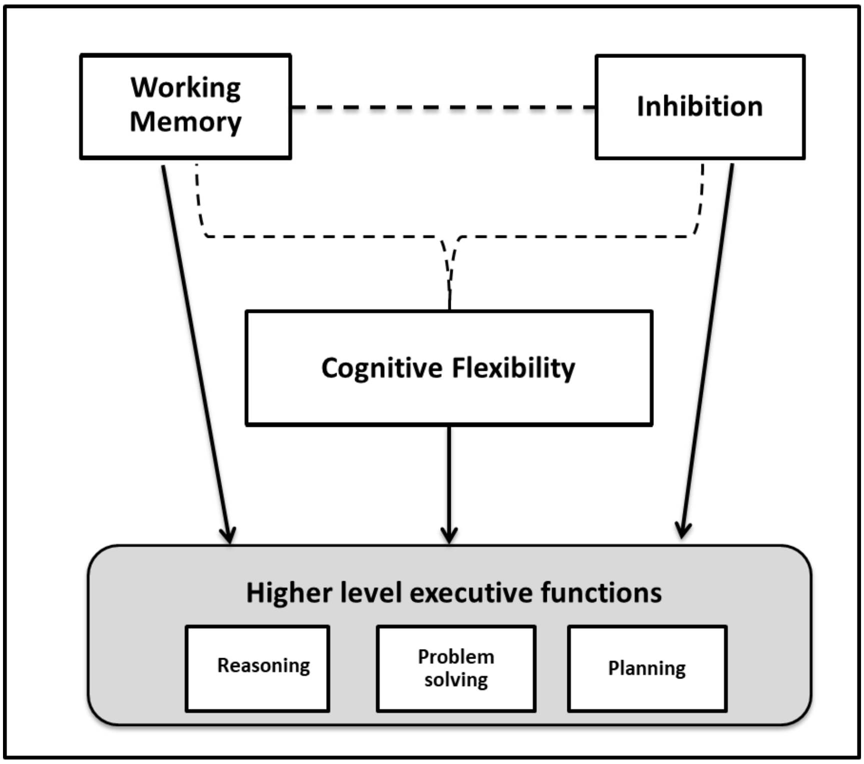
The model proposed by Florez-Lazaro et al. (2012) consists of a conceptual and systemic diagram of EF (Figure 1). It is a model based on the Luria's functional model and, consequently, aims to conceptually organize the frontal functions into levels of functionality and complexity in a systemic perspective, avoiding the direct association between the prefrontal cortex and EF. This conceptual scheme is divided into four hierarchical levels as follows: the first level would comprise the basic frontal functions (inhibitory control, motor control); the second level would refer to the WM system; the third level would comprehend the executive functions (planning, fluency, sequencing, cognitive flexibility, etc.); and the fourth and most complex level would encompass the metafunctions (metacognition and abstraction). It is important to highlight that since this model departs from the historical-cultural perspective of neuropsychology, the dialectical rapport between brain maturation and the culture/development context is at the root of its preposition.

Figure 1. Conceptual EF structure of based on Florez-Lazaro et al. (2012)



Diamond's (2013) conceptual proposal considers EF as distinct but interrelated processes which are differentiated into basic components such as inhibition, cognitive flexibility and WM (Figure 2). It also proposes to distinguish higher-level executive functions, such as logical reasoning, problem solving, and planning, from these three basic executive processes. Diamond's perspective comprises the theoretical formulation of the stages of development and the structure of the executive components. Her model considers that EF are still relatively undifferentiated until approximately the age of 5. After 6 years, they would gradually differentiate approaching a structure such as identified in adults.

Figure 2. Structure of executive processes based on Diamond's proposal (2013)



Diamond’s proposal seems to converge with the aforementioned factorial studies that found only a single factor in children between 3 and 5 years old (Fuhs & Day, 2011; Shing, Lindenberger, Diamond, Li & Davidson, 2010; Wiebe et al., 2008; Wiebe et al., 2011; Willoughby, Blair, Wirth & Greenberg, 2010; Willoughby et al., 2012) and a multifactorial structure from 6 years on (Agostino et al., 2010; Anderson et al., 2001; Brocki & Bohlin, 2004; Lee et al., 2013; Lehto et al., 2003; Rose et al., 2011; Xu et al., 2013). Despite the agreement regarding these aspects, the amount and type of factors found in factorial studies conducted at school age is not consensual with Diamond's proposition (see Table 1).

2.2.2. Executive development, context and socio-demographic aspects

Although not commonly addressed in classical theoretical models, socio-demographic, contextual and cultural aspects should be considered as factors that can influence the development of EF. In fact, currently, it is widely recognized that the development of EF is associated with contextual and cultural factors (Hackman & Farah, 2009). Several studies have demonstrated a significant influence of different sociodemographic and cultural variables on the emergence of executive development. Important variables include the potential effect of gender, bilingualism, socioeconomic status (SES) and culture (way of living and education - literacy and schooling -, types of play, habits) in general (Er-Rafiqi, et al., 2017; Noble et al., 2015; Rosselli & Ardila, 2003). One of the most studied sociodemographic factors in the literature is gender and its role in executive development. Until this moment, scientific data regarding this variable is insufficient to reach a consensus. Some studies reveal significant differences in favor of boys (Halpern, 2012) and some in favor of girls (Ardila et al., 2005). However, the vast majority of studies do not report a statistically significant effect of this factor (Brocki & Bohlin, 2004; Roy et al., 2018). Thus, it is important to note that gender effects seem to vary according to the tasks used (including within the same study) and, more broadly, to culture.

The assessment of environmental factors is often based on SES indicators. These are usually measured through indirect variables such as family income, parents' education or occupation, type of school (public or private) or a combination of these indicators, which may affect the child's neuropsychological development (Johnson et al., 2016). Most researchers suggest that a higher SES would have a positive influence on the development of EF, while a lower SES would be associated with poor executive performance (Johnson et al., 2016). The influence of these factors is likely to be mediated by finer underlying mechanisms that would interfere in executive development. For example, some studies have demonstrated the importance, besides SES itself, of different prenatal factors, nutrition, educational practices, stress, type and quality of cognitive stimulation and early interactions with the family environment, among other underlying mechanisms (Lawson et al., 2017). On the other hand, similar to what could be observed with gender, the effect of SES varies according to the tasks and country in which the studies were conducted, once again highlighting the influence of cultural aspects.

Among other important variables that should be taken into consideration are the language skills developed in a bilingual context (Er-Rafiqi et al., 2017). Several studies have demonstrated a significant positive effect of bilingualism on the development of EF, namely on inhibitory control (Crivello et al., 2016) and mental flexibility (Bialystok & Viswanathan, 2009; Carlson & Meltzoff, 2008). This influence may be linked to the fact that bilingual children must choose or alternate words in the lexicon of one of the languages used in speech, thus requiring more inhibitory control and flexibility. In fact, bilingualism, as well as multicultural families, also introduces to other ways of thinking, other social relationships and other cultural practices.

Given the various empirical studies mentioned above, it seems crucial to consider that the culture and context in which children are raised play a decisive role in executive development (Crivello et al., 2016; Thorell et al., 2013). Each country has its own cultural and educational experiences and each task has specific relationships with school performance in each particular culture (Van de Vijver, 2011). This remark raises questions about the relevance of a universal EF model that disregards cultural and contextual aspects. It should be noted that the majority of executive models for children does not include assumptions regarding the effect of culture and the context of development, such as the models by Diamond (2013) and Dennis (2006). By contrast, the Florez-Lazaro et al. model (2012) and models of socio-cultural neuropsychological assessment are mainly based on children's cultural and contextual differences, which often lead to not using standardized tests, but qualitative tasks instead.

It is then imperative that the instruments are well adapted to the culture and context in which they will be used. EF tools developed in other cultures must go through a rigorous adaptation process (and not just translation) and meet the usual demands for psychometric validity and reliability, based on normative data specific to their population (see Bellaj et al., 2018). However, caution is needed even in the cases in which normative references were established in the same country where the test will be used. In Brazil, for example, studies show a significant difference between the executive performance of children from different geopolitical regions (Hazin et al., 2016), from rural and urban contexts (Santos et al., 2005), and even within the same city but with contrasting SES (Magalhães et al., 2016). In this sense, a critical analysis of the construction/adaptation of these instruments and their respective normative data is always recommended.

Considering the necessity of providing the most appropriate EF assessment strategies for childhood, the objectives of this thesis were designed through three complementary perspectives: developmental, cultural and clinical. These perspectives play a crucial role not only in the cross-cultural validation of the CEF-B, but also in proposing a comprehensive approach to the neuropsychological evaluation of EF in Brazilian children, under typical and atypical developmental conditions. The objectives of the thesis were (I) to perform a critical analysis of the instruments available for clinical evaluation of EF in the Brazilian pediatric population. Additionally, we aimed (II) to investigate the psychometric properties of the Brazilian version of the CEF-B. Lastly, we intended (III) to characterize the development profile of EF in children from the northeast of Brazil, investigating the influence of different socio-demographic contexts, such as gender and socioeconomic level on executive development.

3. Objectives

3.1. General objectives

Analyze the psychometric properties of the Brazilian version of the CEF-B and characterize the development profile of EF in children in northeast Brazil.

3.2. Specific objectives

a) to perform a critical analysis of the instruments available for clinical evaluation of EF in the Brazilian pediatric population

b) to evaluate the validity and reliability of the CEF-B for children in Northeast Brazil;

c) to present initial normative data of the CEF-B in children aged seven to 12 with typical development;

d) to evaluate the development trajectories and structure of the CEF-B, as well as the influence of socio-demographic variables (gender, type of school and socioeconomic level) on executive development.

4. Method

4.1. Participants

The study was conducted in 14 public and private schools in Rio Grande do Norte between February 2018 and June 2019. Data were collected in four private and four public schools in Natal, four public schools in Parnamirim and two public schools in Elói de Souza, one belonging to the rural area and the other to the urban area of the municipality. The research was developed in accordance with the requirements of Resolution N° 466/12, of the National Health Council that establishes the guidelines and regulatory norms for research involving human beings. Its execution was approved by the Research Ethics Committee of the Federal University of Rio Grande do Norte (CEP- UFRN) under CAAE code 48383715.1.0000.5537.

In order to meet specific objectives B, C and D, 230 children with typical development and ages between seven and 12 years, from the cities of Natal, Parnamirim and Elói de Souza in Rio Grande do Norte, participated in the study. The sample was divided into six age groups, and each group comprised approximately 40 children distributed homogenously by sex and type of school (Table 2). Participants were selected based on the following inclusion criteria: a) signing of the consent form by parents and/or guardians; b) regular enrolment in public or private schools; c) no history of developmental, neurological or psychiatric alterations; d) no uncorrected sensory alterations; and e) weighted standardized score equal to or greater than seven points in the subtests Matrix Reasoning and Vocabulary of Wechsler Intelligence Scale for Children - 4th edition (WISC-IV).

Table 2. Sociodemographic data of children with typical development

	Gender				Type of school				Parents' education				Family income						Location					
	F		M		Public		Private		Mother		Father		≤1 minimum wage		Between 2-4 wages		More than 5 wages		Natal		Parnamirim		Elói de Souza	
	N	%	N	%	N	%	N	%	M	SD	M	SD	N	%	N	%	N	%	N	%	N	%	N	%
7 (n=37)	19	16.38	18	15.93	23	19.83	14	12.28	10.84	4.47	12.16	4.45	12	19,04	5	20	6	12	23	13.07	10	25	4	28.57
8 (n=41)	18	15.52	23	20.35	19	16.38	22	19.30	12.34	4.14	11,80	4.10	14	22,22	2	8	9	18	31	17.61	5	12,5	5	35.71
9 (n=35)	19	16.38	16	14.16	17	14.66	18	15.79	12.62	3.68	12.85	3.5	7	11,11	5	20	10	20	30	17.05	3	7,5	2	14.29
10 (n=46)	25	21,55	21	18.58	24	20.69	22	19.30	10.45	5.18	12,60	4,33	14	22,22	5	20	11	22	44	25	2	5	0	0
11 (n=38)	19	16.38	19	16.81	18	15.52	20	17.54	11.91	5.44	12.16	3.97	11	17,46	7	28	8	16	24	13.64	13	32,5	1	7.14
12 (n=33)	16	13.79	16	14.16	15	12.93	18	15.79	10.90	4.66	11.09	5.32	5	7,93	1	4	6	12	24	13.64	7	17,5	2	14.29
Total (n=230)	116	100	114	100	116	100	114	100	11.51	4.62	12.16	4.23	63	100	25	100	50	100	176	100	40	100	14	100

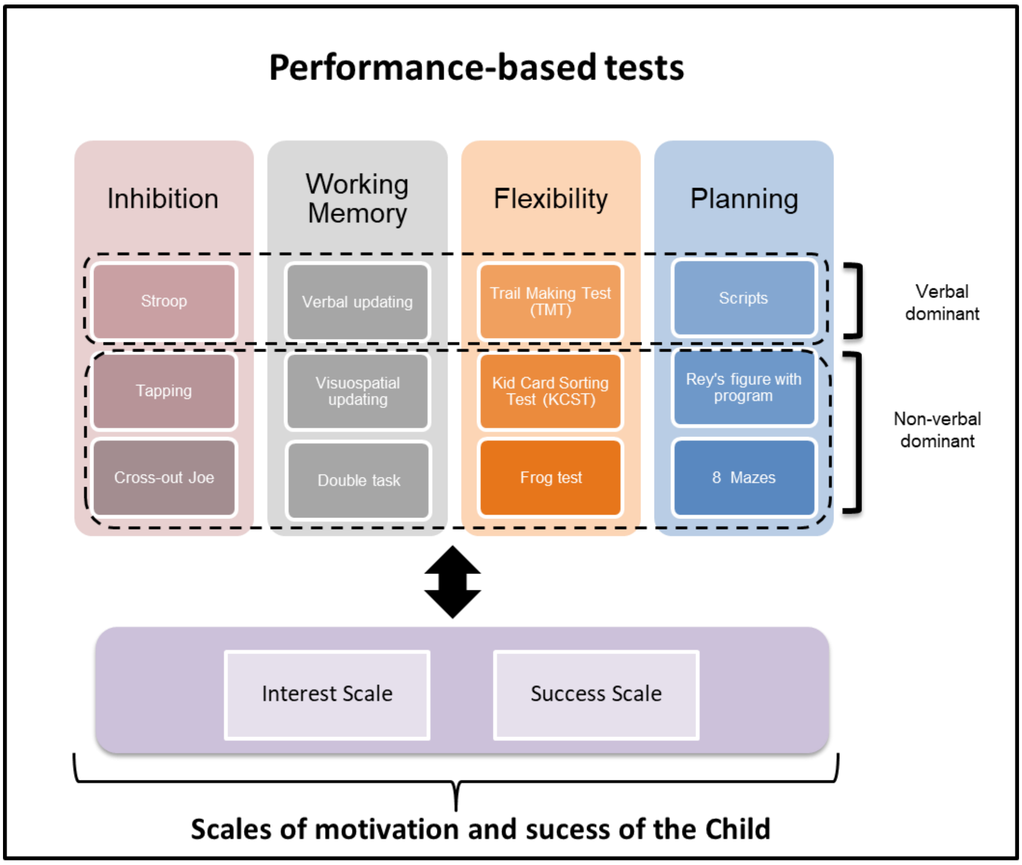
The selection of participants was carried out in collaboration with the coordinators and teachers of each institution. A total of 264 signed consent forms were collected and 244 children and adolescents were submitted to the WISC-IV subtests Vocabulary and Matrix Reasoning. Fourteen of the participants presented weighted points below seven in one of the subtests and were therefore excluded from the sample because they did not meet one of the inclusion criteria.

4.2. Instruments

The protocol consists of a set of 12 tests for the neuropsychological evaluation of EF, aimed at children and adolescents between six and 16 years (Roy et al. 2020). This battery is based on a child-centered theoretical model of EF, and the main processes evaluated correspond to the three basic executive components: inhibition, flexibility and work memory, besides a more complex component - planning (Dennis, 2006; Diamond, 2013). Although this categorization remains partially artificial and questionable (given the interdependent nature of executive processes), three tests were developed for each of these functions (see Figure 2 for an overview).

The CEF-B consists of new experimental tasks and tests existing in the international literature for children or adults, which have been modified or expanded to better serve the pediatric population (see Annex A for a detailed description in Portuguese or Table 2 of study 2 and Table 2 of study 3 for a brief English description). The execution time is approximately two hours, varying according to the age of the child, clinical condition and culture of the country. In addition to the 12 EF evaluation tests, the protocol has scales to evaluate the interest and success of the child in each test, which are answered in the format of self- and hetero-assessment.

Figure 3. Overview of the performance tests and scales that compose the CEF-B



Since performance measures (executive questionnaires) and executive tests access different domains of the construct (Toplak et al., 2013), the protocol also includes the EF behavioral inventory for parents and teachers - BRIEF. In this way it is possible to associate task results with information on the daily life of the child or adolescent (Roy, 2015). It should be noted that this inventory has already been adapted to Brazil (Carim et al., 2012). Although the questionnaire was used to collect the data, its data were not explored in this thesis.

The process of standardization and validation of the CEF-B in France was completed in 2019 and was carried out with 1,000 children with typical development between six and 16 years and over 400 patients with 15 different clinical conditions. In addition to the French collaborations, the project currently has international collaborations established with Tunisia (Bellaj et al., 2015), Morocco (Er-Rafiqi et al., considered for publication), Lebanon (Roukoz et al., considered for publication) and Ecuador (Guzmán, 2019), which provides the instrument with robustness in terms of intercultural validity. Preliminary tests of the validity of the French version were published for the Stroop test (Roy et al., 2018) and BRIEF (Fournet et al., 2014). In addition, different clinical studies were performed with protocol tests, namely: type 1 neurofibromatosis (Roy et al., 2010, 2014), temporal and frontal parietal epilepsy (Campiglia et al., 2014; Charbonnier et al., 2011), brain injury (Chevignard et al., 2017) and brain tumors (Roche et al., 2018).

A detailed description of the tests that compose the CEF-B protocol, the scales of evaluation of executive functioning, the subtests of WISC-IV and the tests used to evaluate convergent validity is attached to this project (Annexes 1, 2, 3 and 4). In addition to the tests that make up the CEF-B protocol, a socio-demographic questionnaire specifically designed for the purposes of this research was applied (Annex 5).

4.3. Procedure

All 230 participants included in the survey were evaluated individually in a room at their own school or at home. Initially, all children were evaluated by the subtests Vocabulary and Matrix Reasoning of WISC-IV with the objective of performing a brief screening of intellectual capacity for the inclusion of participants. Once included in the research, the children were submitted to the application of the tests that compose the CEF-B. Besides the protocol tests, the WISC-IV Digits subtest, the 5-digit test (Sedó et al., 2015) and the Corsi blocks task (Corsi, 1972) were also applied to analyze the evidence of validity of the protocol tasks.

Two to three evaluation sessions were conducted and, depending on the age of the child, each session lasted 30 to 45 minutes. All tests were applied by psychology students or psychologists trained to administer the protocol. It should be noted that for reliability procedures (re-testing and converging validity), an additional session of approximately 30 minutes was conducted with six tests of the protocol and three executive tests recognized in international literature. This additional session was carried out with 33 children in the period between four to six weeks after the last standard evaluation session.

The order of application of the tests that integrate the protocol was established in a systematic and pseudo-random way, alternating the investigated executive abilities and their verbal/non-verbal nature. The tests that request verbal and non-verbal resources were ordered in an interspersed way, with the objective of verifying the influence of basic processes on executive performance, as well as having exploratory tests in case of phase, visuospatial or gestural disorders (Roy et al., 2020).

4.4. Data analysis

Quantitative data analysis was carried out using different statistical tools. Data was evaluated through inferential statistics aiming to investigate psychometric evidences that suggest the validity and precision of the protocol. The following methods were used: a) analysis of variance (ANOVA) to evaluate the effect of age and sociodemographic variables (gender and type of school) on EF; b) exploratory factor analysis through the extraction of principal components by Oblimin rotation to confirm the dimensions of the tests proposed in the investigated protocol; c) Pearson's correlation to verify evidences of precision of the retest, as well as to verify evidences of convergent validity between the sub-tests of the instrument and d) indicators of internal consistency (the Split-half method, Cronbach's α and Ω) to assess the battery's reliability.

4.5. Data presentation and discussion procedures

As mentioned in the initial considerations, this thesis is divided into three parts, each corresponding to relatively independent studies. The first study comprises a theoretical and critical analysis of the current panorama of EF evaluation in the pediatric population in Brazil, considering the contexts of clinical practice and research. The second consists of an analysis of the developmental trajectory and structure of EF in children of the northeast region of Brazil using the CEF-B. Lastly, the third study focuses on the evidence of reliability of the protocol. In the following sections the studies will be presented independently.

5. Study 1: Assessing executive functions in Brazilian children: A critical review of available tools

Article published in Applied Neuropsychology: Child (Brazilian classification QUALIS: A2; SCIMAGOJR: Q3)

Guerra, A., Hazin, I., Siebra, C., Rezende, M., Silvestre, I., Le Gall, D., & Roy, A. (2020): Assessing executive functions in Brazilian children: A critical review of available tools. Applied Neuropsychology: Child.
https://doi.org/1080/21622965.2020.1775598

Abstract

The goal of this review is to perform a critical analysis of the instruments used to assess executive functions (EF) in pre-school and school-age children in Brazil. We identified 37 assessment measures through a systematic review. Some performance-based tests for assessing working memory and inhibition were identified. However, there is a lack of rating measures and instruments to assess flexibility and planning in clinical practice. We observed regional differences in the performance of EF measures. One possible explanation may be the use of normative samples from more highly-developed regions to characterize performance in less-developed regions. However, there may be alternative explanations, such as variations in the exposure to testing and the adequacy of test materials in different regions. Joint efforts among research groups should be encouraged in order to obtain normative references that are more representative of the socio-cultural diversity of the country. This improvement is essential to better understand the typical and atypical development of EF and how the peculiarities of each country's context and culture can impact its trajectory.

Keywords: executive functions; culture; normative data; atypical development; child neuropsychology.

5.1. Introduction

Executive functions (EF) comprise a set of superior cognitive skills that allow the subject to engage in goal-oriented behaviors (Luria, 1966). These skills are especially important in new situations or in circumstances that require adjustment or flexibility of behavior to respond the demands of the environment (Elliott, 2003; Gazzaniga et al., 2006; Huizinga et al., 2006).

EF are a very challenging construct to define due to the various and divergent ideas regarding it. However, researchers examining EF generally agree that EF (1) guide actions and behaviors that are essential to learning and carrying out everyday tasks; (2) contribute to the regulation and monitoring of tasks; (3) concern not only cognitive domain, but also socioemotional and behavioral aspects; and also (4) consist of a multidimensional construct in their essence, with more than one individual component or function (Baggetta & Alexander, 2016).

As a multidimensional construct, EF encompass cognitive, behavioral and emotional processes, which can be distinguished both theoretically and clinically. Cognitive skills (or "cool" components, according to some authors, e.g. Zelazo & Carlson, 2012) mainly require logical reasoning resources without emotional state and are usually associated with lateral prefrontal cortex (Happaney et al., 2004; Zelazo & Müller, 2002). Despite the different classifications, several studies recognize that inhibition, working memory (WM) and cognitive flexibility are the basic components of EF (e.g., Diamond, 2013; Friedman & Miyake, 2017; Lehto et al., 2003; Miyake et al., 2000). Furthermore, planning, abstract reasoning and problem solving are recognized as higher-level executive processes (Diamond, 2013). In general, cognitive components are defined as partially independent, since they are strongly interconnected regarding the execution of complex tasks (Diamond, 2013; Lehto et al., 2003; Miyake et al., 2000). Emotional factors of EF (or "hot" components) refer to the socioemotional domain and are more likely to be evoked in motivationally and emotionally meaningful contexts (Zelazo & Carlson, 2012). Although there is no consensus in the literature, behavior regulation, emotion regulation and affective decision making are considered “hot” EF components (De Luca & Leventer, 2008; Zelazo, Qu, & Kesek, 2010). These processes seem to depend on orbitofrontal cortex and other ventromedial regions, as well as the fronto-limbic circuitry (see Happaney et al., 2004, for a review).

Assessment of EF in children is a major issue given that these processes are fundamental to the psychological development in the broader sense (Diamond, 2013). It allows the identification of early changes in cognitive and behavioral development, which may be associated with early injury or neurodevelopmental disorder (Anderson et al., 2010). The procedures typically used to access EF in clinical settings employ both performance-based and rating measures, which are considered as complementary indicators (Toplak et al., 2013). For that purpose, these measures should be adequate for use in the pediatric population and their normative data should take into consideration the typical characteristics of each stage of child development.

Investigation of EF in children is challenging for several methodological reasons. One of the main problems is that they are necessarily mediated by lower-level processes, which contribute to variations in test performance that must be taken into account in clinical assessment. This problem is particularly important in children, as lower-level functions (i.e., basis skills) that operate in various executive tasks are also potentially under development (Denckla, 1996). In order to analyze which processes are responsible for poor performance in executive tasks, it is essential to dissociate basic skills from executive ones. It is possible, for instance, to modulate the executive load involved in some multicomposite tests, such as Trail Making Test (by subtracting Trails

A score from Trails B score to “isolate” the contribution of executive abilities; Arbuthnott & Frank, 2000) or the complex figure of Rey (through a step-by-step copy of the figure and subsequent subtraction from the performance score in spontaneous copying; Roy et al., 2010). This approach is also applied on a number of Delis–Kaplan Executive Function System (D-KEFS) measures (Delis et al., 2001).

Contextual and cultural issues are also key factors to consider in the assessment of EF in children. (Farah, 2017; Roukoz et al., 2018). There are several constructs that can be used as correlated measures to evaluate the impact of environmental context in executive development. One of the most used is socioeconomic status (SES), which corresponds to a social and economic bundle associated with educational attainment, health, and psychological well-being (Farah, 2017; Johnson et al., 2016). SES can be assessed through indirect variables such as family income, parents’ education or occupation, type of school (public or private) or a combination of these indicators, which may affect the child's neuropsychological development. Most researchers suggest that a higher SES would have a positive influence on the development of EF, while a lower SES would be associated with poorer executive performance (Johnson et al., 2016). The influence of these factors is likely to be mediated by more nuanced underlying mechanisms, such as prenatal factors, nutrition, educational practices, stress, or early interactions with the family environment (Lawson et al., 2017).

Similarly, the cultural context in which children are raised is likely to play a decisive role in executive development (Er-Rafiqi et al., 2017). Each country has its own cultural and educational experiences and each task has specific relationships with school performance in each particular culture (Van de Vijver, 2011). Comparison of the child's performance with samples that do not represent this diversity of variables may jeopardize the interpretation of results and lead to 'false positives' or 'false negatives' in clinical practice. In this sense, it is imperative that instruments are well adapted to the culture and context in which they will be used. EF measures developed in other cultures must go through a rigorous adaptation process and meet the usual demands for psychometric validity and reliability, based on normative data specific to their population (see Bellaj et al., 2018). Therefore, translation is only the first step of the adaptation process. Cultural, idiomatic, linguistic and contextual aspects should be taken into consideration when adapting an instrument to be used in different contexts (Beaton et al., 2000).

To this moment, the main studies on EF in children were carried out in North America and Europe, while data collected in countries with a higher socioeconomic vulnerability are still recent, particularly in South America and more specifically in Brazil. Despite advances, research on the typical and atypical development of EF in Brazilian children still has to deal with aspects inherent to countries with continental dimensions, such as geopolitical, socioeconomic and cultural variety. Brazil is currently considered an advanced emerging economy and the sixth most-populous country worldwide. However, the 2019 Human Development Report published by the United Nations Development Programme (UNDP) reveals that the country has the 2nd highest income inequality in the world. For instance, Brazil's richest 10% concentrate approximately 42% of the country's total income. This economic disparity epitomizes inequalities in key elements of human development such as health, education, dignity and respect for human rights. In fact, guaranteeing access to good education and health services in Brazil is still strongly dependent on SES. Thus, income, type of school (public or private) and the profession of parents are indicators of the different SES and inequality in the country.

It is also important to consider that income distribution is unequal among the country's own regions. The South and Southeast regions of Brazil are the most developed of the country, presenting the highest national Human Development Index (HDI) and the highest urban population density. In contrast, the Northeast region ranks last regarding this index. Some Brazilian studies reported a significant difference between the executive performance of children from different geopolitical regions (Hazin et al., 2016), from rural and urban contexts (Santos et al., 2005), and even within the same city but with contrasting SES (Magalhães et al., 2016; Mata et al., 2013; Sallum et al., 2017). Considering the impact of these factors on executive development, the aim of this study was to perform a critical analysis of the instruments used to evaluate EF in the pediatric population (children and adolescents from birth up to the age of 18 according to the Brazilian statute of the child and adolescent; BRASIL, 1990) through a systematic review of the measures available in Brazil.

5.2. Method

In order to investigate the Brazilian experience in pediatric evaluation of EF, a review of the executive measures that have normative data for this population was carried out. Because of the particularities of psychological evaluation in Brazil, this review was carried out based on the guidelines of the Federal Council of Psychology (CFP – in Portuguese) regarding the use of psychological tests in professional psychology practice.

According to CFP resolution No. 009/2018, the use of psychological tests in Brazil should be guided by the regulations of the Psychological Test Evaluation System (SATEPSI – in Portuguese). This system corresponds to an electronic address developed by the council itself with the purpose of evaluating the technical-scientific quality of psychological instruments intended for professional use. It also aims to disseminate the psychological measures that are allowed for use in professional practice (suitable tests) and those that are not allowed (unsuitable and non-evaluated tests).

The evaluation of the technical-scientific quality of psychological instruments is based on the verification of a set of technical requirements to which they need to comply in order to be recognized as psychological tests. According to the aforementioned resolution, when performing psychological assessment, the clinician must base his decision on psychological methods and/or techniques and/or instruments scientifically recognized for use in the professional practice and may, depending on the context, use auxiliary procedures and resources.

It is important to highlight that the use of psychological tests that are classified as unsuitable or non-evaluated by the SATEPSI is considered an ethical failure in professional practice, except in the case of research subjects. Thus, the use of psychological tests in clinical practice through a quantitative approach is restricted by the SATEPSI classification. However, methods and techniques recognized by the scientific literature are allowed to be used through a qualitative approach.

Given the challenges of the assessment of EF in the pediatric population, the use of experimental tests and the improvement of existing measures is essential to promote advances in the production of knowledge on this domain. Thus, not only the tests that have already been approved by the SATEPSI must be investigated, but also tasks that are yet to be evaluated by it, but are frequently used by researchers and clinicians through a qualitative approach. Therefore, the investigation of the instruments that have normative data for the assessment of EF in the pediatric population in Brazil was conducted based on the search for: 1 - instruments considered suitable by SATEPSI for the clinical use by psychologists; 2 - international instruments that have Brazilian adaptations and have not been evaluated by SATEPSI; 3 - instruments designed in Brazil that were not submitted to evaluation by SATEPSI.

5.2.1. Eligibility criteria

We included peer-reviewed studies published as full-text, printed Brazilian publications and test's manuals. The review focused on studies conducted with population aged 3-18 years or when the reported mean/median age was comprised within this range. The studies should have considered EF or one of EF core elements (inhibition, working memory, cognitive flexibility, planning). They also should have been carried out in Brazil and with children with typical development. Validation, cross-cultural adaptation and developmental studies, studies about tests, questionnaires, and self-reported and performance-based outcome measures published in English, Spanish and Portuguese were considered for inclusion. No restrictions were considered regarding the date of publication or the type of assessment. Studies in which population had clinical conditions, papers including cognitive, motor and other constructs measurements that did not mention EF in any domain were excluded. The primary outcomes of interest were EF or their core components; and secondary outcomes of interest were sample size and characteristics (region of Brazil where the study was conducted and type of school) and evidences of validity and reliability.

5.2.2. Search methods

The review of the psychological instruments allowed for use in professional practice was performed in the SATEPSI platform (http://satepsi.cfp.org.br/). Furthermore, the review of international executive measures with Brazilian versions and national executive measures which were not evaluated by SATEPSI was performed in four digital databases (Scielo, Google Academic, PubMed, PsycInfo) and in printed Brazilian publications that focused on the study of EF in pediatric populations. The search for publications in these databases was conducted by using the following English-language descriptors and their translated versions in Spanish and Portuguese, combined with one another: "executive function", "children" and "Brazil". The databases were surveyed from 25 February 2019 until 28 July 2019.

5.2.3. Study selection

The article's selection process according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram is displayed in Figure 1. Firstly, duplicate documents were filtered and removed using Microsoft Excel. Afterwards, the titles and abstracts of the retrieved references were screened by an author (AG) for inclusion in the review. The first author (AG) sought full-texts of all studies identified as potentially relevant and assigned them to one of three categories: "included", "excluded" and "awaiting assessment". A different author (CS) independently assessed all articles in the "included" and "awaiting assessment" categories and randomly verified articles in the "excluded" group. Disagreements between the two reviewers (AG & CS) were resolved by discussion. Inclusion was based on compliance with inclusion criteria as well as agreement between authors. The reasons for exclusion were registered.

5.2.4. Data collection and management

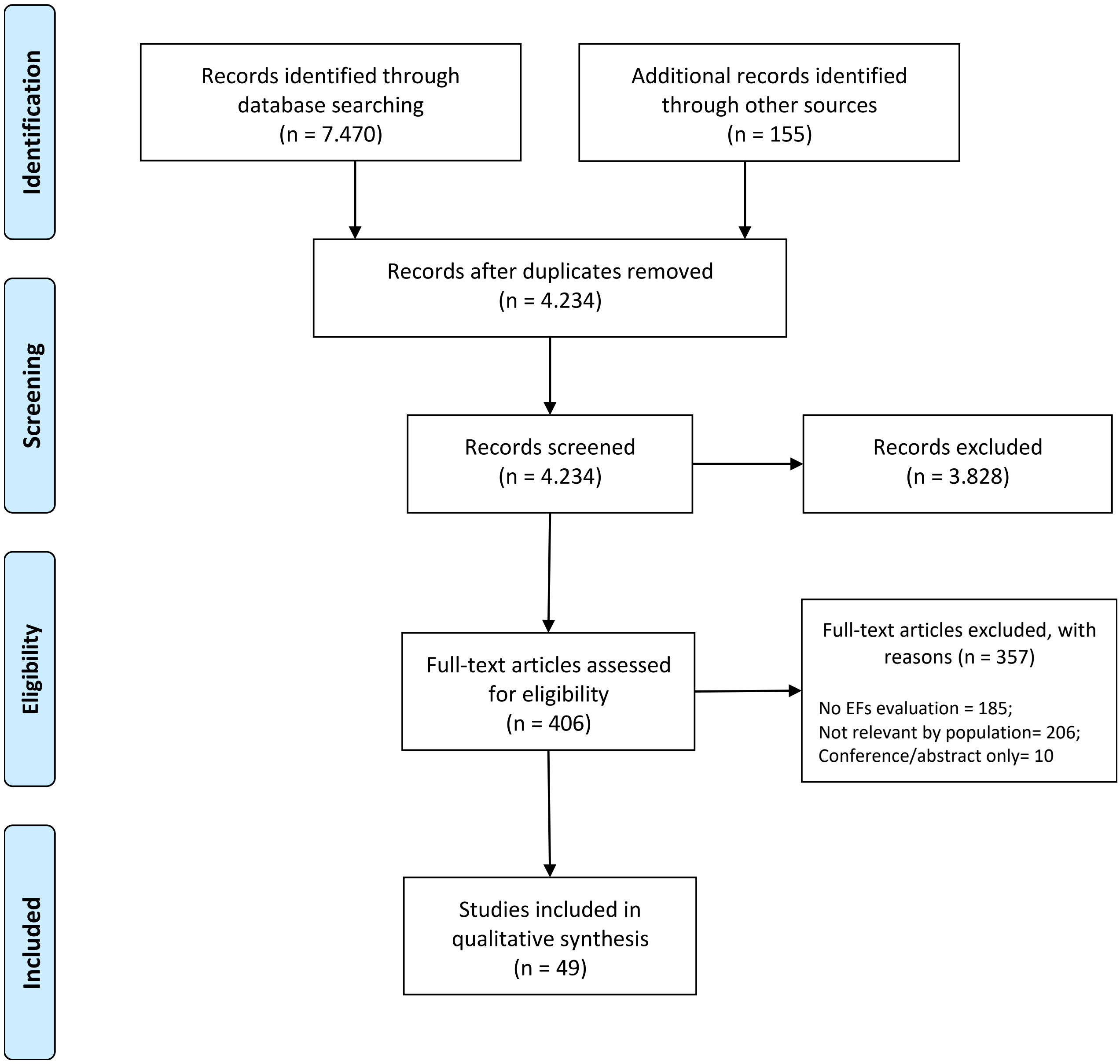
A data extraction sheet was designed to collect the following information: sample size, age range or average, region and city of Brazil where the study was conducted, type of school, characteristics of the instrument: type of instrument, evaluated EF, evidences of validity and reliability.

4.3. Results

The research retrieved 7,470 potentially relevant articles. After duplicates removal and screening by two authors, 406 studies met the inclusion criteria for a detailed evaluation. In total, 357 papers were excluded from the review based on the reasons reported in Figure 1. The remaining 49 studies were selected and categorized based on the investigated instruments as follows: 1 - instruments considered suitable by SATEPSI for the clinical use of the psychologist; 2 - international instruments with Brazilian adaptations that were not evaluated by SATEPSI; 3 - instruments designed in Brazil that were not evaluated by SATEPSI.

The systematic review of the instruments allowed the identification of 13 measures approved by SATEPSI (Table 1); 15 tests disseminated in the international literature (26 studies, Table 2); three scales of executive functioning (three studies, Table 2); and six tests designed by Brazilian researchers (seven studies, Table 3). Most of these instruments are performance-based measures, traditionally carried out through the use of pencils and paper, although a few computerized instruments were also identified (Visual Attention Test - TAVIS-4, d2 Test of Attention - Revised, Magic Card Game, Tidy up the Closet Test, Computerized Semantic Generation Test, Conners' Kiddie Continuous Performance Test, Continuous Performance Test). Scales, interviews and questionnaires on daily life were not only scarce but also did not have normative data, although they have been translated and adapted to Brazil.

Figure 1 A flow diagram illustrating selection strategy, according to PRISMA guidelines



Regarding evidence of psychometric properties, we found data for 27 of the 37 identified tests. The most commonly used methods were test-retest reliability (9), convergent validity (9), internal consistency measures (8) and factorial analysis (5). Results seemed to vary according to the quantity of methods studied per test and the quality of the indicators.

Table 1 Executive Tests for Children approved by SATEPSI for the clinical use by psychologist

Type of measure	Tests	Year	Sample age	N	Editor	Sample construction	Main evidences of validity and reliability
Working Memory	Digit Span – WISC-IV	2013	6-16	1861	Pearson	public and private school students in 9 Brazilian states from 3 regions of the country	**Criterion validity: age** r= .60 **Correlation with others measures:** Cloze test – r= .35
	Letter-Number Sequencing – WISC-IV	2013	6-16	1861	Pearson	public and private school students in 9 Brazilian states from 3 regions of the country	**Criterion validity: age** r= .70 **Correlation with others measures:** Cloze test – r= .32
	Pseudowords span – Neupsilin-Inf	2016	6-12	840	Vetor	public and private school students in 2 cities (São Paulo and Porto Alegre) from 2 regions of the country.	**Test-Retest:** r=.681
	Digits Reverse – Neupsilin-Inf	2016	6-12	840	Vetor	public and private school students in 2 cities (São Paulo and Porto Alegre) from 2 regions of the country.	**Test-Retest**: r=.554
	Visuospatial Working Memory – Neupsilin-Inf	2016	6-12	840	Vetor	public and private school students in 2 cities (São Paulo and Porto Alegre) from 2 regions of the country.	**Test-Retest:** r=.657
	Five Digit Test	2016	6-89	332 between 6-18 years	Hogrefe	students from the 5 regions of the country	**Internal consistency:** split-half r=. 883 **Test-Retest:** r=.80 for counting and choosing steps and .60 for alternation step. **Convergent**

							validity: stroop Victoria – r= 0,831;
Inhibition	Psychological Battery of Attention (BPA)	2013	6-82	1759, which 350 were between 6-17 years	Vetor	students in 4 Brazilian states (Bahia, Minas Gerais, São Paulo and Sergipe) from 2 regions of the country.	**Test-Retest:** r=.68 to .89 **Convergent validity:** Concentrated attention test– r=.56 to .60; Divided attention test– r=.47 to .66 and Alternate attention test– r=.34 to .51
	d2 Test of Attention - Revised	2019	9-52	3809 which 1475 were children between 9- 18 years	Hogrefe	public and private school students in 3 Brazilian states (Rio Grande do Sul, São Paulo and Rondônia) from 3 regions of the country.	**Internal consistency:** Cronbach's α = .43 to .96 Split-half = .40 to .93
	Visual Attention Test TAVIS-4	2019	6-17	631	Hogrefe	students from 3 schools in Rio de Janeiro	**Internal consistency:** Cronbach's α =.83 Correlation between the TAVIS-4 test variables: r=.083 to r=.898
	Go no go task Neupsilin-Inf	2016	6-12	840	Vetor	public and private school students in 2 cities (São Paulo and Porto Alegre) from 2 regions of the country.	**Test-Retest Reliability:** r=.560
	Verbal fluency (orthographic (phonemic and semantic) Neupsilin-Inf	2016	6-12	840	Vetor	public and private school students in 2 cities (São Paulo and Porto Alegre) from 2 regions of the country.	**Test-Retest Reliability:** r=.669 for phonemic criteria and .501 for semantic criteria
Flexibility	Wisconsin Card Sorting Test – WCST	2019	6-89	2708 which 1249 were between	Hogrefe	public and private school students in 3 cities (São Paulo, Porto	**Clinical validity:** Discriminatory analysis separated the

				6-19 years		Alegre and Manaus) from 3 regions of the country	ADHD group from the control group. Centroid = 0.609. Percentage of correct classification of 75%.
Planning	Rey–Osterrieth complex figure - ROCF	2010	5-88	932 which 455 were between 5-20 years	Pearson-	students in 2 Brazilian states (São Paulo and Rio Grande do Sul) from 2 regions of the country.	**Test-Retest Reliability:** r=.76 in copy **Internal consistency:** Cronbach's α =.864 **Correlation with intelligence measures:** WISC III – r=.37 to r=.38

Table 2 Normative data of internationally recognized tests published in articles or books

Type of measure	Tests	Year	Sample age	N	Authors	Sample construction	Validity and Reliability
Working memory	Test of Pseudoword Repetition	2003	4-10	182	Santos & Bueno	Rural and urban areas of the States of São Paulo (SP) and Minas Gerais (MG)	**Correlation with other measures:** Digit Span foward – r= 0.50; Digit Span backwards – r= 0.43) **Test-Retest:** r = 0.81; P < 0.01 **Clinical valididy** (Barbosa et al., 2007): Group with literacy disabilities performed poorer than the control group.
	Corsi block-tapping test	2005	7-10	127	Santos et al.	Rural and urban areas of the States of São Paulo (SP) and Minas Gerais (MG)	**Correlation with other measures**: Corsi block – tapping test – r= .41
		2010	7-10	80	Galera & Lis Pereira de Souza	private and public school students *	
	Brown-Peterson task	2010	6-12	103	Vaz et al.	students at Child and	Positive

	(Consonant Trigrams test)					Adolescent Center in Sao Paulo (SP)	correlation with the Digit Span (r=.348 to .402)
	Self-ordered pointing task	2017	3-5	248	Sallum et al.	private and public school students in Belo Horizonte (MG)	**Convergent Validity**: Columbia Mental Maturity Scale, r = .30, p < .001 **Ecological validity**: Child Behavior Checklist (Internalizing r = −.24, p = .001; Externalizing r = −.22, p = .003; Total problems r=−.17, p = .022)
Inhibition	Stroop Victoria/Golden	2006	12-14	132	Duncan	private and public school students in Niterói (RJ).	**Criterion Validity:** Age - 7 years olds were slower than 8 (p=0.03), 9 (p<0.01) and 10 (p<0.01) years olds. **Test-Retest Reliability (**Seabra & Dias, 2012): r=.83, r=.90, r=.91 for each of the three parts of the test
		2009	7-10	119	Charchat-Fichman & Oliveira	private school students in Rio de Janeiro(RJ)	
		2012	6-14	410	Seabra & Dias	public school students in São Paulo (SP)	
	Day Night Stroop Task	2008	4-6	91	Natale et al.	private and public school students in Timóteo (MG)	-
	Child Hayling Test**	2016	6-12	28	Siqueira et al.	private and public school students *	-
	Conners' Kiddie CPT	2009	4-5	91	Miranda et al.	Private and public school students in São Paulo (SP)	-
	Continuous Performance Test - CPT-II	2008	6-11	384	Miranda et al.	Private and public school students in São Paulo City (SP)	**Clinical validity** (Miranda et al. 2011): ADHD group performed worse than control in all of the test measurements (p=<.001)
		2013	12-17	480	Miranda, Rivero & Bueno	Private and public school students in São Paulo (SP)	

							Dyslexia group exhibited higher percentages of commissions, variability and perseverations in some measures (p=<.001). When comparing the ADHD and dyslexia groups, ADHD displayed poorer performance (p=<.001).
Flexibility	Trail Making Test	2012	11-13	122	Seabra & Dias	public school students in São Paulo (SP)	**Convergent validity:** Auditory working memory test r =.60 and .54
	Letter and category fluency tasks	2007	7-10	101	Malloy-Diniz et al.	public school students in Belo Horizonte (MG)	**Discriminant validity** (Abreu et al., 2013) : Performance of the subjects with ADHD particularly for letters was poorer than controls (p < 0.05)
		2011	7-10	119	Charchat-Fichman et al.	private school students in Rio de Janeiro (RJ)	
		2014	6-14	413	Dias & Seabra	public school students in the state of São Paulo (SP)	
		2016	7-10	298	Hazin et al.	private school students in the following geopolitical regions of Brazil: northeast (cities located in the states of Paraíba and Rio Grande do Norte), north (city of Belém), and southeast (city of Rio de Janeiro), belonging to socioeconomic classes C and D	
		2016	7-10	102	Leite et al.	private school students from the states of Paraíba and	

						Rio Grande do Norte, belonging to socioeconomic classes C and D	
Planning	Tower of London	2012	11-13	122	Seabra & Dias	public school students in São Paulo (SP)	**Convergent validity:** Auditory working memory test r =.32, Trail making test r=.26; Visual working memory test r=.24 and Attention by Cancelling Test, r=.19.
		2008	4-9	371	Malloy-Diniz et al.	private and public school students *	
	Tower of Hanói	2010	9-16	100	Gonsalez et al.	private and public school students in São Paulo (SP)	-
		2018	6-7	83	Da Mata et al.	public school students *	
		2007	13-16	60	Sant'Anna et al	public school students in São Paulo (SP)	
	Mazes – WISC-III	2003	6-16	801	Wechsler & De Figueiredo	private and public school students in Pelotas (RS).	-
Rating measures	Childhood Executive Functioning Inventory **	2017	4-7	408	Trevisan et al.	public school teachers and parents in São Paulo (SP)	**Reliability:** Cronbach's α of .94 for the parent version, and .98 for the teachers, respectively. The Spearman-Brown coefficient was 0.92 and 0.96 for parents and teachers. **Construct validity:** exploratory factor analysis found two factors, which explain 76.92% of total variance
	Behavior Rating Inventory of Executive Function –	2012	5-18	671	Carim et al.	public school teachers, parents and adolescents in São Paulo (SP)	**Reliability:** Cronbach's α values ranged from .901 to .957,

	BRIEF **						considering the 3 forms (parents, teachers and self-report). **Construct validity:** The principal components analysis identified two dimensions (metacognition index and the behavior regulation index)
	Working Memory Rating Scale**	2014	6-8	355	Engel de Abreu et al.	Public and private school teachers in the cities of São Paulo (SP) and Salvador (BA).	**Reliability:** Cronbach's α across the total sample was .98, with coefficients of .97 and .98 for private and public school samples, respectively. **Construct validity:** Exploratory factor analysis with oblique rotation showed that a single factor accounted for 69.16% of the total variance (61.78% for private and 71.49% for public schools)

*It does not specify the city/region of the country.
** Initial adaptation studies of the instrument

Table 4 Normative data from tests created in Brazil that were not submitted to SATEPSI analysis

Type of measure	Tests	Year	Sample age	N	Authors	Sample construction	Main evidences of validity and reliability
Working Memory	Tidy up the Closet Test **	2018	6-12	-	Abreu et al.	-	-
Inhibition	Attention by Cancelling	2012	5-14	631	Seabra & Dias	public school students in São	**Convergent validity:**

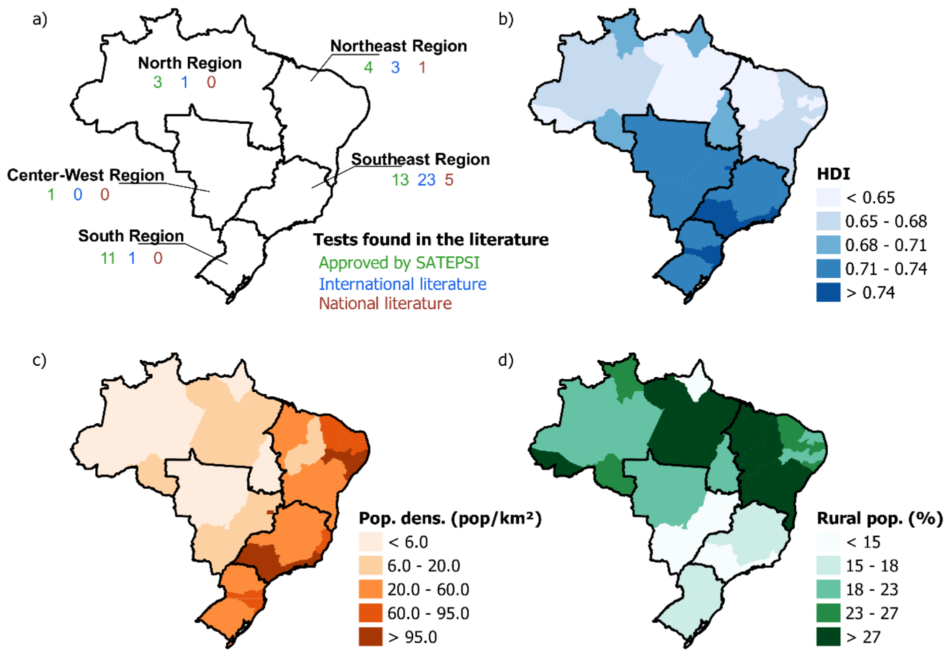
	Test (ACT)					Paulo (SP)	Trail making test: r=.23 to .41 for children in the 1st to 4th grades and r=.16 to .30 for children in the 5th to 8th grades.
		2012	7-16	524	Hazin et al.	public and private school students in Natal (RN)	
	Computerized Semantic Generation Test	2005	8-13	154	Assef, Seabra, & Capovilla	public school students in São Paulo (SP)	-
Flexibility	Magic Card Game (MCG)	2017	6-9	113	Massalai	public and private school students in São Paulo (SP)	**Reability:** Correlations between the 3 parts of the test were between r= .66 to .79. **Convergent validity:** Digit Span, r=.564; Verbal Fluency (animals r=.424; fruits r=.542; clothes - r=.549); Trail making test, r=.214 and Stroop, r=-.119.
		2016	3-8	126	Uehara et al.	private school students in Rio de Janeiro (RJ)	
	Trail Making Test for Preschoolers (TMT-P)	2012	4-6	223	Seabra & Dias	public school students in São Paulo (SP)	**Convergent validity:** Stroop - r =.37 Attention by Cancelling Test r=.34

** The standardization studies of this test are in progress.

Concerning the characteristics of the sample, normative data from empirical research show a great diversity of instruments and studies carried out in different regions of the country (Figure 2). Most normative studies (22) have incorporated data on children from both public and private schools (Tables 1, 2 and 3). However, 20 studies have considered only one of these educational contexts and seven studies did not specify the type of school.

Figure 2 shows the number of normative studies found by region. Data are predominantly concentrated in the South and Southeast regions of Brazil. Only a few studies were conducted in the Northeast region of the country, while only one presented data from the North region. No studies were identified in the Center-West region of Brazil. The figure also shows the distribution of the HDI, population density and the percentage of rural population in each of the five regions of Brazil. The South and Southeast regions are the most developed of the country, presenting the highest HDI and the highest urban population density. Contrasting, Brazil's Northeast region ranks last regarding national HDI, followed by the North region, which has the lowest population density.

Figure 2 Regional distribution of: a) number of normative studies found; b) Human Development Index (HDI); c) population density; d) percentage of rural population. Source: IBGE Census 2010



5.4. Discussion

5.4.1 Characterization of available tests and their suitability for clinical use in children

Despite the great variety of measures found, psychologists in Brazil are allowed to formally use only 1/3 of these. It should be noted that out of the 13 available measures, only eight correspond to measures designed especially for the assessment of

EF in children. The remaining five correspond to tests created for the assessment of EF in adults that had their sample expanded for the evaluation in children (Five Digit Test, Psychological Battery of Attention - BPA, d2 Test of Attention - Revised, Wisconsin Card Sorting Test – WCST and the Rey–Osterrieth complex figure - ROCF). The normative data of these tests have a large age variation, which in most cases range from school-age children to the elderly population. Due to these sample variations, the number of children per age group in these cases is usually limited when compared to studies that are conducted only with children.

It is also important to notice that these tests do not consider key dynamic aspects of child development in their design. The transposition of adult-centered measures to children is not obvious and should be accompanied by discussions on the adequacy of the measures to this population and on the theoretical models of EF in children. Actually, the fact that a child is capable of performing a task designed for adults does not mean that it is suitable for the pediatric population. It is crucial to consider that EF are interdependent and necessarily mediated by lower-level functions that are also potentially under development in children. Therefore, it is important to prioritize approaches that allow the dissociation from the contribution of executive abilities. The manuals of these instruments lack discussions and studies about the implication/motivation of the child to the task, the development of the functions that operate when executing the test, and their applicability in specific pediatric populations. In order to improve tests deemed suitable for clinical practice, the authors suggest that the SATEPSI guidelines should demand a minimal sample size and a specific theoretical discussion for each stage of development (in addition to a minimum overall sample) when the tests present wide age variations in their normative sample.

Regarding measures created especially for pediatric populations, five are measures that compose a battery of brief assessment for children - NEUPSILIN-Inf (Pseudowords span, Digits Reverse, Visuospatial Working Memory, Go no-go task, and Verbal fluency - orthographic and semantic); two are internationally recognized tests for the assessment of WM and one is a Brazilian computerized measure created especially for the assessment of inhibitory control in children. The tasks of NEUPSILIN-Inf are interesting for a brief and preliminary assessment of EF. However, the use of these measures in a comprehensive assessment may be insufficient and other tests are required. Also, NEUPSILIN-Inf does not propose flexibility and planning tests, as contemplated in classic theoretical models. Therefore, it would represent a partial measure for the assessment of EF. Apart from the NEUPSILIN-Inf, the other measures we found are designed for a more detailed assessment of executive functioning and represent good measures of WM (Digits and Sequence of Numbers and Letters) and inhibitory control (TAVIS-4). On the other hand, no measures for the comprehensive assessment of flexibility and planning designed specifically for children were found.

All instruments approved by SATEPSI correspond to performance-based tests and no rating measures were evaluated/approved by the system for clinical use. Thus, although we found rating measures adapted for the use in pediatric populations (Trevisan et al., 2017, Childhood Executive Functioning Inventory, Thorell and Nyberg (2008); Carim et al., 2012, Behavior Rating Inventory of Executive Function—BRIEF, Gioia et al. (2000) and Engel de Abreu et al., 2014, Working Memory Rating Scale, Alloway et al. (2008)), they have not yet been submitted to evaluation by SATEPSI and, therefore, are not allowed to be used in clinical practice to this date. According to the systematic review of Barros and Hazin (2013) and de Santana et al. (2019), BRIEF is one of the main instruments for the assessment of EF in children and is more frequently used in research than tests approved by SATEPSI. This restricted use of rating measures may be a barrier to clinical practice given the importance of employing multiple data sources to assess children's behaviors outside the testing environment (Gioia et al., 2002).

5.4.2. The representativeness of the different regions of Brazil in the normative data

Normative data from empirical research show a great diversity of instruments and studies carried out in different regions of the country (Figure 1; Tables 2 and 3). Most normative studies have incorporated data on children from both public and private schools, which highlights the importance of considering the impact of this variable (which in Brazil represents a measure of SES) on the development of EF (de Siqueira et al., 2016; Duncan, 2006; Galera & de Souza, 2010; Hazin et al., 2012, 2016; Leite et al., 2016; Malloy-Diniz et al., 2008; Miranda et al., 2008, 2009, 2013; Natale et al., 2008; Sallum et al., 2017; Wechsler, 2002). However, some studies have considered only one of these educational contexts (Assef et al., 2005; Charchat-Fichman et al., 2011; Da Mata et al., 2018; Malloy-Diniz et al., 2007; Montiel & Seabra, 2012; Sant'Anna et al., 2007; Seabra & Dias, 2012; Uehara et al., 2016; Trevisan et al., 2012).

Most normative studies showed a predominant concentration of data from the South and Southeast regions of Brazil (Figure 1; Assef et al., 2005; Charchat-Fichman & Oliveira, 2009; Dias & Seabra; Duncan, 2006; Malloy-Diniz et al., 2007, 2008; Massalai et al., 2018; Mata et al., 2013; Miranda et al., 2008, 2009, 2013; Natale et al.,2008; Sallum et al., 2017; Sant'Anna et al., 2007; Santos & Bueno, 2003; Santos et al., 2005; Seabra et al., 2012; Uehara et al., 2016; Vaz et al., 2010; Wechsler, 2002). Only a few studies were conducted in the Northeast region of the country (Figure 1; Hazin et al., 2012, 2016; Leite et al., 2016) while only one presented data from the

North region (Figure 1; Hazin et al., 2016). No studies were identified in the Center-West region of Brazil. This scenario limits, for example, a comprehensive approach of the different trajectories of EFs development in children in Brazil. In addition, given that Brazilian studies show differences in executive performance among children from different geopolitical regions (Hazin et al., 2016), the interregional use of normative data as reference in clinical research should be carried out with caution. Also, considerable differences in executive performance were found between children living in the same city but with different SES (Magalhães et al., 2016; Mata et al., 2013; Sallum et al., 2017). Thus, the use of normative data that were developed considering only one social context should be questioned. Research also indicates differences between the executive performance of children from urban and rural backgrounds (Santos et al., 2005; Santos & Bueno, 2003). Given that only a few studies have included samples from rural areas, the assessment of children from this context requires prudence when comparing and generalizing results.

The representativeness of Brazilian social and cultural disparities is still a challenge for the construction of normative data from executive measures. Even measures considered suitable by SATEPSI do not usually contemplate the regional and cultural diversity of the country (see Table 1), although this is an evaluation criterion used by the system. The instruments flagged as quality “level A” (Supplementary Annex A) are those that have normative data from at least two regions, with a minimum of 250 individuals per region. For instruments in which all the five regions are contemplated (flagged as “level A”), a minimum of 250 individuals per region is required or 1000 individuals divided according to the proportion calculated from population geopolitical data. On the other hand, tests flagged as “level B” consider only one geopolitical region with at least 500 participants. It should be noted that this classification is considered sufficient by SATEPSI.

Considering our findings, only one instrument (5 digit test) approved by SATEPSI comprises data from all regions (Sedó et al., 2015). Apart from TAVIS 4, the other tests have data from either three or two regions of Brazil. The TAVIS 4 (Mattos, 2019) test has normative data from only three schools in the city of Rio de Janeiro, Southeast region (the author does not specify whether they were public or private schools). The NEUPSILIN-Inf (Salles et al., 2016) and the ROCF (Rey, 2010) tests have normative data only from the South and Southeast regions. Given the social and cultural contrast between these two regions and the rest of the country (Figure 1), these data should be used with caution, especially in the North and Northeast regions. On the other hand, the WISC-IV (Wechsler, 2013), and BPA (Rueda, 2013), WCST (Heaton et al., 2019) and D2 test (Brickenkamp et al., 2019) instruments have data that better represent the social contrast of Brazil because children from some of the states in the Northeast and North region were included in the sample.

4.5. Conclusion

Currently, Brazil has 13 tests approved by SATEPSI for the assessment of EF in children, as well as 18 internationally recognized tests with Brazilian versions and six tests developed in Brazil. Despite notable advances, we still found limitations in the tests available for clinical use, especially concerning the lack of instruments to evaluate flexibility and planning and also the absence of rating measures for the assessment of EF in daily life. In addition, most of the available performance-based tests do not provide complementary steps to dissociate lower-level processes (i.e., basic skills) from executive ones.

Furthermore, it was possible to identify that most part of the studies were carried out in the South and Southeast regions of Brazil. Although there are few interregional studies, they suggest differences in executive performance between regions. One possible explanation may be the use of normative samples from more highly-developed regions to characterize performance in less-developed regions. However, there may be alternative explanations such as variations in the exposure to testing and the adequacy of test materials in different regions.

Due to the long-term and costly nature of the standardization and validation process (especially in a country with great socioeconomic and cultural diversity such as Brazil), it is of the uttermost importance to encourage joint efforts among research groups in order to obtain normative references that are more representative of the Brazilian reality. Thus, research aimed at the construction/adaptation of instruments specially designed for children must be carried out preferably at all five regions of Brazil, in view of socioeconomic and cultural differences. In addition, indicators of SES (type of school, income, etc.) must be taken into consideration and psychometric data studies (validity and reliability) should be encouraged.

We suggest that the guidelines established by SATEPSI should be refined to consider the specificities of child development. To this end, the guidelines should require a minimal sample size and specific theoretical discussions for each stage of development when the tests present wide age variations in their normative sample. In addition, the use of SATEPSI-approved tests that had their normative studies conducted in only one city or exclusively in the most developed regions of the country may compromise interpretation in other regions. In order to provide Brazilian psychologists with tests that represent the socio-cultural diversity of the country, it seems necessary to provide, in addition to the proportion calculated from population geopolitical data, socioeconomic aspects of the children that compose the sample and their cities/regions.

Concerning the limitations of our study, although the review was conducted following the recommendations of PRISMA, it was not possible to perform the qualitative assessment of risk and bias recommended by the guidelines given the heterogeneity and number of studies found. It is recommended that these analyses should be performed in subsequent studies. In addition, the analysis did not include precise information on the developmental status of children (whether children had some developmental delays or disorders), what should also be carried out in future studies.

In summary, the study of different cultural and socioeconomic contexts seems to be necessary to better understand the typical and atypical development of EF. Since Brazil is a melting pot of cultural and socioeconomic contexts, it represents an important subject to better understand the impacts of these factors on the trajectories of EF both in typical and atypical development.

5.6. References

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6. Study 2: Developmental profile of executive functioning in school-age children from Northeast Brazil

Article under review in Frontiers in Psychology (QUALIS: A1; SCIMAGOJR: Q1)

Guerra, A., Hazin, I., Guerra, Y., Roulin, J., Le Gall, D., Roy, A. (Under review). Developmental profile of executive functioning in school-age children from Northeast Brazil. *Frontiers in Psychology.*

Abstract

The development of executive functions (EF) is recognizably correlated to culture, contextual and social factors. However, studies considering all the basic EFs are still scarce in Brazil, most notably in the Northeast region, which is known for its social inequality and economic gap. This study aimed to analyze the developmental trajectories and structure of four EF, namely inhibition, flexibility, working memory and planning. In addition, the potential effects of socioeconomic status (SES) and gender were examined. The sample included 230 Brazilian children between 7-12 years old, homogeneously distributed by age, gender and type of school. The EF were assessed through the Brazilian version of the Child Executive Functions Battery (CEF-B). A global effect of age was found for most of the EF measures evaluated. Gender effect was mostly non-significant, except for 4 of the 12 tasks. There was a significant SES effect on 8 tasks, all in favor of private school children. Exploratory factorial and correlation analysis showed a 4-factor EF structure, corroborating the theoretical distribution considered in the CEF-B. A developmental progression is evident in the results for all of the EF measures evaluated. While gender had little influence on EF, SES seems to significantly impact the development of EF. As normative data are still lacking in Northeast Brazil, this study may help to understand EF development trajectories and provide tools for neuropsychological evaluation.

Key-words: Socioeconomic status, Development, Child, Culture, Neuropsychology

6.1. Introduction

Executive functions (EF) comprise a set of superior cognitive skills that allow the subject to engage in goal-oriented behaviors (Luria, 1966). These skills are considered as a predictor for success in various aspects of life and are essential for guiding and regulating intellectual, emotional and social abilities (Diamond, 2013; Zelazo, 2015). Especially in children, EF have been pointed out as predictors of academic success. In several studies, the performance in executive tests is more correlated with school success than the performance in intelligence tests during the first years of school (Follmer, 2017; Shaul & Schwartz, 2014).

Most of classical studies recognize that EF consist of three core skills: inhibition, working memory (WM) and cognitive flexibility (e.g., Friedman & Miyake, 2017; Lehto et al., 2003; Miyake et al., 2000), all of which are implied in the operation of higher-level EF such as planning, reasoning and problem solving (Diamond, 2013). Despite EF components are considered an independent construct, they are strongly interrelated (Diamond, 2013; Lehto et al., 2003; Miyake et al., 2000).

EF start operating since the first years of life, but would follow a progressive developmental trajectory and reach a late functional maturity at approximately 25 to 30 years of age (Lebel et al., 2008; Tamnes et al., 2010). This long trajectory would be characterized by spurts or peaks in development and by different organizational and structural transformations (Anderson, 2002). Factorial analysis studies in preschoolers have shown that EF are still relatively undifferentiated until approximately the age of 5 (see Lee, Bull, & Ho, 2013). In fact, studies conducted with 3-year-olds have described an EF structure comprising a single latent variable (Willoughby et al., 2010, 2012). Studies carried out with 4 and 5 years old children support both a unitary model (Fuhs & Day, 2011; Shing et al., 2010) and a two-factor model (Lee et al., 2013; Muller et al., 2012; Usai et al., 2014; van der Ven et al., 2013). In contrast, studies seem to agree that after 6 years, EF would gradually specialize, approaching a multifactorial structure such as identified in adults (Brocki & Bohlin, 2004; Huizinga et al., 2006).

These developmental studies have also reported the influence of other demographic variables on EF, such as gender. In the majority of researches, gender effect on executive performances has proven to be non-significant (Anderson, 2002; Brocki & Bohlin, 2004; Huizinga et al., 2006; Lee et al., 2013; Xu et al., 2013). However, some North American studies showed significant differences in favor of boys (Halpern, 2012) while studies in Mexico and Colombia were in favor of girls (Ardila et al., 2005). In these cases, gender effect seems to vary according to the tasks used and, more broadly, to cultural aspects (Roukoz et al., 2018).

In fact, the role of social, cultural and contextual factors in the emergence of EF in children has been increasingly recognized (Farah, 2017; Lawson et al., 2017; Sbicigo et al., 2013). Several constructs are used as correlated measures to evaluate the impact of environmental context in executive development. Socioeconomic status (SES) is currently considered one of the most used factor to assess the impact of different life contexts on EF development. However, SES is a challenging construct to measure because it comprises multiple social and economic variables related with educational achievement, health, and psychological well-being (Farah, 2017). Different indicators such as parents' education and profession, family income, type of school (private or public) or a combination of these factors recognizably impact the development of EF, especially WM, selective attention and cognitive flexibility (Johnson et al., 2016; Noble et al., 2015; Ursache & Noble, 2016). Most researchers suggest that a higher SES would have a positive effect on the development of EF, while a lower SES would be associated with poorer executive performance (Johnson et al., 2016).

Although the impact of SES on executive development is relatively well known, studies are mainly conducted in more economically developed countries (Johnson et al., 2016). However, poverty and social inequality contexts are more pronounced in low- and middle-income countries (UNDP, 2019). Brazil is the fifth largest and sixth most populous country of the world, characterized by a remarkable cultural variability and socioeconomic inequality. Currently, Brazil is considered a middle-income country and presents the 2nd highest income inequality in the world (UNDP, 2019). This economic gap reveals disparities in key elements of human development such as health and education. In the Brazilian context, guaranteeing access to good education and health services is still strongly dependent on high SES.

In addition, it is important to consider that income distribution is also unequal between the country's own regions. The South and Southeast regions of Brazil are the most developed of the country, presenting the highest national Human Development Index (HDI) and the highest urban population density. Contrasting, the Northeast region ranks last regarding the HDI. Specifically, the State of Rio Grande do Norte ranks third worst regarding performance in reading, writing and mathematics (PISA, 2018). In addition, Brazilian cities are characterized by a noteworthy socioeconomic variability even within their own boundaries. For example, areas with high HDI levels can be commonly found nearby extremely poor zones (IBGE, 2010).

In this context, it is important to note that 22.6% of children and adolescents between 0 and 14 years of age live in extreme poverty in Brazil. This corresponds to 9.4 million minors with monthly per capita income below or equal to a quarter of the Brazilian minimum wage (IBGE, 2019). This rate is even more expressive in the northeast region, where the percentage of children in extreme poverty reaches 36.3%. It is necessary to emphasize that poverty in childhood and adolescence goes beyond the lack of money and must take into account other factors that influence a lower quality of life. Considering the fact that access to good education and health in Brazil is strongly associated with a higher SES, children in poverty situation are more susceptible to experiencing worse health conditions, more developmental delays, less school achievements, and more behavioral and emotional issues than their more favored peers (Berthelsen et al., 2017; Johnson et al., 2016).

Brazilian studies have shown differences in EF between children from different geopolitical regions (Hazin et al., 2016), from urban and rural backgrounds (Santos et al., 2005; Santos & Bueno, 2003), and even between children living in the same city but with different SES (Magalhães et al., 2016). However, to the best of our knowledge, studies that considered at least the three basic executive components are scarce and no study proposed so far the analysis of the structure and organization of EF in Brazilian children (Guerra et al., 2020). Therefore, the main objective of this study was to investigate the developmental trajectories of the three basic components of EF, namely inhibition, cognitive flexibility, and WM, and one more complex component, planning. Also, this study aimed to assess the potential effects of two demographic factors (gender and SES) in the development trajectories.

The study was carried out with 7- to 12-year-old children from the Northeast region of Brazil using a battery of performance-based EF tests specially designed for the pediatric population. We expected (1) an improvement in performance of children between the ages of 7 and 12 years in EF tasks of the different assessed domains (Brocki & Bohlin, 2004; Diamond, 2013; Lehto et al., 2003). We expected progress in inhibition, flexibility, WM and planning skills to be evident in executive tests. Regarding the structure and organization of EF, we expected to (2) find a 4-factor structure grouping the tests according to its theoretical assumption. We also expected weak but significant correlations between results of tasks evaluating the same EF if compared to results of tasks that evaluate other executive components (Bellaj et al., 2015; Lehto et al., 2003; Miyake et al., 2000). Considering the relative consensus on the effects of demographic and contextual variables on the development of EF in school-aged children, we expected (3) a positive effect of higher socioeconomic status on executive performance (Magalhães et al., 2016 - Brazilian study; Noble et al., 2015; Sbicigo et al., 2013; Shayer et al., 2015), and (4) a non-significant effect of gender on executive performance (Hazin et al., 2016; Magalhães et al., 2016 - Brazilian studies).

6.2. Materials and methods

6.2.1. Participants

A total of 230 Brazilian children from the cities of Natal, Parnamirim and Elói de Souza in the Rio Grande do Norte state participated in the study. The children were aged between 7 and 12 years. The sample was divided into six age groups and each group was composed of approximately 40 children homogeneously distributed by gender and type of school. The study was conducted in 14 public and private schools in the period between 2018 and 2019. The data were collected in four private and four public schools in Natal, four public schools in Parnamirim and two public schools in Elói de Souza, one belonging to the rural area and the other to the urban area of the municipality.

The research was carried out in accordance with the ethics requirements of the Research Ethics Committee of the Federal University of Rio Grande do Norte under the code 48383715.1.0000.5537. Participants were selected based on the following inclusion criteria: a) signing of the informed consent form by parents and/or legal guardians; b) regular registration in public or private school; c) absence of a history of developmental, neurological or psychiatric disorders; d) absence of uncorrected sensory alterations; and e) scaled score equal or higher than seven points in the WISC-IV Matrix Reasoning and Vocabulary sub-tests. The selection of participants was carried out in collaboration with the coordinators and teachers of each institution. A total of 264 signed informed consent form were collected and 244 children and adolescents were submitted to the application of the WISC-IV Vocabulary and Matrix Reasoning sub-tests. Fourteen of the participants scored below seven in one of the subtests and, therefore, were excluded from the sample. Table 1 shows the demographic data for the study population.

Table 1 Sociodemographic data

	Gender				**Type of school**			
	F		**M**		**Public**		**Private**	
	N	%	N	%	N	%	N	%
7 (n=37)	19	16.38	18	15.78	24	20.68	13	11.40
8 (n=41)	18	15.52	23	20.17	18	15.51	23	20.17
9 (n=34)	18	15.38	16	14.03	17	14.66	17	14.91
10 (n=46)	25	21,55	21	18.42	23	19.83	23	20.17
11 (n=39)	20	17.24	19	16.66	19	16.38	20	17.54
12 (n=33)	16	13.79	17	14.91	15	12.93	18	15.79
Total (n=230)	116	100	114	100	116	100	114	100

6.2.2. Materials

The EF were assessed through the Child Executive Functions Battery (CEF-B). It consists of a set of 12 performance-based tests for the neuropsychological assessment of EF (Figure 1), aimed at children and adolescents between 6 and 16 years old (Roy et al., 2020). The battery is based on a child-centered theoretical model and assesses the main executive processes: inhibition, flexibility, working memory and planning (Diamond, 2013). It comprises new experimental tasks and tests that already exist in the international literature but have been modified or expanded to better attend the pediatric population.

Given the shortage of EF test batteries based on specific theoretical models in Brazil, CEF-B was adapted to the Brazilian context (Guerra et al., 2020). Psychometric data of this version indicated good validity and reliability properties (Guerra et al, considered for publication). Also, preliminary evidence of validity of the French version has been published regarding the Stroop test (Roy et al., 2018), and studies with different clinical groups, such as neurofibromatosis type 1 – NF1 (Remigereau et al., 2018; Roy et al., 2010, 2014), parietal temporal and frontal epilepsy (Charbonnier et al., 2011) and brain tumors (Roche et al., 2018). These initial data indicate a good sensitivity of the battery for the evaluation of EF in pediatric populations (Good developmental validity for the Stroop test – $F(5, 108) = 10.42$, $p < .001$; Good clinical sensitivity of tasks with significant statistical differences between clinical and control groups for Rey Osterrieth Complex Figure - $F\ 1{,}69 = 6.889$, $p = .011$ – for the NF1 group and Z score = 2,89 for frontal epilepsy case; KCST – $p = <.001$ for the NF1 group).

Table 2 presents a brief description of the tests that compose the CEF-B. The order of application of the tests that integrate the protocol was defined in a systematic and pseudo-random manner, alternating the executive skills investigated and their verbal/non-verbal nature. The purpose of this order is to control the influence of basic processes on executive performance, as well as to have usable tests in case of communication, visuospatial or gestual disorders (Roy, 2015). In order to limit measurement errors, the variables of CEF-B were designed to modulate the executive load involved in some multicomposite tests. This approach consists in providing "control" conditions which are supposed to be less demanding on executive processes

(as in subtracting the Trails A score from Trails B score to “isolate” the contribution of executive abilities in the Trail Making Test; Arbuthnott & Frank, 2000)

Regarding the evaluation of SES indicators, a questionnaire for parents was created to retrieve information on the type of school (public or private) the child is enrolled, family income, level of education and profession of the parents. All variables were initially considered for analysis. However, the only variable with no missing values was ‘type of school’. Thus, we opted to use it as the sole indicator of SES, because the existence of missing values in any independent variable impairs the analysis of the other variables. In addition, we verified that ‘type of school’ was highly correlated with parents' level of study and family income ($r = .675$ to 750; $p < .001$), assuring the representativeness of the measure. It is important to highlight that in the Brazilian context, guaranteeing access to good education and health services is strongly dependent on high SES. In fact, children from higher SES attend private schools and children from more disadvantaged contexts attend rural schools.

Figure 1 Overview of the CEF-B

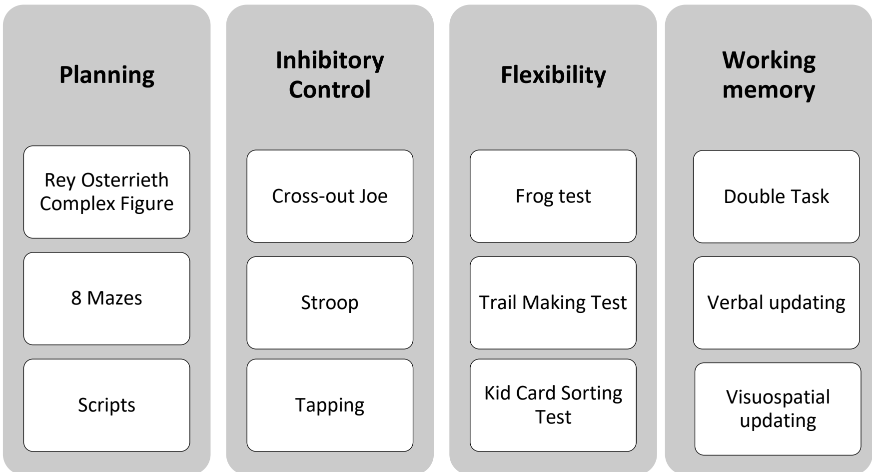

Table 2 Brief description of the tests and variables used in the study

EF	Test	Variables	Brief description of the tests
Inhibitory Control	Stroop	Interference Time Interference Errors	This version is divided into three stages: 'Naming', 'Reading' and 'Interference'. The test comprises 100 items per stage, organized into 10 rows of 10 stimulus varying in three different colors.
	Tapping	Errors Go-No-Go Errors Conflict Time Go-No-Go Time Conflict	Evaluates motor inhibitory control. The task is divided into three stages: 1- simple conditioning: the child must reproduce the motor action presented by the evaluator; 2- Go/No-Go: the child must inhibit the automated response pattern; 3- conflict: the child must be able to do the contrary of the first stage, incorporating a new "no-go" condition. Each stage comprises a series of 30 items.
	Cross-out Joe	Time Speed	The child must cross-out the Joe character among other characters. The test material comprises two A3 blank pages in portrait orientation in which two series of 240 items are randomly distributed.
WM	Verbal updating	Baseline Performance score	Evaluates verbal updating of working memory. The task consists of two stages: 1- baseline: globally assesses the ability to remember the letters enunciated by the evaluator and; 2- update: assesses the ability to retain the last three or four letters of a given sequence.
	Visiospatial Updating	Baseline Performance score	As the verbal updating task, this test consists of two stages: 1- baseline: globally assesses the ability to remember the item tapped by the evaluator (visual memory) and; 2- update: assesses the ability to retain the last three or four items of a given sequence.
	Double task	Span score Clowns score Score Mu	Evaluates the central executive component of working memory. The task comprises four stages lasting 1 minutes and 30 seconds each: 1- baseline: definition of the digits span which the child can remember; 2- simple condition: after defining the span, sequences of the same length are presented for 1 minute and 30 seconds; 3- clown cancelation: for 1 minute and 30 seconds the child must check with an X the clown heads which they find in the sheet; and 4- double condition: the child must repeat tasks 2 and 3 simultaneously.
Flexibility	Trail Making Test	Flexibility Index Alternance Errors	Consists of an adaptation of the TMT, which evaluates the ability to alternate the focus of attention between groups of stimuli. This version comprises three stages: "A Numbers", "A Letters" and "B Numbers and Letters". In the first stage, the child is asked to connect the numbers in ascending order. In the second stage, the child must connect the letters in alphabetic order. In the third stage, the child must connect letters and numbers in alphabetic, ascending and alternating order.
	Kid Card Sorting Test	Time Perseverations	In this test, the child is required to combine a series of 48 response cards with one of four target cards. Each response card can be combined according to its color, shape and number, and the child must guess what is the combination rule based solely on the evaluators feedback ('yes' or 'no'). After six correct answers, the combination rule is changed. In this version, the child is informed of the three possible classifications beforehand.
	Frog test	Time Score	Evaluates the ability to abstract and deduce rules, requiring cognitive flexibility. The child must deduce the logical rules according to which a frog moves around several water lilies disposed in a lake. The child must also adapt to the actions of the frog, which changes the movement rule without previous warning.
Planning	8 Mazes	Completed Total time Impasses	The test comprises eight mazes of increasing difficulty. For each maze, a dinosaur has to find its way out. The test requires the child to draw, with a pencil, the path connecting the starting point to the maze's exit.
	Rey Osterrieth Complex Figure	Planning Index	In this version, besides the traditional copy of the figure, we added a programmed stage in order to assess planning, visuospatial and visuoconstructive abilities individually. In this second stage, the child is required to reproduce the figure based on a sequential display of five cues that progressively expose the elements of the figure.
	Scripts	Time Sequence errors Intruders	This test evaluates the ability to organize daily tasks based on verbal material. The child must put in order a sequence of phrases, elaborating a coherent script according to a given title.

6.2.3. Procedure

All participants were individually evaluated in a quiet room in their school or home environment. Depending on the age of the child, two or three assessment sessions were needed with a duration of approximately 30–40 minutes each. All the tests were administered by trained neuropsychologists using standardized instructions. The tests were systematically presented in the same order: 8 Mazes, Stroop, Visuospatial updating, Scripts and Tapping tasks were proposed at the first session and the Rey Complex Figure, Trail Making Test, Double task, New Card Sorting test, Cross-out Joe, Verbal updating test and Frog test were proposed during the second session. An additional session was conducted with younger children. In this case, each session consisted of 4 tests per session, in the aforementioned order.

6.2.4. Statistical Analyses

The scores obtained in the various tests were subjected to descriptive and inferential statistical analysis. The Kolmogorov-Smirnov test revealed that the data is not normally distributed. Given the importance of examining the effects of interactions between dependent variables (age, gender, type of school), we opted for carrying out a data normalization process (Soloman & Sawilowsky, 2009) and using parametric statistical tools. For this end, we used three-way analysis of variance (ANOVA) followed by an assessment of the weight of the effect by means of partial eta squared. Through this procedure we were able to study both the developmental and differential aspects of each executive process. When the effects were significant, we used the Tukey HSD post hoc test to refine the results.

In order to preliminarily analyze the structure of the executive development in our sample and to examine the theoretical grouping considered in the CEF-B, the variables were subjected to a correlation and exploratory factor analysis. To control the effect of age on variables, a transformation of the normalized scores to score z per age group was performed. Only the variable representing the child's best performance per task was chosen because children in a test situation usually favor one of the strategies (e.g. time or error) to complete the task. Therefore, the use of an average value instead could mask the child's true best score. Horn's parallel analysis was used to determine the number of components of factor analysis (Horn, 1965). The oblimin extraction method was used beforehand given that EF tend to correlate among themselves. All statistical analyses were performed using SPSS v.20.0 (IBM Corp., Armonk, NY, USA).

6.3. Results

6.3.1. Age, gender and SES effects

To test the effect of age, gender and type of school on all EF measures, we conducted a three-way ANOVA. The descriptive data and a summary of the main effects are shown in Tables 3 and 5. Post-hoc analyses and trend analyses for age affect are described in Table 4. In the following sections, we describe the results of the analysis by EF process. Significant results showed a moderate to high effect size for age and moderate effect size for gender and type of school, according to Cohen (1992) classification. For all analyses, the significance level for *p* was set at .05.

6.3.1.1. Inhibition

The analysis revealed a significant effect of age for all inhibition measures. We found a linear improvement with age in results for all variables, with exception of Tapping *Go/No-Go Time* variable. In addition, a significant quadratic trend was observed for Tapping test (*Conflict Error*, *Go/No-Go Time* and *Error* variables) and Stroop (Errors variable). Also, a significant cubic trend was observed for Tapping test (*Go/No-Go Time* and *Error* variables). In the other hand, the gender effect was non-significant for all inhibition measures.

Table 3 Age effect on EF variables

	7 years old N=37		8 years old N=41		9 years old N=34		10 years old N=46		11 years old N=39		12 years old N=33		Age effect		
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	F	*p*	η 2
INHIBITION															
Stroop															
Time	145.4	68.5	124.4	75.7	97.5	37.3	89.1	34.4	85.2	36.1	88.0	50.3	5.038	**<.001**	.117
Errors	6.6	7.1	4.7	5.9	2.2	3.2	2.5	3.0	2.9	4.6	3.0	3.5	3.093	**.010**	.076
Tapping															
Go/No-Go Time	8.7	12.6	1.5	8.4	1.8	8.3	0.6	7.4	4.5	9.1	2.4	6.2	2.794	**.018**	.065
Go/No-Go Error	2.8	2.5	1.2	1.6	0.5	0.8	0.7	1.1	0.9	1.1	0.9	1.2	7.690	**<.001**	.160
Conflict Time	29.5	17.0	24.7	13.1	18.7	9.8	20.0	8.9	18.8	12.0	17.3	8.5	5.027	**<.001**	.112
Conflict Error	4.5	3.6	1.9	2.0	1.4	1.8	1.1	1.5	1.1	1.4	1.7	1.8	9.300	**<.001**	.189
Cross-out Joe															
Time	1065.5	266.1	862.0	297.8	775.2	227.3	754.5	156.9	673.2	178.6	627.1	192.1	11.821	**<.001**	.251
Imprecision	41.0	36.1	21.5	21.0	20.9	19.8	19.8	15.7	16.7	12.4	17.6	15.7	3.126	**.010**	.082
FLEXIBILITY															
Kid Card Sorting test															
Time	293.0	112.5	256.9	64.5	237.9	75.1	238.8	62.3	231.8	104.5	206.8	62.9	5.470	**<.001**	.122
Perseverations	7.0	4.5	7.2	4.4	6.2	4.3	5.0	3.6	5.2	4.6	5.0	3.4	2.443	**.036**	.058
Trial Making Test															
Alternance Error	0.8	1.2	0.3	0.7	0.2	0.5	0.2	0.5	0.3	0.7	0.1	0.2	5.219	**<.001**	.119
Flexibility Index	61.0	53.3	50.4	47.5	44.8	34.9	36.5	37.3	28.5	33.9	21.8	18.3	3.488	**.005**	.081
Frog Test															
Time	315.7	101.2	264.0	65.2	267.4	76.5	274.8	76.8	230.7	97.0	243.0	93.6	5.285	**<.001**	.126
Score	52.1	9.5	52.7	9.9	55.7	7.3	55.3	9.7	57.8	10.7	56.3	8.8	3.184	**.009**	.074
WORKING MEMORY															
Verbal updating															
Baseline	17.4	3.4	19.8	4.0	21.0	4.3	21.9	4.0	21.7	4.4	21.8	4.1	5.252	**<.001**	.123
Performance score	33.6	6.0	33.8	5.6	43.5	43.8	35.5	6.8	36.4	8.5	37.9	9.6	.661	.653	.025
Visuospatial updating															
Baseline	22.0	4.0	24.9	2.7	24.9	3.4	26.0	3.0	26.4	2.2	25.8	2.1	8.996	**<.001**	.186
Performance score	18.4	10.1	20.1	8.9	21.2	9.4	27.2	10.7	26.4	8.7	30.0	9.3	5.963	**<.001**	.148
Double Task															
Evolution digit span	90.2	52.5	108.1	37.3	107.7	96.9	91.9	37.5	92.5	36.8	87.0	39.1	1.051	.389	.026
Evolution clowns	93.1	13.5	99.9	20.4	91.6	15.2	100.2	11.2	98.4	15.1	100.7	21.3	2.159	.060	.052
PLANNING															
8 Mazes															
Completed	6.0	1.5	6.8	0.9	7.1	1.1	7.0	1.3	7.3	1.0	7.1	1.1	6.245	**<.001**	.137
Total Time	123.8	51.6	108.9	35.7	102.3	42.0	104.1	46.3	79.9	28.1	99.1	48.2	4.208	**.001**	.103
Impasses	0.4	0.2	0.4	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1	11.355	**<.001**	.233
Scripts															
Time	293.3	189.9	204.7	72.7	186.6	65.8	187.4	60.0	155.4	55.0	171.3	52.4	5.622	**<.001**	.161
Sequence error	11.1	3.9	9.6	4.4	8.0	4.4	6.2	4.6	6.0	4.2	5.5	3.9	5.812	**<.001**	.165
Intruder	0.3	0.7	0.7	1.0	0.4	1.0	0.1	0.3	0.1	0.4	0.2	0.6	5.159	**.001**	.149
Rey Complex Figure															
Planning Index	126.2	30.5	116.5	26.2	105.5	27.4	109.9	26.8	105.7	17.9	112.6	30.7	2.674	**.023**	.068

Note. M= Mean, SD= Standard deviation

Table 4 Post-hoc analyses and trend analyses for age effect

	Linear	Quadratic	Cubic	Post hoc comparisons
INHIBITION				
Stroop				
Time	**<.001**	.084	.974	7 < 9-12; 8 < 11-12
Errors	**.020**	**.014**	.587	7 < 9
Tapping				
Go/No-Go Time	.266	**.004**	**.034**	7 < 8; 7 < 10
Go/No-Go Error	**<.001**	**<.001**	**.049**	7 < 8-12
Conflict Time	**<.001**	.092	.612	7 < 9-12
Conflict Error	**<.001**	**<.001**	.481	7 < 8-12
Cross-out Joe				
Time	**<.001**	.212	.081	7 < 8-12; 8 < 11-12; 12 > 9-10
Imprecision	**.004**	.077	.160	7 < 11-12
FLEXIBILITY				
Kid Card Sorting test				
Time	**<.001**	.838	.269	7 < 10; 7 < 12
Perseverations	**.004**	.526	.232	7 < 11-12
Trial Making Test				
Alternance Error	**<.001**	.138	.090	7 < 11-12; 8 < 12
Flexibility Index	**<.001**	.905	.929	7 < 11-12; 8 < 12
Frog Test				
Time	**<.001**	.650	.767	7 < 11-12; 11 > 8-10
Score	**.002**	.528	.155	11 > 7-8
WORKING MEMORY				
Verbal updating				
Baseline	**<.001**	**.012**	.599	7 < 9-12
Performance score	-	-	-	-
Visuospatial updating				
Baseline	**<.001**	**<.001**	.584	7 < 8-12
Performance score	**<.001**	.850	.854	7 < 10-12; 8 > 10; 12 > 8-9
Double Task				
Evolution digit span	-	-	-	-
Evolution clowns	-	-	-	-
PLANNING				
8 Mazes				
Completed	**<.001**	**.007**	.535	7 < 9-12
Total Time	**<.001**	.238	.290	7 < 11; 8 < 11
Impasses	**<.001**	.110	.930	7 < 9-12; 8 < 9-12
Scripts				
Time	**<.001**	**.038**	.879	7 < 9-12; 8 < 11
Sequence error	**<.001**	.178	.661	7 < 10-12; 8 < 10-12
Intruder	**.005**	.740	**.007**	8 < 10-12
Rey Complex Figure				
Planning Index	**.016**	**.014**	.959	7 < 9; 7 < 11

Table 5 Gender and type of school effect on EF variables

	Gender							Type of school						
	Girls N=116		Boys N=114		Gender effect			Public N=116		Private N=114		Type of school effect		
	M	SD	M	SD	F	*p*	η 2	M	SD	M	SD	F	*p*	η 2
INHIBITION														
Stroop														
Time	106.7	51.6	99.6	60.0	.566	.453	.003	108.3	55.7	98.5	55.6	1.194	.276	.006
Errors	4.0	5.2	3.1	4.5	1.407	.237	.007	4.3	4.9	2.9	4.8	6.647	**.011**[A]	.034
Tapping														
Go/No-Go Time	2.4	8.5	4.0	9.9	2.066	.152	.010	4.3	10.4	2.1	7.8	.374	.541	.002
Go/No-Go Error	1.1	1.6	1.2	1.7	.001	.970	.001	1.5	1.9	0.9	1.2	6.354	**.012**[A]	.030
Conflict Time	22.0	12.4	21.3	12.7	.406	.525	.002	22.9	13.2	20.4	11.9	1.186	.277	.006
Conflict Error	2.0	2.5	1.9	2.4	.902	.343	.005	2.3	2.7	1.5	2.1	2.2	**.020**[A]	.027
Cross-out Joe														
Time	776.5	240.5	779.6	266.1	.021	.884	.001	802.6	225.7	753.8	275.2	2.835	.094	.016
Imprecision	22.5	22.9	21.2	19.5	.136	.713	.001	23.5	22.9	20.1	19.4	.298	.586	.002
FLEXIBILITY														
Kid Card Sorting test														
Time	243.2	84.2	245.8	86.9	.023	.879	.001	249.3	87.1	239.7	83.7	.460	.498	.002
Perseverations	5.7	4.2	6.1	4.2	.719	.398	.004	6.5	4.0	5.4	4.3	5.132	**.025**[A]	.025
Trial Making Test														
Alternance Error	0.3	0.7	0.3	0.8	.642	.424	.003	0.4	0.8	0.2	0.6	.905	.343	.005
Flexibility Index	43.7	41.5	36.3	39.8	.018	.894	.001	40.6	44.0	39.6	37.5	2.693	.102	.013
Frog Test														
Time	281.4	93.0	249.4	80.0	7.533	**.007**[B]	.039	274.2	95.6	257.3	79.3	1.030	.311	.006
Score	54.0	10.4	56.1	8.5	2.673	.104	.013	54.0	9.7	55.9	9.3	1.883	.171	.009
WORKING MEMORY														
Verbal updating														
Baseline	20.5	3.8	21.0	4.8	1.158	.283	.006	19.7	4.1	21.7	4.3	12.228	**.001**[A]	.061
Performance score	35.6	7.9	35.5	7.3	.941	.334	.007	34.0	6.6	37.0	8.1	2.138	.146	.017
Visuospatial updating														
Baseline	25.6	3.0	24.6	3.4	5.803	**.017**[G]	.029	24.4	3.6	25.8	2.6	8.003	**.005**[A]	.039
Performance score	23.7	9.5	25.1	11.0	.222	.638	.001	22.9	10.7	25.9	9.5	2.204	.139	.013
Double Task														
Evolution digit span	98.6	40.6	93.3	63.2	2.536	.113	.013	89.6	38.7	102.4	63.4	1.367	.244	.007
Evolution clowns	99.1	17.3	96.1	15.6	5.493	**.020**[B]	.027	99.1	18.0	96.1	14.9	4.074	**.045**[A]	.020
PLANNING														
8 Mazes														
Completed	6.7	1.3	7.0	1.1	5.795	**.017**[B]	.029	6.7	1.3	7.0	1.1	3.153	.077	.016
Total Time	107.5	45.9	98.3	41.3	5.077	**.025**[B]	.027	110.2	49.6	95.2	35.4	5.802	**.017**[A]	.031
Impasses	0.2	0.2	0.3	0.2	2.400	.123	.013	0.3	0.2	0.2	0.2	.067	.796	.001
Scripts														
Time	196.8	92.7	196.8	103.7	.107	.744	.001	215.4	118.9	177.5	65.5	5.838	**.017**[A]	.038
Sequence error	7.4	4.2	7.9	5.1	1.225	.270	.008	8.1	5.1	7.1	4.2	1.476	.226	.010
Intruder	0.3	0.7	0.3	0.8	0.001	.783	.001	0.3	0.8	0.2	0.7	2.306	.131	.015
Rey Complex Figure														
Planning Index	108.7	24.2	116.3	29.6	2.798	.096	.015	115.6	28.9	109.3	25.1	.996	.320	.005

Note. M= Mean, SD= Standard deviation, G= Girls had a higher mean value than boys, B= Boys had a higher mean value than girls, A= Private school children had higher mean values than public school children.

The age by gender interaction effect was also non-significant. Regarding type of school, results revealed a significant effect for the Stroop test *Errors,* Tapping *Go/No-Go Errors* and Tapping *Conflict Errors* variables. In both cases, private school children performed better than those from public school. Interaction between type of school and gender was significant only for *Imprecision* ($F(1) = 8.298$, p .004, ηρ2 = .046). However, post-hoc analysis did not show significant differences between groups. In addition, the age by type of school interaction effect was significant for Cross-out Joe *Imprecision* $F(5) = .298$, p .586, ηρ2 = .002 and *Go/No-Go*

Errors $F(5) = 6.354$, p .586, ηρ2 = .002. For the Cross-out Joe test, post-hoc analysis showed that 7-year-old children from private schools had worse results than 8 and 12-year old. Regarding *Go/No-Go Errors,* 7-year-old children from public performed poorer than 8, 9, 10 and 12-year-old from the same type of school and 8 to 12-year-old from private schools. The post-hoc analysis showed that children of 11 years old from private schools performed better than children at the same group age from public schools.

6.3.1.2. Flexibility

A significant age effect was observed in the totality of flexibility measures. In addition, all results presented a linear trend. A significant effect of gender in favor of boys was found only for Frog test *Time* $F(2) = 7.533$, p .007, ηρ2 = .039. Gender interaction with age and with type of school were non-significant. Regarding type of school, the analysis revealed a significant effect for NSCT. Public school children had worse scores than private school children. Age by type of school interaction effect was significant only for TMT *Flexibility Index* ($F(5) = 2.479$, p .033, ηρ2 = .060). Post-hoc analysis showed that children aged 7 from private school has worse scores than children aged 12 and 10 from public school and 12 years-old children from private school. Also, post-hoc analyses revealed that 8-year-old from public schools has performed worse than 10 and 12-year-old from the same type of school.

6.3.1.3. Working memory

A significant age effect was observed for the Verbal (*Baseline* variable) and Visuospatial updating (both *Baseline* and *Performance score* variables). These variables presented a linear trend in the means across age groups. Moreover, the *Baseline* variable showed a significant quadratic trend for Verbal and Visuospatial updating tasks. Analysis revealed a significant effect of gender in favor of boys for the Visuospatial updating (*Baseline*), and for the Double task (*Evolution clowns*). The age by gender interaction effect was significant only for the Double task (*Evolution clowns*). Post-hoc analysis showed that 12-year-old girls have lower scores than 7 and 9-year-old boys. In addition, interaction between gender and type of school was also significant for the Double task (*Evolution Clowns* variable). Post-hoc analysis revealed that public school girls have lower scores than public and private school boys, and private school girls. Type of school had a significant effect for Double Task (*Evolution clowns*), Verbal and Visuospatial updating (*Baseline*). Public school children had worse performances than private school children. Age by type of school interaction was significant for Verbal updating (*Performance score*). However, post-hoc analysis did not show significant differences between groups.

6.3.1.4. Planning

The analysis revealed a significant effect of age for all planning measures. We found a linear improvement with age in results for all variables. In addition, a significant quadratic trend was also observed for 8 Mazes (*Completed* variable), Script (*Time* variable) and ROCF (*Planning index*) tests. A significant cubic trend was also found for the Script test (*Intruder* variable). A significant effect of gender in favor of boys was found for Mazes (*Completed* and *Total Time* variables). In addition, the age by gender interaction effect was non-significant, as well as the gender by type of school interaction. The type of school effect was significant for Mazes *Total Time* and Scripts *Time*. In both cases, private school children performed better than those from public school. Furthermore, the age by type of school interaction effect was non-significant

5.3.2. Factor analysis and correlations between EF components

Concerning the exploratory factor analysis, Table 6 presents the factor loadings with oblimin rotation. This analysis was conducted with caution in view of the small number of children in the sample. Four factors emerged: tasks known to be related to inhibition (Stroop, Tapping Go/No-Go, Tapping Conflict) were represented by the first factor; one task related to inhibition (Cross-out Joe) and other related to WM (Double tasks) were explained by the second factor; two WM tests (Verbal updating and Visuospatial updating) and one flexibility test (TMT) were captured by the third factor; and the other scores related to flexibility (Frog test and KCST) and planning (ROCF, Mazes and Scripts) were represented by the fourth factor. We chose to name Factor 1 as ‘‘Interference’’, Factor 2 as ‘‘Distractor inhibition’’, Factor 3 as “Working Memory” and Factor 4 as ‘‘Flexibility and Planning’’. It should be noted that the variables that constitute Factor 2 include measures of both WM (Double task) and inhibition (Cross-out Joe), while Factor 3 includes a flexibility task (TMT).

In order to evaluate correlations among CEF-B tasks, we performed several correlation analyses between the scores (Table 7). Results show that inhibition measures are significantly correlated, with the exception of Tapping Go/No-Go and Cross-out Joe. Similarly, flexibility measures are also significantly correlated, with the exception of the KCST and the frog test. WM tasks also presented significant correlations for verbal and visuospatial updating; although the double task did not correlate with them. On the other hand, planning measures did not correlate with each other.

It is important to note that the measures from one component also correlated with other components. In this perspective, the Cross-out Joe and KCST were the tests that most correlated with tasks from other theoretical components. Cross-out Joe correlated with 2 flexibility measures (KCST and TMT), all WM tasks and one planning measure (8 Mazes). Meanwhile, the KCST correlated with the 3 inhibition tasks, 2 WM measures (Verbal and visuospatial updating), and all planning tests.

Table 6 Factor analysis pattern matrix for CEF-B tasks

	Factor loading			
	1 (Motor & cognitive INH)	2 (Distractor INH)	3 (WM)	4 (FLEX & PLAN)
Stroop	-.53			
Tapping Go/No-Go	-.71			
Tapping Conflict	-.76			
Cross-out Joe		.72		
Trail Making Test			.47	
KCST				.55
Frog test				.52
Double task		.84		
Verbal updating			.56	
Visuospatial updating			.70	
Mazes				-.40
ROCF				.64
Scripts				.79

Note. Values less than .40 were exclude.

Table 7 Correlation between CEF-B tasks

	Inhibition				Flexibility			Working memory			Planning		
	Stroop	Tapping Go/No-Go	Tapping Conflict	Cross-out Joe	Trail Making Test	KCST	Frog test	Double task	Verbal updating	Visuospatial updating	Mazes	ROCF	Scripts
Stroop	1												
Tapping Go/No-Go	.15*	1											
Tapping Conflict	.19**	.34**	1										
Cross-out Joe	.20**	.09	.15*	1									
Trail Making Test	.14	-.02	.15*	.19**	1								
KCST	.15*	.11	.19**	.29**	.19**	1							
Frog test	-.07	.04	-.04	-.06	-.19**	-.05	1						
Double task	-.02	-.01	-.02	.20**	.01	.09	.01	1					
Verbal updating	-.14	-.10	-.02	-.18*	-.12	-.18*	-.13	-.14	1				
Visuospatial updating	.22**	-.09	-.14	-.27**	-.15*	.27**	.18*	-.07	.26**	1			
8 Mazes	.17*	.16*	.16*	.34**	.13	.27**	-.13	.14	-.34**	-.30**	1		
ROCF	.02	.15*	.03	.13	.04	.22**	-.08	-.10	-.07	-.15*	.12	1	
Scripts	-.07	.10	.17*	-.04	.08	.17*	.07	-.13	-.09	-.06	.12	.04	1

Note. *= p <.05; **= p <.01

On the other hand, other measures were weakly correlated with tests that do not belong to their theoretical grouping, such as Frog test (only one significant correlation with visuospatial updating), Tapping Go/No-Go (significant correlation with 8 Mazes and ROCF) and Stroop (significant correlation with Visuospatial updating, KCST and 8 Mazes).

6.4. Discussion

The main objective of this study was to investigate the developmental trajectories of four EF: inhibition, cognitive flexibility, WM, and planning. Furthermore, this study aimed to assess the potential effects of two demographic factors (gender and SES) in the development trajectories and present an initial analysis of the structure and organization of EF in Brazilian children.

Regarding the developmental objective, the analyses of the age effect on inhibition measures revealed a linear improvement in results for all inhibition variables. Our results are consistent with those found in other Brazilian versions of Stroop conducted with children between 7 and 10 years old (Charchat-Fichman & Oliveira, 2009) and adolescents between 12 and 14 years (Duncan, 2006), which also presented a linear downward trend with age for time and errors. In addition, the reduction of the Stroop effect with age is also consistent with studies conducted with 7 to 12-year-old children in America (Mexico - Armengol & Méndez, 1999; United States - Adleman et al., 2002; Davidson et al., 2006), Europe (Sweden - Brocki & Brolin, 2004; France - Roy et al., 2018), Africa (Tunisia - Bellaj et al., 2015) and Asia (China - Xu et al., 2013). This finding supports the idea of an active development of EF during childhood (Best & Miller, 2010). Also, regarding the Tapping test, previous Brazilian studies with similar Go/No-go paradigm also showed an improvement in speed and in the amount of errors committed by the children (Charchat-Fichman & Oliveira, 2009; Salles et al. 2016).

Developmental data on WM revealed a linear and quadratic trend increase on verbal and visuospatial updating tasks for the *Baseline* variable. Also, we found a significant linear trend for the variable *Performance score* of visuospatial updating. Our results are consistent with other Brazilian studies that used different paradigms, but aimed to evaluate the cognitive load of a verbal or visuospatial task (Santos et al., 2005; Weschler, 2013). They are also in consonance with findings from international literature that aimed to evaluate verbal and visuospatial WM skills (Best & Miller, 2010). It is important to note that the significant effect of age was found only for the visuospatial component of the updating task. One possible explanation for this result is associated with a poorer baseline performance found for the verbal task if compared to its visuospatial version. In fact, the baseline represents a cut-off point for performing the update task, and consists of retaining the maximum number of items presented by the examiner. The authors established that the cut-off point for the visuospatial component should be 15 points (out of a maximum of 30), while for the verbal component the cut-off point should be 18 (out of a maximum of 30) (Roy et al., 2020). These different threshold values were defined based on the studies by Yue et al. (2008), which indicated a better performance in verbal short-term memory skills than in spatial ones.

However, these assumptions did not seem to be pertinent in the Brazilian context, since we find poorer verbal baseline performance if compared to visuospatial baseline performance, especially in public school children. In fact, 53 children scored less than 18 in the verbal updating task while only 8 children did so in the visuospatial updating task. If we set the cut-off point to 15, this number reduces to 18 children for the verbal updating task, and only one child for the visuospatial component (as currently calculated). Thus, only the most performant children had their scores accounted for at the updating stage of the test. Therefore, it seems appropriate to consider an adjustment of the cut-off point of the verbal baseline in order to match it with the visuospatial version.

Furthermore, the type of school factor also plays an important role in the interpretation of these results. They show that the scores of children from private schools improve with age, while the performance of children from public schools tends to be stable. To support this finding, we conducted complementary comparison analysis to investigate possible differences in the performance of children from private and public schools on the Vocabulary (verbal competences) and Matrix reasoning (spatial perception, visual and abstract processing) subtests of the Wechsler Intelligence Scale for Children (WISC-IV). We found a significant difference for Vocabulary ($p < .001$), with public school children performing poorer than private school children, while for Matrix reasoning the comparisons were non-significant ($p < .103$). This result is consistent with the current literature that reports the impact of SES on cognition, especially language skills. Numerous studies show that the verbal abilities of children from disadvantaged socio-economic backgrounds are poorer than those of children from privileged backgrounds (Johnson et al., 2016; Merz et al., 2019). These results represent a measurement bias and an adaptation issue for the Brazilian context that must be reconsidered in future studies.

In addition to verbal and visuospatial updating tasks, we proposed the evaluation of WM in double condition. Dual-task paradigms involve performing two tasks separately first, and then simultaneously. The difference in performance between each separate task and the dual-task condition provides an indicator of dual-task ability (Della Sala et al., 2010). Thus, two variables were used to access WM skills in double condition

(Evolution digit span and Evolution clowns) and no significant age effect was found. The absence of this effect can be explained by the fact that this variable is adjusted to age. In fact, the first part of the Double task consists of defining the child's baseline through a span score. This baseline represents the level of difficulty of the task, which is determined by the child abilities' and corresponds to the maximum number of sequential digits that the child can remember without committing an error. Thus, difficulty levels differ according to individual variations, but also according to age given the improvement in auditory spam memory (Baddeley et al., 1997). These particularities of the Double task may have minimized a potential age effect on this task.

Regarding flexibility measures, analyses of the age effect revealed a significant difference between groups and a linear trend for all tasks. For the KCST, older children tend to complete more categories and be more agile in performing the task, as shown in previous studies performed with the Wisconsin Card Sorting test (Chelune & Baer, 1986; Heaton et al., 2007). Concerning both variables of the Frog test, results revealed a significant overall improvement with age, as evidenced in similar tasks (Burgess & Shallice, 1997). In general, behavioral profiles of the performance of Brazilian children in flexibility tasks show that the increase is more evident when comparing performances between the oldest (10-12 years) and the youngest children. Older children were faster and more precise in performing the task, which is used worldwide and has many variants.

Concerning planning skills, developmental data revealed a linear increase in performance on the Mazes, ROCF and Scripts tasks. Additionally, a quadratic (Mazes - *Completed;* Scripts - *Time*; ROCF – *Planning Index*) and cubic (Scripts – *Intruder* variable) trend was also observed, revealing a propensity to spurts or developmental peaks. Performance profiles of Brazilian children in planning tasks show that the strategies used to complete the test depend on its nature and on the child's age. For example, concerning the ROCF planning index, two peaks of improvement seem to emerge at 9 and 11 years of age. On the other hand, Script and 8 Mazes tasks seem to present gradual improvement profiles with differences between the ages of 9 to 12 and the age group of 7. Studies that used different assessment paradigms, but aimed to evaluate planning skills for visuospatial and verbal paradigms also showed a similar improvement profile (Marquet-Doléac et al., 2010; Rey, 2009; Wechsler, 2003). These studies showed that planning skills improved with age, although they suggest different peaks in maturity, that occur mainly in adolescence. In this sense, our data would only represent the early maturation of this function at school age and should be extended to include the adolescent population.

Regarding the effect of other demographic variables studied, our results showed that the comparison between gender and executive measures did not reveal a significant difference for Brazilian children, except for the Visuospatial updating task, Double Task, Frog test and 8 mazes. These findings are consistent with data in the literature which show no or little gender effects on executive development (Anderson, 2002; Brocki & Bohlin, 2004; Lee et al., 2013; Xu et al., 2013). Our results are also consistent with Brazilian data which showed that this factor has little influence on EF (Hazin et al., 2016; Magalhães et al., 2016). These results support the idea of a global performance equivalence between girls and boys regarding EF (Brocki & Bohlin, 2004; Lehto et al., 2003). However, it should be noted that the significant results are all in favor of boys, although they were found in only four of the 12 tasks. In addition, interactions between gender and type of school for Double task (Evolution clowns) revealed that public school girls have lower scores than public and private school boys, and private school girls. These gender results show that girls in vulnerable situations are at a disadvantage if compared to boys, which was previously demonstrated in international reports and studies (Qadir et al., 2011).

Regarding the effect of SES on executive development, we found a significant effect on 8 tasks (Stroop – *Error*; Tapping – *Go/No-Go Error* and *Conflict Error*; KCST – *Preservation*; Verbal and Visuospatial updating - *Baseline*; Double task – *Evolution clowns*; Scripts – *Time*; Mazes – *Total time*). It is important to mention that all executive components were accounted for and all results were in favor of private school children. Our findings are in accordance with the literature regarding the beneficial effect of a favorable SES on executive development (Farah, 2017; Johnson et al., 2016; Lawson et al., 2017). Additionally, other Brazilian studies have also found differences in favor of higher SES regarding inhibition, WM and decision-making skills (Hazin et al., 2016; Magalhães et al., 2016; Mata et al., 2013; Sallum et al., 2017). Our study also highlights the impact of socioeconomic disparities on the development of cognitive flexibility and planning skills.

An exploratory factorial analysis and several correlation analyses were performed in order to preliminarily analyze the structure of the executive development in our sample and to examine the theoretical grouping considered in the CEF-B. We found a 4-factor structure, which matches the theoretical distribution proposed by the battery. However, the organization of the tasks in the components did not fully correspond to our initial expectations. Factors were named as follows: factor 1 ‘‘Interference’’, factor 2 ‘‘Distractor inhibition’’, factor 3 “Working Memory” and factor 4 ‘‘Flexibility and Planning’’. Indeed, factor 1 and 3 are similar to the classification originally designed by the authors of CEF-B, and correspond essentially to tasks of inhibition and WM, respectively. On the other hand, factor 2 correspond to a combination of inhibition and WM tests.

Evidences in the literature on the development of EF in children suggest that inhibition and WM are the first components to differentiate (around 5-6 years of age) during development (Diamond, 2013; Lee et al., 2013); this might explain the clearer grouping of inhibition and WM tasks in factor 1, 2 and 3. Regarding the fact that factor 2 includes measures of both WM (Double task) and inhibition (Cross-out Joe), we believe that the association of the Double task with an inhibition factor is related to an important maintenance of attentional resources to perform two tasks simultaneously, requesting distractor inhibitions skills. Similarly, the long duration of the Cross-out Joe task also demands an important maintenance of attentional resources, requesting distractor inhibitions skills. On the other hand, the association of TMT with WM tasks (factor 3) could be related to the major requirement of keeping both the letter and number sequences in mind and alternating between them, which could indicate the use of WM skills. In general, the first three components encompass the two most basic EF skills, while factors 2 and 3 also represent their interdependent nature.

Factor 4 grouped flexibility and planning tasks. There are two main explanations for this result. First, the flexibility and planning components are the last to differentiate themselves according to the developmental logic (Diamond, 2013). Studies show an improvement in flexibility and planning skills from 10 to 12 years and in adolescence (Anderson et al., 2001; Brocki & Bohlin, 2004; Lee et al., 2013) In this sense, it is important to consider that the age limit of 12 years in our sample may have contributed to the clustering of flexibility and planning tasks, since these components would only differentiate themselves later in development. In this sense, expanding the sample to include adolescents is essential in order to assure analyses that are more consistent with the development of these complex functions. Another explanation is associated with the fact that flexibility and planning, especially, are complex tasks, and may have been grouped together because of their complexity.

Concerning correlation analysis, inhibition measures were significantly correlated among themselves, with the exception of Tapping Go/No-Go and Cross-out Joe. Similarly, flexibility measures were also significantly correlated among themselves, with the exception of the KCST and the frog test. Regarding WM tasks, verbal and visuospatial updating were significantly correlated but the double task did not correlate with them. On the other hand, planning measures did not correlate with each other. Results of the correlation analysis corroborate with the findings of the factorial analysis, which better differentiated inhibition and WM if compared to flexibility and planning. However, these results also diverge from those found by the factor analysis by not differentiating a flexibility factor. Overall, they are consistent with factorial studies and theoretical modelling in children that consider inhibition, WM and flexibility the main basic components of EF (e.g., Diamond, 2013; Lehto et al., 2003).

There are some limitations to our study that should be addressed in future researches. Firstly, the sample size does not allow normative data to be used in clinical settings and does not allow for generalization to the Brazilian context (see Guerra et al., 2020 for a review). In addition, analyses of the structure and organization of the EF can only be conducted as an initial approach. A series of methodological considerations must be taken into account regarding the factorial analysis. Firstly, our sample was reduced to 144 subjects because children missing one or more measurements needed to be excluded from the sample to meet the method's requirements. In addition, the entire sample was composed of children with typical development. The lack of children with clinical conditions reduces the discriminating power of the analysis since the variance of measurements in children without pathologies is limited. Finally, the variables selected to be used in the factorial analysis corresponded to the indicators of the best child performance per task. Although it is an interesting approach that favors the best strategy used by the child when performing the task, it would be more interesting to dispose of the vulnerability score which consists of an average of low scores. In this case, however, normative data would be required in addition to clinical data, which was not possible at this stage of the research. Thus, the sample should be expanded considering Brazil's social disparities and the tests should be submitted to other stages of psychometric validation. In addition, studies comprising different clinical conditions should also be carried out in order to test the sensitivity of the battery and to assure its clinical validity.

To conclude, this study reveals a dynamic developmental progression in all EF assessed by CEF-B tasks in Brazilian children from the northeast region. While gender seem to have little impact on EF development in our sample, the impact of SES on children's performances confirms the influence of poverty on the development of EF. Thus, the findings of our study highlight the urgent need to design consistent public policies that stimulate children development in vulnerable and disadvantaged populations. In addition, health and education professionals need to consider these differences in the development trajectories of EF and provide stimulation strategies that promote the development of children from unfavorable contexts. Although normative data are still lacking in Brazil, we believe that the next stages of this research will allow a better understanding of the trajectories of EF both in typical and atypical development. Also, these future data will provide clinical neuropsychologists with an improved theoretical basis for child executive development and tools for identifying executive disorders.

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7. Study 3: The Brazilian version of the FEE protocol: evidences of validity and reliability

Article under review in Psicologia: Reflexão & Crítica (QUALIS:A1; SCIMAGO: Q3)

Guerra, A., Hazin, I., Roulin, J., Le Gall, D., Roy, A. (Under review). Evidences of reliability of the Brazilian version of the Child Executive Functions Battery (CEF-B). *Psicologia: Reflexão & Crítica.*

Abstract

Dysfunctions in executive functions are central symptoms in different neurological, developmental and context-related conditions. The assessment of these functions is then essential in neuropsychological pediatric clinical practice. Given the need for reliable and valid evaluation batteries for clinical practice in Brazil, this study aimed to present the proofs of reliability of the Child Executive Functions Battery (CEF-B). A total of 230 Brazilian children with typical development aged between 7 and 12 years participated in the study. Internal consistency was determined by the Split-half method, Cronbach's α and Ω. In addition, measurements of test-retested reliability and intraclass coefficient were also performed Retest indicators were mostly moderate and strong (between .43 and .75). Coefficients show internal consistency overall satisfactory reliability for planning and inhibition measures (between .72 and .92). Considering the measures of WM, results were also satisfactory for both α and Ω indexes. This study revealed that the CEF-B has satisfactory retest and internal consistency reliability coefficients. These findings suggest that the adapted version of the battery has good proofs of reliability which endorses the use of CEF-B for assessing EF in the Brazilian context. Future investigations will provide clinical neuropsychologists with an improved theoretical basis for child executive development and tools for better identifying executive disorders in the pediatric population.

Key-words: executive functions, child, neuropsychological assessment.

7.1. Introduction

The scientific advancement of child neuropsychology allowed the identification of numerous contexts of brain vulnerability that represent risks of cognitive and behavioral disorders during childhood. Acquired brain injuries, congenital, neurodevelopmental and neuropsychiatric disorders constitute clinical conditions with potential risk for early neuropsychological dysfunctions. In addition, social and cultural conditions such as maternal nutrition, abuse of alcohol and other drugs by the mother during pregnancy, inadequate living conditions, physical violence and sexual abuse, among others represent potential risk conditions for developmental dysfunctions. These clinical settings greatly impact executive functions (EF) as central symptoms (Craig et al., 2016; Evinç et al., 2018; Lonergan et al., 2019; Mauger et al., 2018; Zelazo, 2020). In fact, the early and prolonged physiological maturation of the prefrontal circuits involved in the development of EF imposes a substantial vulnerability to these high-level skills (Denis, 2006). Since these functions are essential to behavioral control and regulation skills, their efficient functioning provides a fundamental basis for psychological development, including cognition, emotions and social interactions (Diamond, 2013). Thus, the identification of early changes on EF in the pediatric population constitutes a substantial clinical and scientific issue.

Performance-based tests are still the most usually method for the assessment of EF in children. They provide a standardized and structured evaluation framework that is relatively objective and easy to operate. Over the last twenty years, numerous performance-based tests have been developed or adapted around the world. However, the influence of historical, social, and cultural factors on the emergence of EF in children demands particular considerations when using tests. In Brazil, it is particularly important to consider these aspects because it is a country with a remarkable cultural variability and socioeconomic inequality (Piccolo et al., 2016).

A recent systematic review identified 37 executive measures used in Brazil in the pediatric context (Guerra et al., 2020). Despite the great variety of tests found, only 13 are allowed to be used in clinical practice by the Federal Council of Psychology. In addition, only eight correspond to measures especially designed for the assessment of EF in children. The remaining five correspond to tests created for the assessment of EF in adults that had their sample expanded for the evaluation in children, without considering the dynamic aspects of executive development. Also, researches that considered at least the three basic executive components are scarce and, to date, no specific battery for assessing EF in Brazilian children is available (Guerra et al., 2020).

Measurement errors in executive tasks represent another concern that is still often neglected in child evaluation (Van der Linden et al., 2000). The inevitable participation of more basic skills in executive tasks necessarily makes them "impure", and requires (i) the use of dissociate methods to differ basic skills from executive ones and (ii) to ensure the executive nature of the difficulties encountered by confronting various tasks requiring different non-executive processes (Denckla, 1996). This inherent "noise" in executive measures is enhanced in child assessment since the non-executive processes are potentially under development and contribute to age-related variations (Roy et al., 2017). These variables highlight the importance of using appropriate and reliable executive measures for children to meet the objectives of neuropsychological assessment and reduce potential risk of false positives and false negatives in clinical practice (Guerra et al., 2020).

In order to overcome the aforementioned assessment challenges, the Child Executive Functions Battery (CEF-B) was created in France to overcome the scarcity of instruments adapted for the pediatric population (Roy et al., 2020). The CEF-B consists of a set of 12 performance-based tests aimed at children and adolescents between 6 and 16 years old. The battery is based on a child-centered theoretical model and assesses the main executive processes: inhibition, flexibility, working memory (WM) and planning (Diamond, 2013). It comprises new experimental tasks and tests that already exist in the international literature but have been modified or expanded to better attend the pediatric population. Each component (inhibition, WM, flexibility and planning) is represented by three tests, which are assumed to preferably capture the corresponding dimension. However, this task affiliation is not exclusive because of the interdependent character of EF. One verbal test is proposed per component, while the others are predominantly nonverbal (and mixed, in the case of WM). This approach was conceived in order to cross-reference indicators and provide clinicians with appropriate tests in the case of communication, visuospatial or gestual disorder (Roy, 2015).

The design of a battery specially conceived for children aroused the interest to develop a larger cross-cultural project. Thus, an intercultural dynamic approach has been consolidated with several countries, including Brazil. Given the shortage of EF test batteries based on specific children theoretical models in Brazil, CEF-B was adapted to the Brazilian context (Guerra et al., 2020). However, the adaptation of a test is only the first step to its implementation into a new culture (Borsa et al., 2012). A crucial point regarding the scientific approach of neuropsychological measures is associated with psychometric validity and reliability. These characteristics refer to the legitimacy of the interpretations provided by the test result and the empirical evidence regarding the correspondence between theoretical expectations and the measurement itself (Muniz, 2004).

Regarding the CEF-B, preliminary evidence of validity of the French version has been published for studies with children with typical development (Roy et al., 2018), and with different clinical conditions, such as neurofibromatosis type 1 – NF1 (Remigereau et al., 2018; Roy et al., 2010, 2014), parietal temporal and frontal epilepsy (Charbonnier et al., 2011) and brain tumors (Roche et al., 2018). These initial data indicate a good sensitivity of the battery for the evaluation of EF in pediatric populations. Good developmental validity was found for the Stroop test ($F (5, 108) = 10.42$, $p < .001$). In addition, a good clinical sensitivity was observed through significant statistical differences between clinical and control groups for Rey Osterrieth Complex Figure ($F 1,69 = 6.889$, $p = .011$ – for the NF1 group and Z score = 2,89 for frontal epilepsy case) and for the Kids Card Sorting Test ($p= <.001$ for the NF1 group).

Concerning the Brazilian version, a good overall developmental validity was observed between 7 and 12 years-old children (Guerra et al., considered for publication). A 4-factor EF structure was also found through an exploratory factorial and correlation analysis, that corroborate with the theoretical assumption considered in the CEF-B. The same study showed a sensitivity of CEF-B to identify the impact of low socioeconomic status on executive development, which agrees with the current literature (Farah, 2017; Merz et al., 2018). This study on the trajectory and structure of the EF in the pediatric population of northeast Brazil presents initial evidence of validity which endorses the theoretical and methodological premises of CEF-B. However, given the relevance of providing numerous indicators which attest the importance and utility of a test, we propose to evaluate complementary and different proofs of reliability of the CEF-B in Brazil.

7.2. Method

7.2.1. Participants

A total of 230 Brazilian children with typical development aged between 7 and 12 years participated in the study. The sample was homogeneously distributed by age, gender and type of school (Table 1). Participants were selected based on the following inclusion criteria: a) signing of the informed consent form by parents and/or legal guardians; b) regular registration in public or private school; c) absence of a history of developmental, neurological or psychiatric disorders; d) absence of uncorrected sensory alterations; and e) scaled score equal or higher than seven points in the WISC-IV Matrix Reasoning and Vocabulary sub-tests.

Table 2 Sociodemographic data

	Descriptive
N	230
Age mean (SD)	9.95 (1.65)
Age range	7-12
Gender (%)	
Girls	116 (50.4)
Boys	114 (49.6)
Type of school (%)	
Public	116 (50.4)
Private	114 (49.6)

Note. SD standard deviation, % percentages (frequencies)

7.2.2. Materials

Table 2 presents a brief description of the 12 tests and variables measures that compose the CEF-B. The order of application of the tests that integrate the protocol was defined in a systematic and pseudo-random manner, alternating the investigated executive skills and their verbal/non-verbal nature. In order to limit measurement errors, the variables of the CEF-B were designed to modulate the executive load involved in some multicomposite tests. This approach consists in providing "control" conditions which are supposed to be less demanding on executive processes (i.e. subtracting the

Trails A score from Trails B score to “isolate” the contribution of executive abilities in the Trail Making Test; Arbuthnott & Frank, 2000).

7.2.3. Procedure

The study was conducted in 14 public and private schools in Natal, Parnamirim and Elói de Souza in the Rio Grande do Norte state. The project was submitted to and approved by the Research Ethics Committee of the Federal University of Rio Grande do Norte, under code 48383715.1.0000.5537. After the Informed Consent Term was signed by legal guardians, children were evaluated using the Vocabulary and Matrix Reasoning subtests in a single session lasting approximately 20 minutes at the school itself and during the regular school term.

All participants were individually evaluated in a quiet room in their school or home environment. The tests were administered by trained neuropsychologists using standardized instructions. The assessment of the children consisted of the application of the entire CEF-B, requiring two or three assessment sessions with a duration of approximately 30–40 minutes each, depending on the age of the child. The tests were systematically presented in the same order. The first session included: 8 Mazes, Stroop, Visuospatial updating, Scripts and Tapping tasks. The second session contemplated the Rey Complex Figure, Trail Making Test, Double task, Kid Card Sorting test, Cross-out Joe, Verbal updating test and Frog test. In case an additional session was needed, four tests were presented per session in the aforementioned order.

Table 2. Description of CEF-B tests and scientific rationale for controlling measurement errors and methodological bias

	Tests	Description/Objective	Proposals for measurement errors and methodological biases control
Inhibition	Stroop	Consists of ignoring the reading of colored words written with non-congruent printing ink (for example, "blue" written in red), to focus on the color of the ink (interfering condition)	-Preliminary control conditions (naming and reading) -Unlimited time, no mistake correction, consideration of time and errors
	Tapping	Tap or not on the table depending on what the examiner is doing: (1) Go/no go: respond if the examiner types once and inhibit if he types twice. (2) Conflict: antagonistic conditioning (tap once if the examiner taps twice and vice versa) while incorporating a new No go condition (do not tap if the examiner taps with two fingers)	-Preliminary phase of simple conditioning (repeat a motor action in echo)
	Barre-Joe	Identify and cross out a visual target (Joe) among several morphologically similar distractors	-Evaluate inhibition in a long-term task
Working Memory	Verbal updating	Sequentially recall the most recent elements (the last three or four) of a series of letters of varying length	-Task adjusted to span capacities. -Variation in the amount of information to be updated to control the executive load (contrasted with items where no update is required)
	Visuospatial updating	Sequentially recall the most recent items (the last three or four) touched in a series of blocks of varying length	
	Double task	Simultaneously perform a figure span task and a visuomotor clown head crossing test	- Preliminary execution of both tasks individually - Task adjusted to span capacities
Flexibility	TMT	Connect circles on a sheet of paper that contain numbers or letters, alternating numeric and alphabetical order (1-A-2-B...).	- Control of numerical and alphabetical chain mastery, visual exploration and perceptual-motor skills in two preliminary parts (numbers then letters, respectively)
	KCST	Initiate, maintain and change the ranking rule of a series of 48 test cards according to 4 target cards that vary in three dimensions (form, color, number), based on the examiner's feedback	-Only cards that are unambiguous regarding the pairing with the target cards are used - The rules are presented to the child, which reduces the possibility of not understanding the categories
	Frog test	The child must deduce the logical rules according to which a frog moves around several water lilies disposed in a lake. The child must also adapt to the actions of the frog, which changes the movement rule without previous warning.	- Random and variable rule change to make the test less predictable
Planning	Scripts	The child must put in order a sequence of phrases, elaborating a coherent script according to a given title and disconsidering those that are not relevant (intruders)	-New task created to evaluate the child's ability to anticipate the order necessary for the execution of a daily action
	ROCF	Copy the ROCF spontaneously and progressively recopy the figure according to a program consisting of five successive stages of different colors.	-Measurement of the facilitating effect of copying with the program in contrast to spontaneous copying -Rigorous and objective instructions for the evaluation of the precision and location of the figure elements
	8 Mazes	The test comprises eight mazes of increasing difficulty. For each maze, a dinosaur has to find its way out. The test requires the child to draw, with a pencil, the path connecting the starting point to the maze’s exit.	-Consider time and error

The second phase contemplated the tests that were selected for the retest method. This step was carried out 4 to 6 weeks after the last assessment session of the child. One 40-minute session was required to perform the 6 CEF-B tasks that were retested, which were administered in the following order Stroop, Tapping, Kid Cards Sorting Test, TMT, Double task and Frog test.

7.2.4. Statistical Analyses

The reliability of the CEF-B was verified by several methods. The retest was applied for all flexibility measures, two inhibition measures (Stroop and Tapping) and one WM test (Double task). Correlation was calculated by the Spearman–Brown's Rho prediction formula (Spearman's Rho). The three planning tests, the Cross-out Joe and the two updating tasks were not considered for retest due to their nature.

In the cases of the Scripts, the 8 Mazes and for Verbal and visuo-spatial updating tasks, two indicators of internal consistency (Cronbach's alpha and omega – Cronbach, 1951; Cho, 2016) were applied instead. Also, the split-half method (spearman-Brown correction in even and odd items) was used for the 8 Mazes test. Pearson's correlation was calculated for both parts of the Cross-out Joe test. Since part B of this test corresponds to the mirrored version of part A, the purpose of this measure was to demonstrate the equivalence of these two steps. To this end, we calculated the correlation between A-B (A being applied first, followed by B), and we calculated the correlation between parts when they were applied in the opposite order (B-A). Regarding Rey's Figure, an intraclass coefficient was calculated for three indices: the copy score, the program score and the planning index. For the calculation of this coefficient, four different examiners corrected the figures. All statistical analyses were performed using SPSS v.20.0 (IBM Corp., Armonk, NY, USA) and the R software (Core Team, 2013). For all analyses, the significance level was set at .05. Correlations between .20 and .40 were considered weak, between .40 and .60 were considered moderate and higher than .60 were considered strong (Hair Júnior et al., 2009).

7.3. Results

7.3.1. Test-Retest Reliability

Table 3 summarizes, by domain and task, the reliability index obtained with the Spearman-Brown prediction formula and the number of children for which it was calculated. The coefficients observed are occasionally weak (i.e. Tapping *Go/No-Go Time* - *r*=.18; Double task *Evolution clowns* – *r*=.23), but mostly moderate and strong (between .43 and .75).

Table 3. Reliability coefficients obtained through the test-retest method

EF	Test	Variable	N	*r*xx*
Inhibition	**Stroop**	*Time*	28	.53
		Error		.50
	Tapping	*Go/No-Go Time*	31	.18
		Go/No-Go Error		.43
		Conflict Time		.44
		Conflict Error		.43
Working Memory	**Double task**	*Evolution digit span*	31	.57
		Evolution clowns		.23
		Mu Score		.56
Flexibility	**TMT**	*Flexibility index*	28	.27
	KCST	*Time*	30	.60
		Categories		.59
		Perseverations		.75
	Frog test	*Time*	30	.43
		Score		.70

7.3.2. Split-half method, internal consistency and intraclass coefficients

The results obtained through the split-half method, internal consistency and intraclass coefficients are described in Table 4. Coefficients show overall satisfactory reliability for planning and inhibition measures (between .72 and .92). Considering the measures of WM, results were also satisfactory for both alpha and omega indexes.

Table 4. Reliability indicators using the split-half method, internal consistency and intraclass coefficients for planning, WM and inhibition tests

EF	Test	Variables	N	*r*xx*	alpha	*ωt*	ICC
Planning	Scripts	*Time*	171	-	.86	.86	-
	8 Mazes	*Time*	221	.76	.83	.83	-
		Errors	221	.86	.86	.87	-
	ROCF	*Spontaneous copy*	207	-	-	-	.92
		Copy with program	207	-	-	-	.86
		Planning index	207	-	-	-	.89
WM	Updating tasks	*Verbal updating*	150	-	.82	.84	-
		Visuospatial updating	195	-	.85	.86	-
Inhibition	Cross-out Joe	*Correlation A-B*	184	.77	-	-	-
		Correlation B-A	29	.71	-	-	-

Note. ROCF= Rey-Osterrieth Complex Figure; ICC= Intra Class Coefficients

7.4. Discussion

The aim of the present study was to present the additional psychometric properties of the CEF-B in a sample of 7-12 age children from Northeastern Brazil. Results revealed initial adequate proofs of reliability for the CEF-B for the assessment of EF in Brazilian children.

Different alternatives are reported in the literature to evaluate reliability (Gregory, 2010). It is currently suggested to use several methods that provide proof of the test’s reliability, similar to what is observed for validity. However, these various methods produce complementary but sometimes contradictory estimates. In executive tasks, the study of the reliability of measurements is complex because test-retests can affect the validity of the second measurement (Soveri et al., 2018). Also, analysis by internal consistency and split-half methods are in most cases not applicable. Finally, the examiner is sometimes an important source of measurement error, which means that reliability among examiners must also be calculated (Urbina, 2007).

To examine the evidences of reliability in the Brazilian CEF-B version, we used different methods that were employed according to the nature of each executive test. For tasks where the time factor was central to the accomplishment of the task (half of the tasks), the retest was applied. In general, a significant test-retest effect was observed on all tasks. These results indicate a good reliability of the measures evaluated by the retest method. The lowest values concern the Tapping task (r=.18), for which the results seem to be very dependent on testing conditions. In fact, this finding could be related to examiner bias, since the delay between the presentation of the stimulus and the children's response can vary between examiners. Another task that also seems to have problematic evidence concerns the Double task (*Evolution clowns* variable; r=.23). Results observed on the retest may reflect changes in strategies (prioritizing the motor task over the cognitive task and vice versa) that lead to indirect effects on reliability scores. The same reasoning is valid for the TMT index. It is important to note that this variation has also been observed in previous studies on the assessment of EF. In fact, when several EF tasks are administrated, performance in these tasks is often poorly correlated and reliability rates are low (e.g., Lemay et al., 2004; Soveri et al., 2018; Willoughby et al., 2017). This weak reliability, most often associated with the test-retest situation, is usually explained by the fact that these EF tasks are susceptible to a practical effect that partially distorts this assessment.

For tests in which it was possible to use different methods of reliability other than retest, we prioritized the use of classical methods such as split-half, internal consistency and intraclass coefficients. Regarding the reliability assessed through Cronbach's alpha and omega coefficients, satisfactory indicators were found for Scripts, 8 Mazes, and the updating tasks (between .82 and .87). According to the Brazilian Federal Council of Psychology (CFP, 2003; Primi et al., 2004), the minimal acceptable value for these indices is .60. In addition, some authors have suggested the following value classification: .80-.90, very good; .70-.80, respectable; .65-.70, acceptable; .60-.65 undesirable; below .60, unacceptable (Freire & Almeida, 2001). It is also important to note that the split-half method indicators for the 8 Mazes tests were also high, showing a good internal consistency of the task. The coefficients for Cross-out Joe were also acceptable, both under the A-B application order (r=.77), as well as under the reverse order (B-A; r=.71). This result also indicates an adequate internal consistency of the task.

Regarding the ROCF, reliability issues are mostly associated with the method of task correction. In fact, the correction of the task is often considered as subjective. In the CEF-B version of the test we adopted more rigorous and objective instructions for the evaluation of the precision and location of the figure elements drawn by the children. Thus, the agreement between examiners was measured by the interclass coefficient for the three measures of the test. Results showed a good consensus (.86 to .92) and indicate that a more rigorous and objective correction of the test may lead to more stable scores between examiners.

Some limitations of the present study should be addressed in future researches. Firstly, the lack of children with clinical conditions limits the investigation of the battery's sensitivity for the identification of EF perturbations. The study of psychometric properties contemplating different clinical conditions is essential to test the sensitivity of the battery and to assure its clinical validity proofs. Another limitation concerns the sample size and its generalization to the Brazilian context. In fact, Brazil's population and its social and economic diversity require a wider sample in order to assure the representativeness of its cultural diversity (see Guerra et al., 2020 for a review). Thus, the validity and reliability proofs investigated in the present study should be extended to be effectively considered as valid to the entire Brazilian context.

Conclusions

This study revealed that the CEF-B has satisfactory retest and internal consistency reliability coefficients. These findings suggest that the adapted version of the battery has good proofs of reliability which endorses the use of CEF-B for assessing EF in the Brazilian context. Although normative data are still lacking for other regions of Brazil, we believe that the next steps of this research will allow the clinical use of the CEF-B in several medical settings. These future investigations will provide clinical neuropsychologists with an improved theoretical basis for child executive development and tools for better identifying executive disorders in the pediatric population.

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8. General conclusion

The objective of this thesis was to perform a critical review of the available instruments of EF for clinical practice in pediatric neuropsychology, as well as to present psychometric evidence and initial normative data for the CEF-B in Brazil, while also investigating the developmental trajectories of EF in Brazilian children. Its relevance lies on the need to improve the understanding of the development of EF in children from different socio-cultural and economic contexts, specially due to the scarcity of Brazilian studies that contemplate a comprehensive approach of these functions in the pediatric population.

In this sense, this thesis promoted important discussions and improvements in the field of Brazilian neuropsychological assessment of children. In the first study, the existing shortcomings in the Brazilian scenario of neuropsychological assessment of EF in children were listed. Among the results obtained in this study, the scarcity of rating measures and instruments to assess flexibility and planning that are allowed for use in clinical practice was highlighted. Furthermore, the findings show a concentration of normative data on the South-Southeast regions of the country. These results reinforce the importance of regional normative data in countries with remarkable regional cultural variability, such as Brazil. Also, the findings suggest that normative data for neuropsychological tests in Brazil should consider cultural and socioeconomic differences.

In view of the findings of the first study, study 2 allowed a broader understanding of the impact of contextual variables, particularly SES, on the executive development of Brazilian children. Previous studies showed differences on executive development of children with different SES between Brazilian regions, rural and urban areas, and within the same city. These studies, however, only provided data regarding inhibition, WM and decision-making skills. This thesis presented data on those three skills but also included mental flexibility and planning functions, supporting the idea that the differences in SES would impact the overall executive functioning in the context of the Brazilian Northeast region. These findings highlight the urgent need to design consistent public policies that stimulate children development in vulnerable and disadvantaged populations. In addition, health and education professionals must consider these differences in the development trajectories of EF and must provide stimulation strategies that promote the development of children from unfavorable contexts.

It should be noted that the SES indicator used to access the different contexts of inequality used in this thesis was the type of school. This variable was chosen because it represents an actual space of social segregation in the Northeast region of Brazil. Children from low SES are usually enrolled in public schools and children from families with high/medium SES systematically frequent private schools. In Brazil, higher SES is associated with satisfactory living conditions, including access to education and health. Considering this scenario, children living in poverty are more susceptible to experiencing worse health conditions, more developmental delays, less school achievements, and more behavioral and emotional issues than their more favored peers (Berthelsen et al., 2017; Johnson et al., 2016).

Since children with typical development in situations of vulnerability and poverty are already disadvantaged if compared to their peers from families with better SES, pathological conditions should also be considered according to the context. Given the multiple factors that can aggravate clinical conditions in the pediatric population, it is necessary to consider that children in a context of poverty can have a qualitatively different development than their peers. In this sense, having tools and normative data that account for this reality is essential.

Considering this scenario and in order to propose performance-based tests that are more adapted to the pediatric population (control of the influence of instrumental functions on executive performance, more ludic tests that consider aspects of motivation and interest), the CEF-B was adapted to the Brazilian context. Moreover, the CEF-B is based in a theoretically guided approach, and considers the multidimensional character of FE in the proposition of tasks (Roy et al., 2020). Study 2 also allowed to expand the CEF-B adaptation studies carried out at the master's level by presenting preliminary normative data and proofs of validity that favor the use of this version in the Brazilian context. Results revealed proof of developmental validity and a factorial structure compatible with the theoretical proposition of the battery, revealing consistent evidence of construct validity. In addition, data regarding the impact of SES on EF also corroborate with the literature and show a satisfactory sensitivity of the battery in identifying these potential differences.

In addition to the analyses presented in this article, convergent and divergent validity analyses were also carried out, although they were not presented in the articles that compose this thesis. In order to provide external validity evidence for the CEF-B, participants' scores on three prestigious executive tests used in the literature (5 digits test, Digit span and Corsi block-tapping tests) were correlated with the CEF-B executive and non-executive measures (Annex 7). The findings indicated good external validity in relation to the three renowned executive tasks use.

It is important to note that, classically, the validity status of a test used to be conceived based on the renowned triad: content, criteria and construct (Cronbach &

Meehl, 1955). However, contemporary discussions consider that the validity of a test would be associated with different sources of evidence of a given construct (Urbina, 2007). Thus, the current paradigm would be associated with the degree to which evidence and theory support the interpretations of the scores proposed by the test. The validation process would then be cumulative, assembling a set of scientific proofs that ensure the interpretation of the tests and their relevance and utility. This process does not validate the test itself, but rather the proposed practical interpretations and applications in a given context.

Considering the concept of EF and their issues regarding performance-based testing in childhood, proofs of validity must focus on the potential of the test to (i) differentiate itself from non-executive constructs (and to resemble EF constructs), (ii) be sensitive to executive development and age-variation, (iii) discriminate executive disorders in clinical practice (Borsboom et al., 2004). In this sense, the data presented in this thesis demonstrate CEF-B's sensitivity to developmental variations in different socioeconomic contexts, and the potential to dissociate EF measures from lower-level measures based on methodological adjustments.

The various procedures that allow the test to be adapted to another culture are often considered very technical and are sometimes underestimated. However, only a rigorous process can scientifically guarantee the use of the new test. In this sense, study 3 provided reliable data for all tasks of the CEF-B. Results show moderate to high reliability indicators for all battery tests. These initial indicators are compatible with those found in the French population. It is important to note that the analyses were carried out similarly in both countries, which adds to the robustness of the results found. On the other hand, the low number of participants in the retest studies and the lack of data from children with clinical conditions in the sample (leading to a higher variance of data) constitute important limitations to the potential for generalization of the obtained results.

The lack of battery sensitivity studies in different clinical populations is a major limitation of this study. Although classical measures of validity and reliability are necessary to prove the scientificity of the battery, only the proof of clinical utility regarding the dissociation of a deficit and the expected result is able to truly attest the relevance of the battery. Thus, one of the future objectives of the project in Brazil are to provide clinical data in order to assess the clinical sensibility of the CEF-B. This endeavor is currently being carried out in several research centers in Rio Grande do Norte.

Another important aspect concerns the cross-analysis of performance-based tests and rating measures. The current literature considers that these indicators are necessary and complementary for identifying the child's executive profile. Thus, a more ecological approach to EF assessment for children could complement the results of this research and refine the current knowledge about executive development in the Brazilian context. It should be noted that BRIEF data were collected from parents and teachers for most children participating in this study. Such data will also be processed in the sequence of this project.

Given the central role of EF in psychological development and the risk of disorders in these functions in clinical conditions, their early and comprehensive evaluation is a requirement and a challenge. In this context, it seems essential that professionals and researchers in child neuropsychology join efforts in expanding the current understanding of the impact of regional, contextual and cultural factors on executive development. Due to the long-term and costly nature of the standardization and validation process, it is of the uttermost importance to encourage joint efforts among research groups in order to obtain normative references that are more representative of the Brazilian reality. In this sense, the future prospects of this project consist of the standardization of the CEF-B in other regions of Brazil, as well as the expansion of psychometric studies.

Finally, considering the transcultural characteristic of the CEF-B project, the next steps of the research will address cross-cultural analysis of the battery regarding children with typical and atypical development from Latin American countries, Africa, Europe and the Middle East. We expect that the analysis of these factors considering countries with marked cultural differences can encourage discussions about the way we are producing knowledge, tests and normative data regarding EF in children internationally.

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Annex 1 - Article translation and adaptation of CEF-B accepted in the *Avaliação Psicológica* journal

Transcultural adaptation of the Childhood Executive Functions Battery (CEF-B) for brazilian Portuguese

Resumo

Este estudo objetiva descrever os procedimentos de tradução e adaptação transcultural para o português brasileiro do Protocolo Funções Executivas em Crianças (FEC), voltado para a avaliação das funções executivas de crianças e adolescentes de 6 a 16 anos. Para garantir a qualidade do processo, foram realizadas 6 etapas: 1) tradução do instrumento do idioma de origem para o idioma-alvo; 2) síntese das versões traduzidas; 3) avaliação por experts; 4) avaliação pelo público-alvo; 5) tradução reversa e 6) estudo piloto. Buscou-se assegurar as propriedades da tradução e adaptação do protocolo FEC, em termos de equivalência semântica, idiomática, experiencial e cultural entre as instruções no idioma original e no idioma-alvo. Os resultados apontaram evidências iniciais de adequação cultural e boa compreensão das instruções do instrumento pelo público-alvo.

Palavras-chave: avaliação neuropsicológica, funções executivas, infância, adolescência, protocolo FEC.

Abstract

This study aims to describe the processes of translation and transcultural adaptation of the Childhood Executive Functions Battery (CEF-B), designed to evaluate executive functions in children and adolescents from 6 to 16 years old, to Brazilian Portuguese. Six steps were carried out to ensure the quality of the processes: 1) instrument translation into the new language; 2) synthesis of the translated versions; 3) evaluation of the synthesized version by experts; 4) evaluation by the target population; 5) back-translation and 6) pilot study. We sought to ensure the translation and adaptation properties of the CEF-B in terms of semantic, idiomatic, experiential and cultural equivalence between the instructions in the original language and the target language. Results showed preliminary evidences of cultural adequacy and a satisfactory comprehension of the instrument instructions by the target population.

Key words: neuropsychological assessment, executive functions, childhood, adolescence, Childhood Executive Functions Battery.

Resumen

Este estudio objetivó describir los procedimientos de traducción y adaptación transcultural para el portugués brasileño del protocolo Funciones Ejecutivas en Niños (FEN), centrado en la evaluación de las funciones ejecutivas de los niños y adolescentes de 6-16 años. Para garantizar la calidad del proceso, se realizaron 6 etapas: 1) traducción del instrumento del idioma de origen al idioma de destino; 2) síntesis de las versiones traducidas; 3) evaluación por expertos; 4) evaluación por el público destinatario; 5) traducción inversa y 6) estudio piloto. Se buscó asegurar las propiedades de la traducción y adaptación del protocolo FEN, en términos de equivalencia semántica, idiomática, experiencial y cultural entre las instrucciones en el idioma original y en el idioma de destino. Los resultados apuntaron evidencias iniciales de adecuación cultural y buena comprensión de las instrucciones del instrumento para por el público de destino.

Palabras clave: Evaluación neuropsicológica; funciones ejecutivas; niños; adolescentes; protocolo FEN.

Executive functions (EF) are among the most studied and debated cognitive processes in the current neuropsychological literature. These high-level processes are particularly important in dealing with new situations or circumstances that require adjustment, adaptation or flexibility of behavior (Luria, 1966). Currently, there is a relative consensus in literature that such skills constitute a multidimensional construct (e.g, Diamond, 2013; Friedman & Miyake, 2017; Miyake et al., 2000). Inhibition (inhibitory control and interference), working memory (WM) and cognitive flexibility are considered the main and most basic components of EF, despite the great variability of processes classified as executive. However, there is no consensus on how they contribute, either alone or in combination, to the solution of tasks (Dias et al., 2015).

In children as in adults, EF are essential for the orientation and regulation of intellectual, emotional and social abilities (Diamond, 2013). Especially in children, these abilities have been pointed out as predictors of academic success, being considered more significant than the intelligence quotient (IQ), especially during the first years of school (Follmer, 2017). Given the recognition of the importance of EF for quality of life at all stages of development, research on this topic has become central in neuropsychological assessment, especially in the clinical context (Zelazo, 2015). However, the great variety in theories and methods for the assessment of EF ends up generating an enormous amount of data but also controversies about the evidences found (Malloy-Diniz, Fuentes, Mattos, & Abreu, 2018).

Specifically in the case of children and adolescents, neuropsychological assessment makes it possible to identify early changes in cognitive and behavioral development, which may be associated with executive symptoms. It should be noted that a large number of neurodevelopmental and psychiatric disorders present executive changes as central symptoms (Dajani, Llabre, Nebel, Mostofsky, & Uddin, 2016). Thus, the identification of these changes during childhood is essential to provide information not only for diagnostic hypotheses, but also for structuring of interventions. In addition to clinical elements (interview), appropriate and reliable psychometric tests (performance-based tests and more ecological methods such as rating measures) specially designed for the pediatric population are needed. For that purpose, these instruments must consider developmental, contextual, and cultural aspects in their theoretical construction and normative data.

Regarding their developmental aspects, EF reach maturity later in comparison to other cognitive functions. Literature indicates that the progression of the development of these functions does not occur in a linear way, but by growth spurts of development. The explanation for this phenomenon lies in its multidimensional nature and the different developmental trajectories of executive skills (Anderson, 2002). Given the relevance of these factors, an adequate tool for the evaluation of EF in the pediatric population should consider the specificities and trajectories of their ontogenetic development. This implies that the material of the test must be adapted to the level of development of the child and must allow the possibility of mediation during the execution of the task. The use of mediational strategies is especially important in case of errors in the execution of the task. The level of mediation (quantity and quality) required to perform the task allows a better understanding of the level of development (acquired/undergoing/unacquired) of the evaluated function and help estimate the presence of potential deficits in children (Tzuriel, 2001).

As for contextual factors, the influence of historical, social, and cultural factors on the emergence of EF in children has been increasingly recognized, given the extended neurobiological maturation of fronto-subcortical networks and the vulnerability of executive development (Farah, 2017; Lawson, Hook, & Farah, 2017). Different variables such as the mother's schooling, parent’s profession, income, socioeconomic level, or the kinds of play in different childhoods, are considered as key factors that influence on the development of EF, especially WM, selective attention and flexibility (Noble et al., 2015; Ursache & Noble, 2016). These aspects suggest that the development of EF assessment tools should consider the cultural aspects of the country and region in which they will be used (Bellaj, Salhi, Le Gall, & Roy, 2015; Er-Rafiqi, Roukoz, Le Gall, & Roy, 2017). In Brazil, this aspect is particularly important because it is a country with a remarkable cultural variability and socioeconomic inequality (Piccolo, Arteche, Fonseca, Grassi-Oliveira, & Salles, 2016).

Despite Brazilian efforts in producing and adapting tests that evaluate EF in infancy, there is still a noticeable concern about the standardization and validation of the available instruments. It is also worth noting that there is a shortage of test batteries based on specific theoretical models. These limitations hamper the broadening of the knowledge on the typical development of these functions in Brazilian context, as well as the semiology appraisal of executive disorders, whether due to neurodevelopmental disorders or contexts of vulnerability and social risk (Barros & Hazin, 2013).

In order to contribute to overcome the aforementioned evaluation methodological challenges, this study aims to provide to Brazilian researchers and professionals a protocol of performance-based tests specially developed for the assessment of EF in school-aged children and adolescents: the Childhood Executive Functions Battery (CEF-B). More specifically, this study aimed to translate and adapt the CEF-B to Brazilian Portuguese. It should be noted that these processes did not only seek equivalence with the original instrument, but also considered the cultural differences and their implications for the development and understanding of EF.

The Childhood Executive Functions Battery

The theoretical-methodological pillars of the CEF-B were, at a first moment, the object of a multicenter study carried out in France. The development of the protocol arose from the interest of French researchers in composing an instrument for evaluating executive functioning in children and adolescents, given the scarcity of instruments adapted and available for the French pediatric population (Roy, 2015). This battery is theoretically based on a child-centered EF model (Diamond, 2013) and consists of a set of 12 tests for the neuropsychological assessment of EF, aimed at children and adolescents between six and 16 years. The main evaluated processes correspond to the three basic executive components: inhibition, flexibility, WM in addition to a more complex component – planning (Diamond, 2013).

The CEF-B is composed of existing tests and new experimental tasks for children or adults that have been modified or expanded to better serve the purpose of evaluating the pediatric population and also to better understand the specificity of EF roles in tasks (see Annex A - accessible at *https://github.com/amandaguerra3/ANNEX-A-Brief-description-of-the-tests-and-scales-that-compose-the-CEF-B/blob/master/ANNEX%20A.pdf* - for a brief description of the tests or Guerra, 2016 for the full description). The total test duration is of approximately two hours, knowing that, naturally, this time varies according to the child's age, clinical condition, and culture. The order of application of the tests that integrate the protocol was established in a systematic and pseudo-random manner, alternating the executive skills investigated and their verbal/non-verbal nature. The purpose of this order is to verify the influence of basic processes on executive performance, as well as to have usable tests in case of communication, visuospatial or praxical disorders (Roy, 2015).

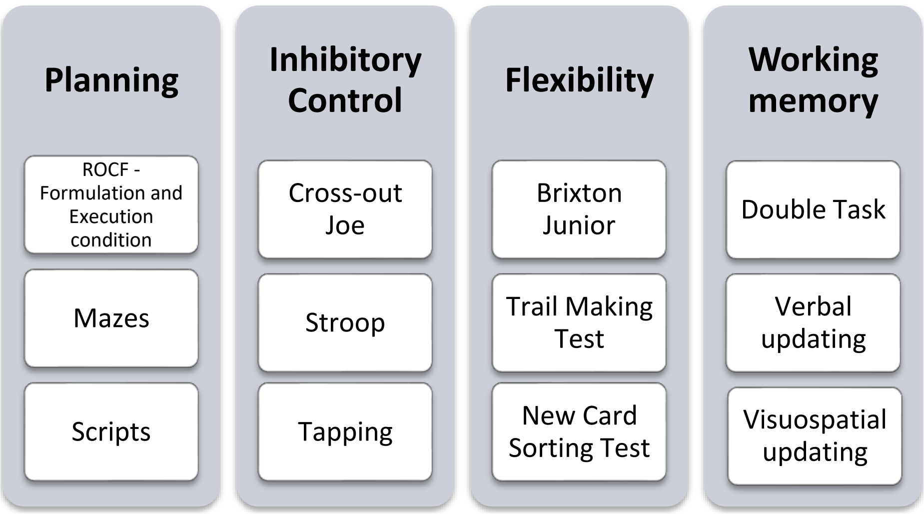


Figure 1. Overview of the CEF-B

Given that the assessment of EF must be based on several indicators and different evaluative sources including performance-based and rating measures (Toplak, West, & Stanovich, 2013), the protocol also includes a behavioral rating inventory of EF for parents and teachers - BRIEF. Therefore, it is possible to associate task results with information about the daily life of the child or adolescent (Roy, 2015). This inventory has already been adapted to Brazil (Carim, Miranda, & Bueno, 2012) and therefore will not be the object of investigation in this study. In addition to the 12 EF performance-based tests, the protocol has scales of interest and success of the child in each test, which are answered in self- and hetero-evaluation.

The CEF-B standardization and validation process in France is expected to be finalized in 2019 and is being conducted with one thousand healthy children aged six to 16 years and more than 200 patients from 15 different clinical conditions. In addition to the French partnerships, the project currently has international collaborations established with Tunisia, Brazil, Morocco, Lebanon, Ecuador and Switzerland which provides the instrument with robustness in terms of cross-cultural validity. Preliminary evidence of validity of the French version has been published regarding the Stroop test (Roy et al., 2018), BRIEF (Fournet et al., 2014), and studies with different clinical groups, such as neurofibromatosis type 1 – NF1 (Remigereau et al., 2018; Roy et al., 2014, 2010), parietal temporal and frontal epilepsy (Campiglia et al., 2014; Charbonnier, Roy, Seegmuller, Gautier, & Le Gall, 2011), traumatic brain injury (Chevignard et al., 2017) and brain tumors (Roche et al., 2018).These initial data indicate a good sensitivity of the battery for the evaluation of EF in pediatric populations, which justifies the proposal of its adaptation to the Brazilian context (Good developmental validity for the Stroop test – $F(5, 108) = 10.42$, $p < .001$; Good clinical sensitivity of tasks with significant statistical differences between clinical and control groups for ROCF - F 1,69 = 6.889, $p = .011$ – for the NF1 group and Zscore = 2,89 for frontal epilepsy case; NCST – p= <.001 for the NF1 group; Brixton – Zscore= -4,03 for frontal epilepsy case, p= <.001 for the NF1 group).

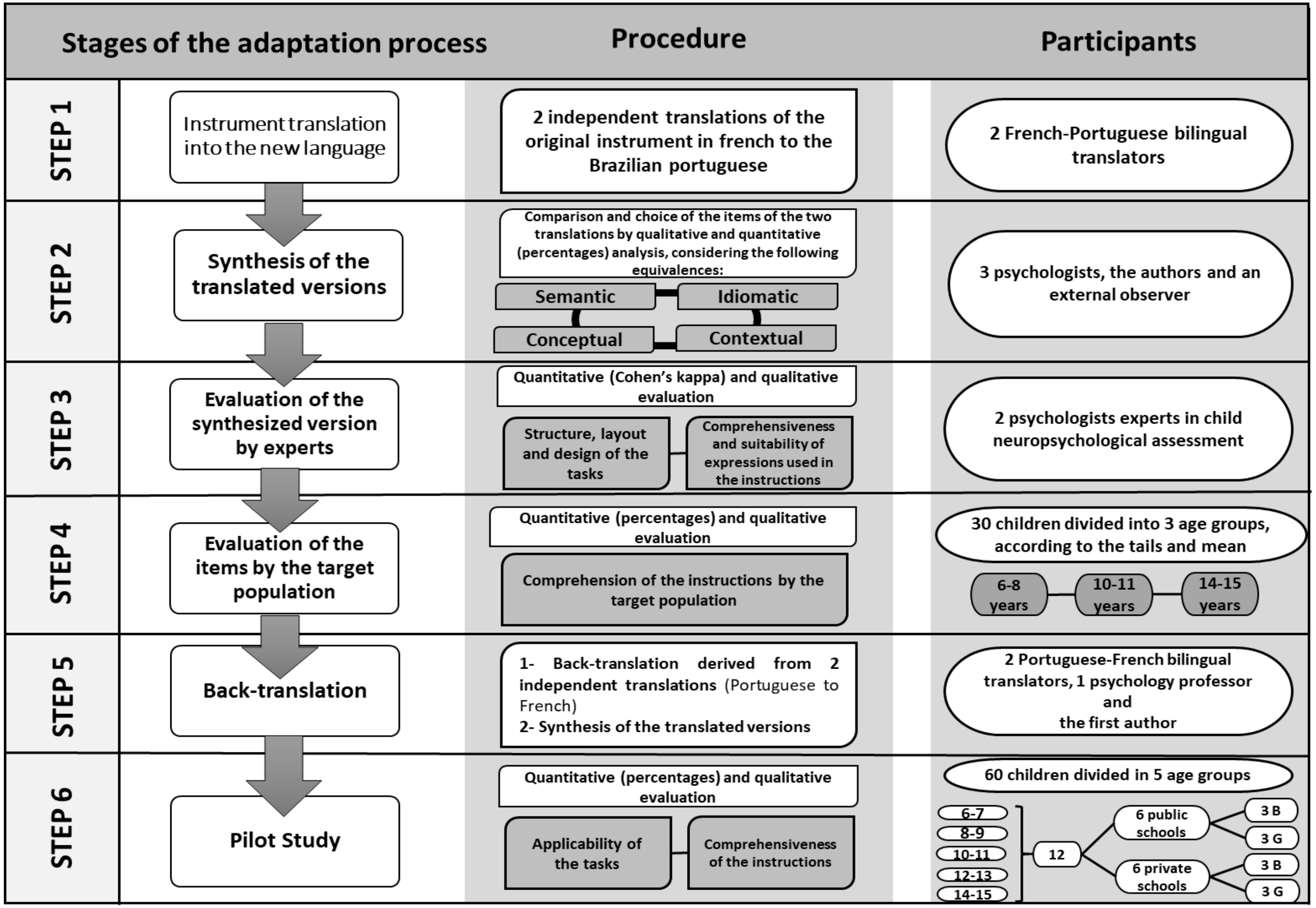
Method and results

Procedures and Participants

The translation and adaptation study was divided in six steps as proposed by Borsa, Damásio, & Bandeira (2012): 1- instrument translation into the new language; 2- synthesis of the translated versions; 3- evaluation of the synthesized version by experts; 4- evaluation by the target population; 5- back-translation; 6- pilot study. The study complied with all the ethical principles required by Resolution 466/2012 of the National Health Council, being approved by the Research Ethics Committee of the Federal University of Rio Grande do Norte under the code CAAE 48383715.1.0000.5537.

An overview of the participants and procedures performed in each step is presented in the following flowchart (Figure 2). We opted to present a detailed description of the method followed by the results of each step to improve reading comprehension.

Figure 2. Overview of summarized method.



Note. B= Boys; G= Girls

Instrument translation into the new language

For the translation of the CEF-B, two Portuguese-French bilingual translators fluent in the original language of the instrument and native in the target-language were involved: 1- a Brazilian psychologist fluent in French and 2- a Brazilian professor with a doctorate in French language and literature, fluent in French. The objectives of the study were explained only to translator one (psychologist). This methodological decision is justified by the literature, since the adaptation provided by the first translator tends to be more scientifically similar to the instrument, providing a greater semantic equivalence (Beaton, Bombardier, Guillemin & Ferraz, 2000). On the other hand, the adaptation from the second translator would be less likely to deviate in terms of the meaning of the original items. Since the second translator is less influenced by the academic objective of the translation, he/she offers a version that better reflects the language used by the target population (Beaton et al., 2000).

This step ended with two translated versions of the instrument (T1 and T2), rich in details and with a good semantic equivalence to the original instrument, showing, however, few discrepancies between them. The initial evaluation of the semantic equivalence of the two translations was carried out qualitatively by the main author of this article, who is fluent in both languages. The differences do not change the meaning of the instructions, but represent different translation styles (see table 1 for an example or Guerra, 2016 for the full description). This result agrees with what Beaton et al. (2000) recommended on obtaining 2 versions with distinct nuances of the language for which the instrument is intended, allowing a greater cultural adequacy of the adaptation process.

Table 1 *Comparison between the original French version, the two translations (T1 and T2) and the synthesis*

Original French Version	**T1**	**T2**	**Synthesis of the translated versions**
Je vais te demander un travail qui demande que tu fasses bien attention. Je te présente Joe. Ici, tu vois, il y a d'autres petits personnages. Tu dois essayer de trouver si Joe se cache parmi ces personnages et si tu le trouves, il faut le barrer avec ce crayon ! Tu as compris?	Eu vou te pedir um trabalho que necessita bastante da sua atenção. Este é o Joe. Aqui, veja, há outros personagens Você deverá tentar descobrir se Joe se encontra entre esses personagens e, se você o encontrar, deverá marcá-lo com este lápis! Você compreendeu?	Eu vou te pedir um trabalho que necessita bastante da sua atenção. Eu te apresento Joe. Aqui, veja, há outros personagens. Você deverá tentar descobrir se Joe se encontra entre esses personagens e, se você o encontrar, deverá marca-lo com esse lápis! Você entendeu?	Agora você vai fazer uma tarefa que precisa você precisa prestar bastante atenção. Este é o Joe*. Aqui, veja, há outros personagens. Você deve descobrir se Joe está entre esses personagens e, se você o encontrar, deverá marcá-lo com este lápis! Você entendeu?

Note. * The change in the name of the character "Joe" was not initially adapted in the synthesis stage, because the committee did not consider, from their expertise in neuropsychological evaluation, that this name would compromise the understanding of the instructions. However, in the stage of evaluation of the synthesis by experts, changing the name "Joe" to a Brazilian name (i.e., João) was suggested and eventually incorporated in stage 3.

Synthesis of the translated versions

The translated versions were analyzed by three psychologists, experts in child neuropsychological assessment, the auteurs and as well by an external observed, aiming to obtain a unique synthetized version. During this phase, it is relatively common to find two possible sources of complications: 1. complex translations that may hamper the understanding of the target population or 2. over-simplistic translations that underestimate the content of the item (Borsa et al., 2012). To better adapt the translations into Brazilian Portuguese, the two versions were compared and evaluated considering their semantic, idiomatic, conceptual, linguistic and contextual discrepancies. Both translations were compared to the original version in order to identify discrepancies and similarities between them.

In this step an evaluation sheet was prepared containing the original version of the instructions for each test and their respective translations (T1 and T2). The sheet presented evaluation elements for semantic, idiomatic, conceptual and contextual equivalence aspects, as presented in Table 2. In addition to these elements, the committee (judges and authors) was invited to choose the best adapted version, as well as to make suggestions to improve the instructions for the target population.

Table 2 *Evaluation elements for each type of equivalence*

Semantic equivalence	Idiomatic equivalence	Contextual equivalence	Conceptual equivalence
(1) Adequate (words have the same meaning) **(2)** Partially adequate (if the item has more than one meaning) **(3)** Inadequate (grammatical errors in the translation)	**(1)** Yes. Items were adapted to an equivalent expression. **(2)** No. Translation does not hold the same cultural significance of the item. **(3)** Does not apply. Item is easily translated.	**(1)** Yes. Applicable in the new culture **(2)** No. The item cannot be applied. Suggestion:	**(1)** Yes. The expression assesses the same aspect in both cultures. **(2)** No. The item does not assess the same aspect. Suggestion:

All three experts and the authors deemed one of the versions (T2) as the overall best adaptation (85,71% of the instructions). Only two items (14,2%) were retrieved from the other translation (T1). In terms of semantic equivalence, the experts judged that the words used in both translations had the same meaning and the protocol items were evaluated as adequate. The evaluation was carried out qualitatively on the basis of the evaluators' knowledge in both languages and their expertise in child neuropsychology. A few changes were made in order to ensure a better adaptation of the instrument to Brazilian children (see table 1 for an example or Guerra, 2016 for the full description). Experts also considered that the translated items were replaced by equivalent expressions, with a satisfactory idiomatic equivalence. Regarding experiential and conceptual equivalences, experts considered that the tasks and instructions proposed by the original instrument were pertinent to Brazilian cultural context.

Evaluation of the synthesized version by experts

In the next step, an evaluation by experts was conducted. Two psychologists experts in child neuropsychological assessment from the south and southeast regions of Brazil participated, who evaluated structure, layout and design of the tasks, as well as comprehensiveness and suitability of expressions present in the instructions. The experts also assessed whether the terms or expressions could be generalized to different contexts and populations (i.e. different regions of the same country) and whether the expressions were suitable for the audience for which the instrument is designed. The experts received an instruction letter, the manual and the tasks of the protocol, as well as an evaluation sheet developed specifically for this step, which included the objective of the study, a brief description of the instrument and information on the population involved. Elements of layout, design and instructions for all tasks to be evaluated were presented on the sheet. Layout elements were evaluated globally and the task instructions were evaluated individually. The experts answered the sheet in a quantitative sense, through three-point Likert scale (adequate, partially adequate and inadequate) and in a qualitative sense, through comments and suggestions for all the instructions of the protocol and the layout aspects.

The agreement between experts regarding all the tasks of the CEF-B was assessed by Cohen's Kappa (Landis & Koch, 1977), which indicated substantial agreement (0.70). The coefficient was calculated globally considering all experts answers. Both experts considered all the aspects of the layout, structure, and design of the protocol as adequate. Most of the instructions were evaluated as adequate (78,57%) and none was considered as inadequate. Only three items (21,42%) were considered as partially adequate by the experts and were modified in order to guarantee the protocol's adequacy for the child population (see table 3 for an example or Guerra 2016 for the full description).

Table 3 *Example of modifications in the ROCF instructions (Execution condition) after Experts evaluation*

	Partially appropriate Item	**Justifications of the experts**	**Item after modifications**
ROCF - Execution condition	Aqui tem mais um desenho. Você vai copiá-lo nesta folha. Tente fazer o melhor que puder. Preste atenção nas proporções e,	E1: Proporções – termo difícil para crianças menores de 11 anos... talvez explicar melhor	Aqui tem mais um desenho. Você vai copiá-lo nesta folha. Tente fazer o melhor que puder. Preste atenção **aos**

	principalmente procure não esquecer nada. Não tenha pressa! Quando você achar que copiou tudo, você me diz. Comece com este lápis.	com exemplo. E2: Proporções pode ser difícil para entendimento de crianças pequenas. Colocar entre parênteses IGUALDADE para o examinador explicar melhor.	**tamanhos** e, principalmente procure não esquecer nada. Não tenha pressa! Quando você achar que copiou tudo, você me diz. Comece com este lápis.

Evaluation of the intelligibility of the items by the target population

After the evaluation by experts, a complementary assessment of the understanding, clarity and suitability of the instructions by the target audience was carried out. To that end, only the instructions and training phase of each test were applied to 30 children and adolescents aged six to 15 years from two public schools. The participants were separated in three groups of 10 subjects, according to the tails and mean point of the protocol age distribution, as follows: Group 1: children between six and eight years old; Group 2: children between 10 and 11 years old; Group 3: adolescents between 14 and 15 years old. At this step, the comprehension of the instructions by the target population was verified. The results were categorized into dichotomous variables (comprehends *vs* does not comprehend) and were analyzed based on the percentages of comprehension of each instruction. A broad understanding of the protocol instructions was observed in all age groups. Full comprehension was identified in eight of the 12 instructions of the tests and in both scales, namely: Mazes, Stroop; Tapping rate; Rey Osterrieth Figure (ROF) - Execution condition; Trail Making Test (TMT), Double Task; New Card Sorting Test (NCST); Cross-out Joe; Brixton Junior; and Interest and Success scales.

Difficulties in comprehending and performing the training phase were identified in four (updating tests – visuospatial and verbal –, Stroop and Scripts tests) of the 12 tests, exclusively in the six and seven-year-old children group (Group 1). The updating tests instructions were not fully understood by Group 1, with 60% and 40% of comprehension for verbal and visuospatial tests, respectively. It is important to point out that comprehension difficulties were related to the acquisition of the concept of "last" position (in the case of said tests, the notion of the "last three or four"), especially by children aged six. Operational problems were also identified in the Stroop and Script tests, again specifically in children with six and seven years old. Because they are verbal tests that require the prior acquisition of reading skills, five children (71,4%) aged six and seven years old who had not yet consolidated this process did not complete the training phase.

Preliminary studies with the CEF-B protocol were carried out with children aged between seven and 12 years old. The six-year-old age group is being added to the French standardization process after discussions about the pertinence of some tests for that particular age, namely: Stroop, Scripts, TMT and updating tests (verbal and visuospatial). Such consideration is justified by potential reading difficulties and, in the particular case of updating tests (verbal and visuospatial), by possible issues in comprehending the task.

After discussing with the authors of the protocol about the pertinence of using updating tests in this age group, an agreement was reached that previous evaluation was needed in order to guarantee that children understand the concept of "last three". To this end, an order identification task was elaborated and incorporated into the pilot study for the updating tests, exclusively for Group 1. In addition, tests requiring automated reading (Stroop and Scripts) or alphabet sequencing (TMT) were not applied to children who did not have these skills consolidated as observed in the training stage.

Back-translation

The back-translation derived from two independent translations of the final version in Portuguese to French. Translations were carried out by two professionals fluent in the original language of the final document (Portuguese) and native in the target language (French). Subsequently, the translated versions were synthetized, in which participated a psychology professor and the first author of this work, both fluent in the two idioms. At the end of the process, the back-translation was sent to the CEF-B original authors, so they could evaluate the translation.

The experts considered that the translated items were replaced by equivalent expressions in French in both versions. However, they opted, in most cases, for the use of items of one of the translated versions, adding only a few excerpts from the other version in order to make the synthesis more authentic to the Portuguese version. Small changes were made to the French translation in order to further adequate it to the original document in Portuguese. The back-translation was sent to the authors of the protocol, who considered it consistent in terms of conceptual equivalence and no modification was needed.

Pilot Study

The pilot study was performed after the protocol was discussed and approved by its authors. This step counted on the participation of 60 children and adolescents aging between six and 15 years, separated in five groups, as follows: Group 1 – children between six and seven years old; Group 2- children between eight and nine years old; Group 3 – children between 10 and 11 years old; Group 4 – adolescents between 12 and 13 years old; Group 5 – adolescents between 14 and 15 years old. Each age group was composed by 12 children, six belonging to public schools and the other six belonging to a private school. Furthermore, these groups were subdivided by gender, with three females and three males each.

The pilot study was carried out in four public schools and one private school from the Natal and Parnamirim (State of Rio Grande do Norte – Northeast of Brazil) educational systems. Its inclusion criteria were: 1. signing of the Informed Consent Form by parents and/or legal guardians; 2. to be properly registered in public or private schools from the educational system of Natal and Parnamirim; 3. no register of past school failure; 4. IQ score inside the normal variation (80 to 119 points of IQ); 5. no complaints of neurodevelopmental alterations or uncorrected sensory disabilities. A total of 68 children were subjected to the application of the Vocabulary and Matrix Reasoning subtests from the Wechsler Abbreviated Scale of Intelligence (WASI). Eight of these participants scored a total IQ below 80 and, therefore, were excluded from the sample.

Discussion

The results of the pilot study showed that all the tests and scales of the CEF-B have clear instructions for all age groups of the evaluated sample and are suitable for use in the new cultural context. This result suggests that the translation and adaptation steps were sufficient for the cross-cultural adaptation of the instrument instructions. Similarly, information contained in the stimuli presented to children was clear and adequate for most tests. However, in the Scripts test, difficulties were observed by different age groups in understanding the stimuli presented. This result indicates that the previous translation and adaptation stages were insufficient for the cross-cultural adaptation of the task stimuli, requiring an additional adaptation study and a second pilot study.

The pilot study showed that the two scales and five of the tests (Brixton Junior, NCST, Tapping, Double Task and the execution condition of ROCF) are suitable for all ages. The applicability difficulties of the seven remaining tests were evidenced exclusively in children of Group 1 (six and seven years), especially in children with six years old. Two types of difficulties were identified in the accomplishment of the tasks by this group: 1- the underlying concepts and abilities necessary for the execution of the tasks seem to not have been developed yet by the age of six; and 2- the level of difficulty and demotivation/frustration in executing the task. Such difficulties can be explained by the fact that the CEF-B was elaborated to a wide age range, considering different stages of development.

Regarding type 1 difficulties (acquisition of underlying concepts and abilities), as evidenced in the evaluation by the target-population step, children in Group 1 (six to seven years old) presented difficulties in executing verbal tasks that require the prior acquisition of reading skills, namely: Stroop, Scripts and TMT. In this age group, the acquisition of these skills is still in active development.

Still regarding type 1 difficulties, children of Group 1 also presented difficulties in performing the updating Tasks (verbal and visuospatial). Therefore, in the pilot study, a previous task was incorporated after the baseline of the Visuospatial updating test in order to evaluate the understanding of the concept "last three and four" by younger children. To that end, five colored pencils were arranged on the table (side by side) and the examiner asked the subject to count how many pencils were on the table. The subject was then asked to point at the first and the last pencil he/she counted. Subsequently, the subject should point at the last three and four pencils he/she counted. Six out of seven children that were part of Group 1 pointed at the three middle pencils (neglecting the extremities) as the last three, and the first four pencils as the last four. Only one child pointed the last three and four pencils correctly, but had difficulty performing the training phase, and failed all attempts. It should be noted that even after explaining the concept, the children struggled to perform the 'Visuospatial Updating Task' training phase. Studies point out that in addition to WM, updating tasks require considerable information processing flexibility and a gradual alternation of attention, for example, when discarding some items while new ones are being registered (Salmon et al., 1996). In order to remember the last items in a sequence in which the ending is not predictable, the child needs to consider all other items, knowing the first and last item and respecting the given sequence. To do so, children must perform opposing actions simultaneously, mentally doing and undoing the same action. However, such skills are still in dynamic development in six-year-old children.

In addition, studies show that cognitive flexibility develops gradually during childhood and experiences a growth spurt around age 12 (Anderson, 2002). WM and inhibitory control seem to develop before flexibility and are underlying components of the development of flexible behaviors (Best & Miller, 2010). Besides difficulties in reversibility of thought, the development of WM in six-year-old children is still insufficient for executing updating tasks, since the differentiate development of underlying mechanisms of executing retaining tasks, such as sequencing and keeping information in the WM (Diamond, 2002), significantly develops only between seven and 13 years old (Lázaro & Ostrosky-Shejet, 2012). Thus, updating tasks seem to be inappropriate for six-year-old children, since the necessary underlying concepts and abilities are not sufficiently developed yet to perform tasks in this age group.

Regarding type 2 applicability difficulties (level of difficulty and demotivation/frustration in executing the task), Group 1 children had difficulties in the Mazes and Cross-out Joe tasks. On the other hand, adolescents considered Tapping an easy and demotivating task. The Mazes test was considered a very difficult task by children in Group 1, who constantly complained about the quantity and complexity of the labyrinths presented even at the beginning of the task. The average number of labyrinths performed within the time limit by children in this group was five out of eight labyrinths. These results indicate the need to establish interruption criteria for this task that take into consideration the level of development of the planning executive component. The Cross-out Joe test was pointed out by children and adolescents of different ages as one of the least pleasant and most demotivating activities because of its length. The activity was mostly disapproved by children between six and seven years old. During the test, children frequently presented facial expressions of disapproval and made negative comments. It should also be noted that two six-year-old children refused to perform part B of the task and one of them gave up during the execution of the task. However, it is important to note that the test was built in an effort to represent tasks of the child's daily life. It was designed to represent long and monotonous tasks that require sustained attention engagement (e.g. school activities). Therefore, it is expected that children in general will find the task less motivating and that children with six years old will have greater difficulties in engaging in the task.

Tapping was pointed out as the easiest test in the protocol by adolescents and children from nine years on, being considered by many to be demotivating. Thus, future analyzes should investigate the presence of a possible 'ceiling effect' and should be considered in the standardization of the instrument. It should be noted that inhibition tasks have shown different sensitivities according to the stage of development, some of which are sensitive to conceptual gains in early childhood and others to the refinement of cognitive abilities in late childhood and adolescence (Best & Miller, 2010).

The literature shows that performance in inhibition tasks of the Go/No-Go type reaches a ceiling effect in children between nine and 11 years old. More precisely, a significant decrease in impulsive errors (commissions) and absence of response (omissions) was identified in the comparison between groups of children aged six to eight years old and groups of children between nine and 12 years old, with little to no variation in the age group of adolescents between 13 and 15 years old. On the other hand, the performance in other classic inhibition tests, such as the Stroop Test, shows a continuous growth in reaction time and precision measures up to 15 years old (Huizinga et al., 2006). However, when dealing with changes in the development of inhibitory control in subjects with clinical conditions, tasks of the Go/No-Go type are pointed out as a sensitive measure, especially in Attention Deficit/Hyperactivity Disorder (Brocki & Bohlin, 2004).

The tasks pointed out in this study as inappropriate for children in Group 1, especially those with six years of age, due to the underdevelopment of underlying skills, were excluded for this age group in undergoing normative studies. In addition, the tasks considered inappropriate due to applicability difficulties for this age group may incorporate start and stop point, after normative studies and analysis based on the item response theory have been carried out. On the other hand, some tasks pointed out as easy may be conducted up to the age limit established by possible ceiling effects.

Pilot study 2: Scripts

In order to avoid any kind of linguistic bias, a group of five neuropsychological assessment experts suggested changes in actions that were not easily comprehensible to the children. Subsequently, the changes were translated into French and presented to the task creators, who considered the suggestions adequate (Table 4). A second pilot study was carried out to assess whether the task is, at last, ready to be used in the Brazilian context (Borsa et al., 2012).

The second pilot study was carried out with 30 children and 80 university students, aged between 20 and 25 years, in order to validate the linguistic adaptations. The pilot study with university students was necessary in order to contemplate the possibility of more than one correct script sequence due to possible cultural differences in the execution of the task. The data were analyzed and discussed in agreement with French data. This allowed for in-depth reflection on the responses given by Brazilian children and on the problematic of cultural differences. After the second pilot study, the adaptation of the task to the Brazilian context was deemed good, which enabled the realization of validation and standardization studies of the protocol.

Table 4 *Changes in the Scripts Test for the Second Pilot Study*

Name of the Script	actions in the first pilot study		changes in the second study pilot	
	original in Portuguese	action in English*	original in Portuguese	action in English*
Take a shower	se lavar	wash yourself	tirar o sabão	rinse yourself
Pack the school bag	ver o horário	check time	olhar o horário das aulas	check class time table
	guardar a mochila para o dia seguinte	put the bag away for the next day	levar a mochila para a escola	take the bag to school
Do the shopping	colocar as compras no carro	put the groceries in the car	colocar as comprar no automóvel	put the groceries in the vehicule

*provided only for the English version of this article

Final considerations

The process of cross-cultural adaptation of the CEF-B to the Brazilian Portuguese allowed verifying that the instructions were well-comprehended by children and adolescents. Additionally, the tests and scales which compose the protocol had good applicability. The continuity of this research is an ongoing study in order to guarantee the availability of validity and reliability psychometric parameters, as well as normative data that consider the variables age, schooling and the particularities of the different regions of Brazil. We expect that the availability of the CEF-B for professionals working with neuropsychological assessment in Brazil will help minimize the shortage of instruments specifically developed for children and adolescents, especially those which consider developmental, cultural and motivational aspects in their proposition.

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Annex 2 - Description of the FEE protocol performance tests

Os testes de desempenho serão expostos a partir da sua classificação executiva, conforme detalhado a seguir:

1.1. Inibição

1.1.1. Tapping

Esta atividade foi desenvolvida por Roy et al. (2012), a partir do paradigma Go/No Go e tem como objetivo avaliar o controle inibitório motor. 'Tapping' é uma tarefa que utiliza apenas o dedo indicador da mão dominante da criança e é constituída de três etapas: 1- 'Condicionamento Simples': consiste em estabelecer as regras gerais da atividade, na qual a criança deve copiar o movimento do examinador (Se o examinador bate uma ou duas vezes na mesa, a criança copia o movimento); 2- 'Go/No Go': tem como objetivo consolidar as regras para copiar ou não o movimento do examinador (Se o examinador bater uma vez na mesa com o dedo indicador, a criança deve repetir o movimento, mas se ele bater duas vezes na mesa, a criança não copia o movimento); 3- 'Condicionamento Conflitivo e Go/ No Go': consiste em conflitar o condicionamento aprendido a partir do paradigma Go/ No Go (Se o examinador bater uma vez na mesa com um dedo, a criança bate duas vezes. Mas se o examinador bater duas vezes com um dedo, a criança bate uma vez, porém se o examinador bater na mesa com dois dedos, uma ou duas vezes, a criança não copia o movimento).

A pontuação dessa atividade é dada a partir do tempo (em segundos) de cada etapa da tarefa o número de erros não corrigidos e o número de erros corrigidos para cada uma das três partes.

1.1.2. Stroop

Esta versão foi originalmente idealizada para adultos, pelo grupo Groupe de réflexion sur l'évaluation des fonctions exécutives (2001), tendo como objetivo avaliar o controle inibitório e a atenção seletiva por meio do 'Efeito Stroop'. Nesta versão foi realizada a adaptação de instruções especialmente para crianças, visto que o original apresenta degradação do score de interferência com a idade e não considera análise qualitativa dos erros produzidos.

O teste é composto de três etapas: 'Denominação', 'Leitura' e 'Interferência'. Cada uma das etapas é apresentada em uma folha A4, em orientação paisagem, contendo 100 itens dispostos aleatoriamente em uma matriz de 10 x 10. Nesta versão, são utilizadas três cores (azul, vermelho e verde) e, antes da administração de cada etapa, é realizado um treino composto por 10 itens onde se verifica a compreensão da tarefa pela criança.

A etapa de 'Denominação' consiste em denominar as cores apresentadas em retângulos na folha de aplicação. Por outro lado, a etapa de 'Leitura' caracteriza-se pela leitura dos nomes das cores apresentados em preto e, por fim, a etapa de 'Interferência" envolve a identificação dos nomes das cores escritos em cores conflitantes com o da impressão.

Os erros são corrigidos para cada uma das três partes e podem ser de três tipos: 1- Palavra incorreta produzida, mas corrigida corretamente pela criança; 2- Erros não corrigidos: palavra incorreta produzida e não corrigida; 3-Hesitações: palavra incorreta incompletamente produzida e corrigida antes da pronúncia completa (ex.: verm.. azul!) anotação. Além da análise dos erros, é calculada a pontuação de interferência a partir do tempo (Equação 01) e os erros corrigidos e não corrigidos (Equação 02), conforme explicitado:

$Score\ de\ Interfer\hat{e}ncia\ Tempo = Tempo[Parte\ C] - Tempo[Parte\ A]$	01
$Score\ de\ Interfer\hat{e}ncia\ Erros = Erros[Parte\ C] - Erros[Parte\ A]$	02

1.1.3. Marque-Joe (Barre Joe)

Trata-se de tarefa que avalia a inibição de estímulos considerados distratores, na qual a criança deve cancelar o personagem Joe dentre um conjunto de outros personagens. Para verificar a compreensão da tarefa, a criança realiza um ensaio com o examinador. Após o treino a criança é convidada a repetir a atividade em duas folhas A3 (A e B). Cada folha possui 240 estímulos distribuídos em 16 linhas constituídas por 15 personagens dispostos de maneira aleatória (um alvo: Joe aparece uma vez sobre cinco, sendo 48 alvos para 192 distratores). Com o intuito de assegurar que a criança percorra todas as linhas do teste, cada linha possui dois quadrados em cada extremidade que devem ser assinalados com um “X” ao iniciar e finalizar as marcações da linha. É solicitado que a criança faça a tarefa o mais rápido que puder, pois o examinador marcará o tempo. A pontuação é dada a partir dos índices: ‘Velocidade’ (Equação 08), ‘Imprecisão’ (Equação 09) e ‘Rendimento’ (Equação 10) e do ‘Score de Evolução (atenção concentrada): ‘Evo1’ (Equação 11), ‘Evo2’ (Equação 12) e ‘Evo3’ (Equação 13). Onde: om = omissões; fa = alarmes falsos; B = número de sinais a marcar.

$Vel = \frac{460 * \mathbf{60}}{\boldsymbol{tempo}}$	0**3**

$$Imp = \left(\frac{om + fa}{B + fa}\right) * 100$$	04
$$Ren = \frac{(B - om + fa) * 60 * 10}{tempo}$$	05
$$Evo1 = Vel_b - Vel_a$$	06
$$Evo2 = Imp_b - Imp_a$$	07
$$Evo3 = Ren_b - Ren_a$$	08

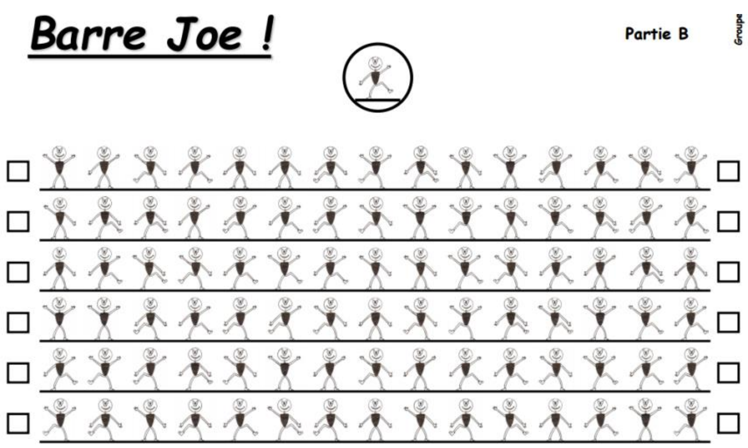

Figura 2. Exemplo do teste Barre Joe

1.2. Memória de Trabalho

1.2.1. Atualização visuoespacial

A tarefa de atualização visuoespacial avalia o aspecto *updating* da capacidade visuoespacial da MT. A versão visuoespacial desta tarefa, desenvolvida para o protocolo FEE, foi inspirada em tarefas do tipo “Running Memory Span” e nos Blocos de Corsi.

Para aplicação desse teste é utilizada uma prancha de madeira branca (21 × 30 cm) na qual 10 cubos de madeira idênticos (3cm x 3cm x 3cm), estão separados espacialmente e dispostos de forma pseudoaleatória. Assim como na tarefa dos Blocos de Corsi, os blocos sobre a prancha são numerados (0 a 9) e os números devem estar direcionados para o examinador, sem que a criança tenha acesso aos mesmos.

A tarefa é constituída por duas etapas: 1- Span visuoespacial (Linha de base): que tem como objetivo avaliar globalmente a capacidade de lembrar as localizações tocadas pelo examinador (memória visual) e; 2- Atualização: na qual devem ser recordados os (três ou quatro) últimos itens de uma sequência dada.

Na primeira etapa, a criança é convidada a observar a sequência de blocos tocados pelo dedo do examinador e em seguida, tocar e reproduzir o máximo de localizações que ela conseguir sem instruções de ordem. Um ponto é dado por localização correta. São apresentadas à criança um total de cinco sequências, com seis itens cada, totalizando 30 pontos.

A partir dos resultados obtidos nessa etapa, é estabelecido o número de localizações a serem recordadas na etapa de 'Atualização', composta por duas modalidades: 3 e 4. Se a criança tem pontuação entre 16 e 19 pontos na linha de base, é aplicada a tarefa de 'Atualização' 3, na qual a criança deve tocar os três últimos cubos da sequência administrada, na mesma ordem que o aplicador. Por outro lado, se a criança fizer pontuação igual ou superior a 20 pontos na linha de base, é aplicada a tarefa de 'Atualização' 4, na qual a criança deve tocar os quatro últimos cubos da sequência, também na mesma ordem que o aplicador. Por fim, se a criança faz pontuação menor ou igual a 15, a tarefa de 'Atualização' não é administrada.

As tarefas de ‘Atualização’ têm tamanhos variáveis e são divididas em três tipos: 1- R0: Sequências em que as crianças tocam a mesma quantidade de cubos que o examinador, compostas de três itens para a Tarefa de Atualização 3 e quatro itens para a Tarefa de Atualização 4; 2- R2: Sequências compostas de cinco itens para a Tarefa de Atualização 3 e seis itens para a Tarefa de Atualização 4; 3-R3: Sequências compostas de seis itens para a Tarefa de Atualização 3 e sete itens para a Tarefa de Atualização 4.

A tarefa tem início com a aplicação de três itens de treinos com os diferentes tipos de sequências (R0, R2 e R3) para confirmar a compreensão da instrução dada à criança. Após o treino é administrada a tarefa, composta de 15 sequências, sendo cinco do tipo R0, quatro do tipo R2 e seis do tipo R3. Cabe salientar que os diferentes tipos de sequência são administrados de forma aleatória para garantir que o fim da sequência seja imprevisível para a criança. Um ponto é atribuído por localização corretamente lembrada para os diferentes tipos de itens. A soma das pontuações de cada tipo de sequência fornece três valores, a saber: X0: soma dos pontos para os itens R0, X2: soma dos pontos para os itens R2, X3: soma dos pontos para os itens R3. A partir desses valores é calculada a pontuação global (Equação 09):

$$PG = (X2 + X3) * \frac{100}{(2 * X0)} \quad (09)$$

1.2.2. Atualização Verbal (*Mise à Jour Verbal*)

A tarefa de ‘Atualização Verbal” avalia a dimensão *updating* da capacidade verbal da MT. A versão verbal desta tarefa, desenvolvida para o protocolo FEE, foi inspirada em tarefas do tipo “running memory span”.

A tarefa é constituída por duas etapas: 1- ‘Span’ (Linha de base): que tem como objetivo avaliar globalmente a capacidade de lembrar as letras ditas pelo examinador e; 2- ‘Atualização’: na qual devem ser recordadas as (três ou quatro) últimas letras de uma sequência dada.

Na primeira etapa, a criança é convidada a ouvir uma sequência de letras ditas pelo examinador e, em seguida, evocar o máximo de letras que ela conseguir sem instruções de ordem. Um ponto é dado por letra correta. São apresentadas à criança um total de cinco sequências com seis letras cada, totalizando 30 pontos.

A partir dos resultados obtidos nessa etapa, é estabelecido o número de letras a serem recordadas na etapa de ‘Atualização’, composta de dois tipos: 3 e 4. Se a criança tem pontuação entre 19 e 25 pontos na linha de base, é aplicada a tarefa de ‘Atualização 3’, na qual a criança deve lembrar as três últimas letras de cada sequência administrada, na mesma ordem que o aplicador. Por outro lado, se a criança fizer pontuação igual ou superior a 25 pontos na linha de base, é aplicada a tarefa de ‘Atualização 4’, na qual a criança deve lembrar as quatro últimas letras de cada sequência, também na mesma ordem que o aplicador. Por fim, se a criança faz pontuação menor ou igual a 15, a tarefa de ‘Atualização’ não é administrada.

As tarefas de ‘Atualização’ têm tamanhos variáveis e são divididas em três tipos: 1- R0: Sequências que as crianças evocam a mesma quantidade de letras que o examinador, compostas de três letras para a Tarefa de Atualização 3 e quatro letras para a Tarefa de Atualização 4; 2- R2: Sequências compostas de cinco letras para a Tarefa de Atualização 3 e seis letras para a Tarefa de Atualização 4; 3-R3: Sequências compostas de seis letras para a Tarefa de Atualização 3 e sete letras para a Tarefa de Atualização 4.

A tarefa tem início com a aplicação de três itens de treinos com os diferentes tipos de sequências (R0, R2 e R3) para confirmar a compreensão da instrução dada à criança. Após o treino é administrada a tarefa, composta de 15 sequências, sendo cinco do tipo R0, quatro do tipo R2 e seis do tipo R3. Um ponto é atribuído para cada letra corretamente lembrada para os diferentes tipos de itens. A soma das pontuações de cada tipo de sequência fornece três valores, a saber: X0: soma dos pontos para os itens R0, X2: soma dos pontos para os itens R2, X3: soma dos pontos para os itens R3. A partir desses valores é calculada a pontuação global (Equação 10):

$$\boldsymbol{PG = (X2 + X3) * \frac{100}{(2 * X0)}} \quad \textbf{3}$$

1.2.3. Dupla Tarefa

Esta tarefa foi desenvolvida por Roy et al. (2012) a partir do paradigma 'Dupla Tarefa' proposto por A. D. Baddeley & Hitch (1974), e tem como objetivo avaliar o componente executivo central da memória de trabalho, bem como a amplitude de memória, em outras tarefas cognitivas. Para tanto são realizadas 4 etapas. Cabe salientar que com objetivo de adaptar temporalmente essa tarefa às crianças, a duração de cada fase (em condição simples e em condição dupla) foi restabelecida para um minuto e 30 segundos.

1) Span de dígitos – linha de base

Incialmente, um procedimento padrão de 'Span progressivo' é utilizado, começando por séries de três dígitos e aumentando progressivamente até que sejam constatados erros. Para cada extensão de série dada, três ensaios são propostos. Os dígitos são lidos na velocidade de um por segundo. As três séries de uma mesma extensão são sistematicamente administradas até que a criança cometa erros em ao menos duas das séries de uma dada extensão. O objetivo é o estabelecimento do ‘Span’ (linha da base), que corresponde ao número de dígitos contidos na última série, para a qual houve ao menos dois sucessos, ou seja, para a extensão anterior à interrupção.

2) Tarefa de Span (condição simples) :

Após o estabelecimento de ‘Span’ na linha de base, são apresentadas sequências de mesma extensão ao longo de um minuto e 30 segundos. Os números devem ser lembrados oralmente pelas crianças na mesma ordem de apresentação. Uma evocação não ordenada é considerada como um erro.

3) Tarefa de Cancelamento de Palhaços (condição simples):

Nesta tarefa é apresentada à criança uma folha contendo cabeças de palhaço dispostas desordenadamente na folha e conectadas por uma linha (Figura 4). Ao longo de um minuto e 30 segundos a criança deve fazer um X nas cabeças de palhaço que encontrar na folha, seguindo a linha. Caso a criança finalize a primeira página, administra-se a segunda e, se for o caso, até uma terceira. Vale salientar, para verificar a compreensão da tarefa pela criança, é apresentado um treino no início da tarefa. Caso ela falhe na execução do mesmo, o teste não deverá ser aplicado.

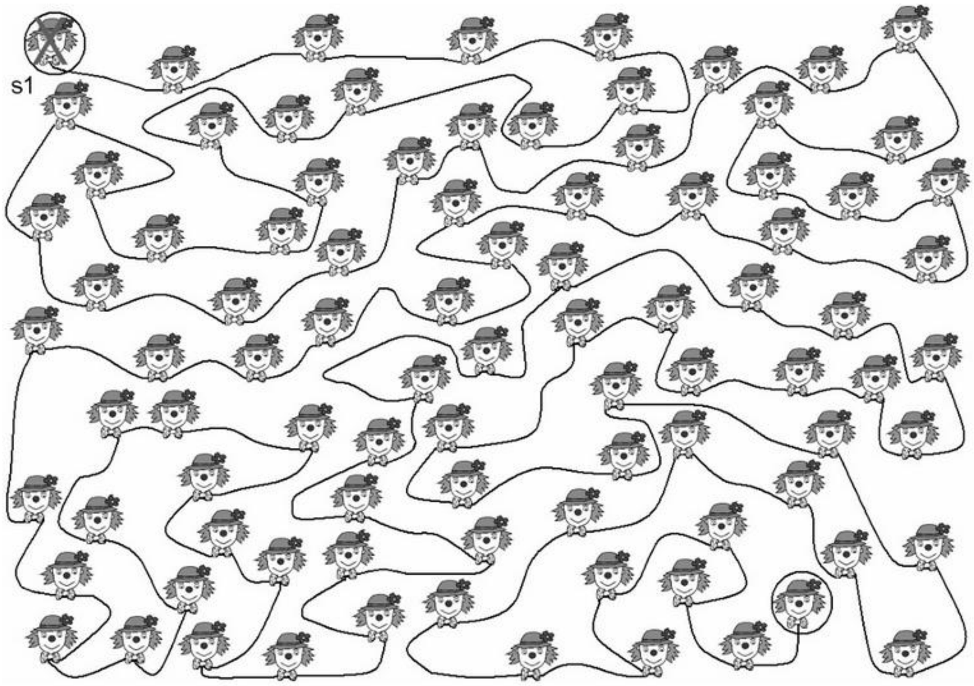

Figura 3. Exemplo da folha de cancelamento de palhaços

4) Condição Dupla :

Nesta etapa, solicita-se à criança a realização simultânea das duas atividades anteriores: fazer um X em todas as cabeças de palhaço, e, ao mesmo tempo, repetir as séries de dígitos apresentadas pelo experimentador de acordo com a linha de base estabelecida para a tarefa de 'Span', por um minuto e 30 segundos. A Pontuação nas três primeiras etapas é realizada a partir da soma do número de dígitos/palhaços evocados-marcados. Para a pontuação da 'Dupla Tarefa' é utilizado o score composto μ (Baddeley, Sala, Gray, Papagno, & Spinnler, 1997), conforme Equação 11:

$$\boldsymbol{\mu} = \left[\mathbf{1} - \frac{(\boldsymbol{P_s} - \boldsymbol{P_d}) + \frac{(\boldsymbol{C_s} - \boldsymbol{C_d})}{\boldsymbol{C_s}}}{\mathbf{2}} \right] * \mathbf{100} \tag{11}$$

P_s : proporção de séries corretamente evocadas em condição simples

P_d : proporção de séries corretamente evocadas em condição dupla

C_s : Número de palhaços cancelados em condição simples.

C_d : Número de palhaços cancelados em condição dupla.

1.3. Flexibilidade

1.3.1. New Card Sorting Test [NCST]

Esse teste combina as propostas do WCST e do *Modified Card Sorting Test* (MCST). O NCST é formado por quatro cartas-estímulo e 48 cartas-resposta que são semelhantes e contém figuras de diferentes formas (cruzes, círculos, triângulo ou estrelas), cores (vermelho, azul, amarelo ou verde) e números (uma, duas, três ou quatro). Os quatro cartões-estímulos não sofreram alterações no teste e correspondem aos mesmos utilizados pelo WCST e MCST (um triângulo vermelho, duas estrelas verdes, três cruzes amarelas e quatro círculos azuis). Porém, o princípio de classificação C-F-N (Cor-Forma-Número) do WCST foi modificado. Nesta versão, assim como no MCST, o primeiro princípio de classificação das cartas escolhido pelo sujeito é o considerado correto. O segundo princípio também é considerado correto, e o terceiro é aquele que faltava para completar a tríade C-F-N. A ordem estipulada pelo sujeito é mantida na repetição das categorias. Além disso, também como no MCST, o número de respostas corretas para completar uma categoria foi modificado, de 10 respostas para seis. Porém, diferentemente do WCST e do MCST o teste é interrompido quando terminam as 48 cartas.

Para garantir a compreensão da tarefa, no NCST os princípios de classificação das cartas são explicados. A tarefa começa quando o examinador entrega à criança o baralho com 48 cartas-resposta e exibe as quatro cartas-estímulo explicando que existem três maneiras de combinar as cartas. Em seguida, o examinador solicita que a criança enumere as três. Se a criança não identifica todos os critérios, eles lhe são dados: cor, forma e número. Posteriormente, solicita-se que a criança combine cada carta do baralho com uma das quatro cartas que estão na sua frente em função da regra que ela escolher. O examinador não pode dizer qual regra escolher para combinar as cartas, por outro lado, a cada vez que a criança combinar uma das cartas, ele dirá sim ou não. Ele explica à criança que se ele disser sim, significa que ela combinou a carta corretamente, e deve seguir a mesma regra para a carta seguinte; se ele disser não, significa que ela não combinou a carta corretamente e tem, então, que mudar de regra para combinar as cartas. Uma vez dadas às instruções, qualquer que seja a categoria (cor, forma, número) escolhida pela criança, ela é considerada como correta e, se as respostas seguintes obedecerem a esse mesmo critério, elas também são consideradas como corretas. Após seis respostas corretas consecutivas, o examinador diz não (na sétima carta). Uma vez que a criança escolhe o segundo critério (regra) diferente do primeiro (cor, forma, número), este é considerado correto, e se as respostas seguintes obedecerem a esse mesmo critério, elas estão corretas. Em caso de falha, a criança não pode fornecer uma segunda resposta (nesse caso, somente a primeira resposta é levada em consideração; eventualmente anotar a correção no protocolo de resposta). Cabe salientar que se a criança comete seis erros consecutivos, as instruções da tarefa são retomadas. Na pontuação do NCST são considerados o número de categorias completadas, o tempo de execução da tarefa, o número de perseverações, de abandonos prematuros da regra e de erros não perseverativos.

1.3.2. Trail Making Test (TMT)

Esta atividade é uma adaptação do TMT, que tem como objetivo avaliar a capacidade de alternar o foco atencional entre conjuntos de estímulos. Diferentemente da versão original, esta tarefa é composta por três etapas: Etapa ‘A Números’, Etapa ‘A Letras’ e Etapa ‘B Números e Letras’. Todas as etapas contêm um item de exemplo e treino, através do qual se verifica a compreensão e a execução da tarefa simplificada. Na primeira etapa (‘A Números’) é solicitado a criança que ligue os números (1-20) em ordem numérica crescente. Na etapa 2 (‘A Letras’) a criança deve ligar as letras em ordem alfabética (A-T) e por fim, na etapa 3 (‘B Números e Letras’) a criança deve ligar letras e números de forma alternada mantendo a ordem alfabética e numérica crescente. Os fatores considerados na pontuação para duas primeiras partes são: ‘Tempo’ (em segundos), ‘Número de erros de ordem na sequência’, ‘Número de erros corrigidos’ (antes que o examinador indique à criança o erro), ‘Número de quase erros’ (início de resposta incorreta autocorrigida). Na terceira parte, além dos itens já citados, avalia-se o ‘Número de erros de alternância’. Por fim, essas pontuações gera um índice: Tempo (Equação 12):

$$\textbf{Índice Tempo} = \frac{\textbf{Parte 3}}{\left[\frac{(\textbf{Parte 1} + \textbf{Parte2})}{\textbf{2}}\right]} \qquad (12)$$

1.3.3. Brixton Júnior

O Teste Brixton Júnior objetiva investigar a dedução de regras e flexibilidade cognitiva em crianças, tendo sido desenvolvido especialmente para compor o protocolo FEE. Nessa tarefa as crianças têm que prever o movimento que o sapo fará, considerando para tanto um conjunto de regras pré-estabelecidas, que são modificadas ao longo da tarefa. É apresentado à criança um livro de estímulos que contém as instruções e diferentes imagens de um lago coberto de vários nenúfares numerados e um sapo sob uma das plantas (Figura 6).

Durante a tarefa, o sapo muda de lugar, mas sempre de maneira lógica, por exemplo, em sequências de n +1, sequências de números pares e ímpares, dentre outras. A criança é orientada a descobrir essa lógica o mais rápido possível, pois será marcado o tempo. Porém, em dado momento da tarefa, o sapo muda de lógica sem avisar e a criança deve descobrir sua nova lógica. Um ponto é dado por cada localização correta e o tempo de administração é de cerca de cinco minutos, de acordo com dados franceses. A pontuação é dada a partir do tempo de execução em segundos e pontuação total da tarefa, calculada pela soma dos pontos por localização correta.

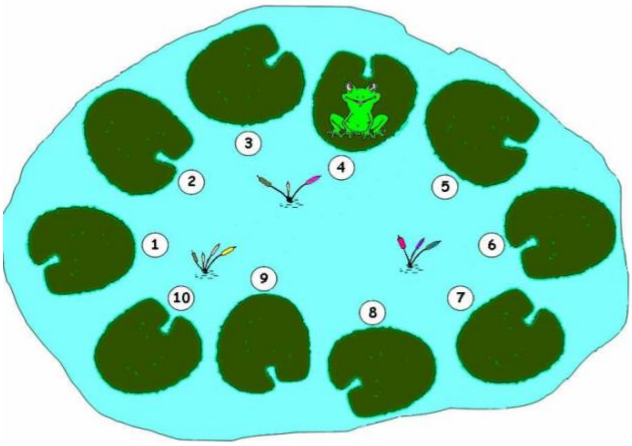

Figura 4. Exemplo do teste Brixton Júnior

1.4. Planejamento

1.4.1. Labirintos

Trata-se de uma tarefa original construída por Roy, Le Gall e Fournet, inspirada em uma adaptação do subteste *Labirintos* da WISC-III. A tarefa proposta consiste em ajudar um dinossauro a sair do labirinto. É constituída de oito labirintos de complexidade variável (Figura 5), numerados de um a oito, sendo os sete primeiros impressos em folhas A4 o último em uma folha A3. O tempo limite para a execução de cada labirinto é de quatro minutos (tempo total 32 minutos), porém, os dados franceses apontam média de 10 minutos para a realização desta atividade.

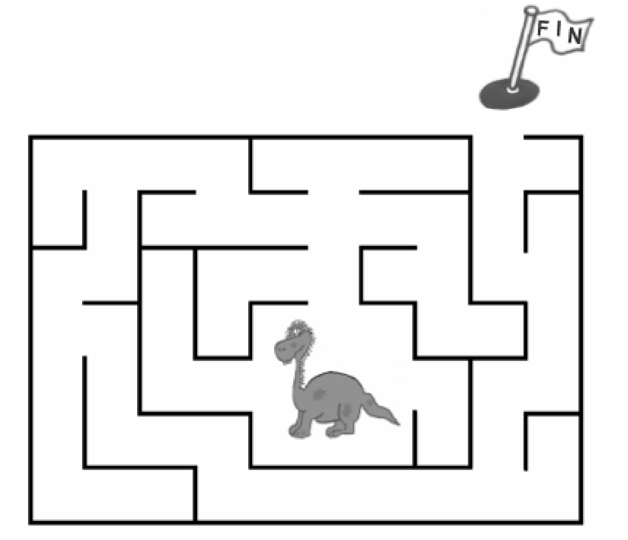

Figura 5. Exemplo de labirinto apresentado à criança

Os critérios de pontuação propostos pelo FEE foram relativamente modificados, quando comparados aos que são fornecidos pela WISC-III. Na versão do FEE, os erros correspondem à entrada em um beco sem saída, conforme os testes tradicionais tais como o *Labirintos* da WISC-III. Porém, nesse último os erros são computados exclusivamente quando a criança entra num beco sem saída, sem que sejam considerados outros pequenos impasses interligados, denominados "adjacentes". Desta forma, a criança é penalizada apenas uma vez, independentemente do número de impasses adjacentes nos quais se envolveu. Ao contrário, no FEE, considera-se que cada impasse adjacente constituiu um erro distinto, e não o prolongamento de um só e mesmo erro.

Durante a tarefa, são recomendadas, quantas vezes forem necessárias, intervenções sublinhando os erros cometidos pela criança (e não apenas uma vez como para o subteste *Labirintos* da WISC-III). Sendo, porém, imperativo anotar essas intervenções de maneira sistemática (de modo a analisar retrospectivamente todos esses comportamentos de forma precisa). A tarefa ainda avalia o tempo de latência, ou seja, o tempo decorrido entre o final das instruções e o início do traçado do caminho pela criança.

1.4.2. Roteiros (*Scripts)*

'Roteiros' é uma tarefa original construída por Roy et al. (2012) para compor o protocolo FEE. O objetivo da tarefa consiste em investigar as capacidades para a organização de atividades cotidianas a partir de material verbal, ou seja, a criança deve ordenar frases de forma a construir um roteiro coerente em função do título dado. Para aplicação desse teste são necessários cinco envelopes: três contendo cartões (12cm x 3cm) com ações escritas em uma linha (em Arial, tamanho 16); um envelope contendo cartões de exemplo; um envelope contendo os Títulos para os quatro roteiros estabelecidos, que constituem atividades do dia-a-dia. Dentre os cartões fornecidos, dois dos envelopes contêm frases de intrusão, ou seja, frases que não estão relacionadas com o roteiro estabelecido. A seguir são descritas as ações propostas:

- Exemplo: Se preparar para ir dormir à noite (sem intrusão). [A menção "exemplo" é indicada sobre o envelope];
- Envelope 1: Tomar banho (com intrusão);
- Envelope 2: Preparar a mochila para a escola (com intrusão)
- Envelope 3: Fazer as compras no supermercado (sem intrusão)

Após a execução do exemplo, a criança é convidada a escolher em qual ordem quer abrir os envelopes. O examinador mostra então os títulos "Tomar um banho" ou "Se preparar para ir dormir à noite" ou "Fazer compras no supermercado" segundo a ordem de abertura dos envelopes escolhida pela criança. Em seguida, o examinador lê o título, abre o envelope correspondente diante da criança e dispõe as ações referentes ao título escolhido de forma aleatória, evitando que as três intrusões apareçam agrupadas.

Na sequência, o examinador lê para a criança todas as ações espalhadas na mesa e convida a criança a coloca-las em ordem de acordo com a forma que as pessoas geralmente fazem, da primeira até a última, fazendo uma coluna logo abaixo do título. A criança então ordena as frases e posteriormente (somente após a finalização dos três roteiros), deve justificar o ordenamento dos arranjos, incluindo as intrusões, explicando seu comportamento em relação às intrusões. É importante salientar que em nenhum momento é dito à criança que existem intrusões nos roteiros e, a cada pergunta sobre as intrusões é dito: “faça como quiser, você decide”, sem dar à criança a impressão de que ela tem o direito de recusar ou aceitar a intrusão.

Quando a criança termina a ordenação do roteiro, o examinador coloca a coluna de ações que ela realizou de lado, respeitando a posição espacial reservada para as intrusões, se estas não forem incluídas na coluna de ações que ela ordenou e passa ao roteiro seguinte. O examinador anota no protocolo o tempo para a realização de cada roteiro e a natureza das intervenções e reações (verbais ou não verbais) da criança sobre as intrusões e o momento em que eles ocorrem (durante a leitura das etiquetas, durante a arrumação, após a classificação, etc.).

A pontuação dessa tarefa é dada a partir do tempo (em segundos) que a criança usa para ordenar as diferentes ações em cada roteiro e o tempo total de realização da tarefa. Além disso, são considerados o número total de ações corretas rejeitadas e o número total de intrusos aceitos, bem como a sequência estabelecida pela criança para cada roteiro.

1.4.3 Figura de Rey

Esta tarefa representa uma ampliação do Teste das Figuras Complexas de Rey, proposto originalmente por Rey (1941). Nesta versão, além da Cópia Espontânea (CE) da figura tradicional, que possibilita a avaliação das habilidades de visuoespacialidade, visuoconstrução e planejamento; foi adicionada a realização de Cópia Programada (CP), proposta por Roy et al. (2010), cujo objetivo é possibilitar a avaliação isolada das habilidades de planejamento e das habilidades visuoespaciais e visuoconstrutivas. A CP (Figura 13) é realizada após decorridos 20 minutos da realização da CE (antes da execução da tarefa de atualização verbal), e consiste na apresentação sequencial de cinco pranchas, conforme ilustrado na Figura 13. Em cada prancha, a criança recebe um lápis de cor correspondente à cor apresentada na prancha (Preto- prancha 1, Cinza- prancha 2, Verde – prancha 3, Azul – prancha 4 e Vermelho – prancha 5). As produções oriundas das duas etapas (tradicional e programada) são avaliadas a partir de três índices: 'Precisão', 'Tempo' e 'Tipo de Cópia' (somente para a CE), considerando-se para tanto a classificação proposta por Osterrieth (1959). Posteriormente, é calculado o 'Índice de Planejamento' (IP), a partir da Equação 04:

$$IP = (\boldsymbol{P} * \mathbf{100})/\boldsymbol{C} \qquad 13$$

Sendo P o score de precisão da CP e C o escore de precisão da cópia tradicional.

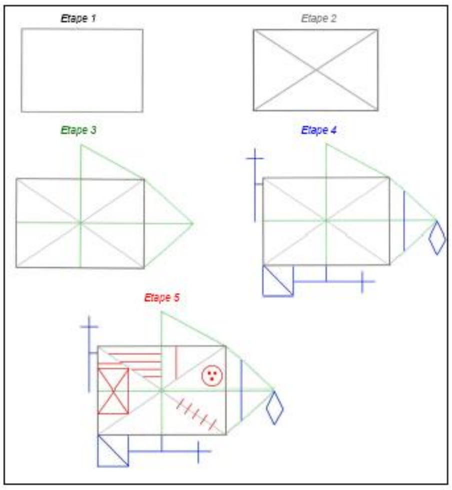

Figura 6. Cópia Programada da Figura de Rey

Annex 3 - Description of the scales that assess the interest and success of the child

2.1 Escala de Interesse

A ‘Escala de Interesse’ do Protocolo FEE é baseada na “Face pain scale” e tem como objetivo avaliar o interesse da criança em relação a cada teste proposto no protocolo. A Escala (corresponde a uma faixa horizontal composta por cinco rostos, cujas expressões variam do ‘mais alegre’ ao ‘mais triste’, conforme Figura 7, e deve ser preenchida pela criança e pelo examinador (auto e heteroavaliação, respectivamente). A pontuação dada varia de 1 (‘mais triste’) a 5 (‘mais alegre’), representando a motivação da criança.

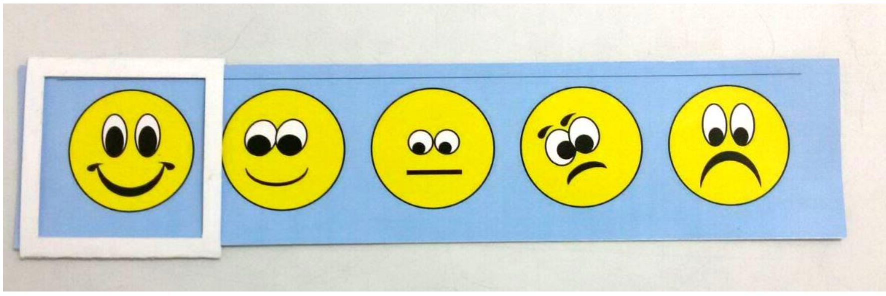

Figura 1. Escala de Interesse

2.2 Escala de Sucesso

A ‘Escala de Sucesso’ foi criada especialmente para compor o Protocolo FEE e é preenchida igualmente pela criança e pelo examinador. Nessa escala avalia-se o sucesso obtido pela criança em cada tarefa, sendo aplicada logo após a ‘Escala de Interesse’. A criança é convidada a mover o cursor (ciclista) em uma montanha com cinco cores – vermelho, laranja, amarelo, verde escuro e verde claro, conforme Figura 8 - para indicar o seu desempenho na tarefa. Se a criança coloca o ciclista no topo da montanha (verde claro) significa que ela acredita que foi muito bem na tarefa e se ela deixa o ciclista na base da montanha (vermelha) ela acredita que foi muito mal. Assim como a ‘Escala de Interesse’, a ‘Escala de Sucesso’ é composta de cinco pontos, sendo 1 o ponto mais baixo da montanha e 5 o ponto mais alto. Essa Escala também deverá ser aplicada ao fim de cada teste que compõe o FEE.

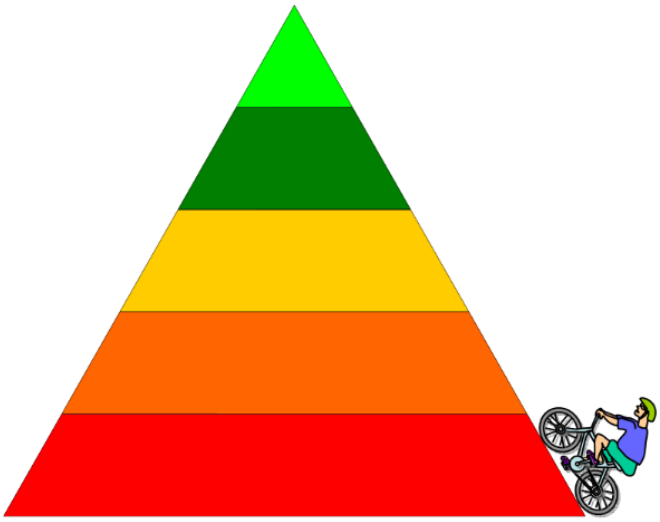

Figura 2. Escala de Sucesso

Anexo 3- Descrição do Behavior Rating Inventory of Executive Function (BRIEF)

O BRIEF é um questionário para pais, professores e adolescentes que avalia o ecologicamente as FE, considerando para tanto os contextos da casa e do ambiente escolar. Foi projetado de forma a contemplar ampla faixa etária (cinco a 18 anos de idade). Há três formas do BRIEF: a 'Forma Pessoal' é uma medida de auto relato projetada para ser preenchida pelo próprio sujeito (com idades entre 11 e 18 anos), constituída por 80 questões, que investigam o ponto de vista do respondente acerca de sua percepção de seu próprio funcionamento executivo no ambiente cotidiano. A forma desenvolvida para ser respondida por pais e professores, é constituída por questionários com 86 questões cada um, considerando para essas duas formas, a faixa etária da criança ou adolescente entre cinco e 18 anos. Os respondentes são instruídos a graduar em uma escala (nunca, algumas vezes, frequentemente) com qual frequência a criança apresenta o comportamento problema. No Protocolo FEE, apenas as versões para pais e professores são aplicadas.

O resultado da Escala oferece uma medida global do funcionamento executivo assim como fornece outros dois índices: 'Regulação do Comportamento' e 'Metacognição". O índice de 'Regulação do Comportamento' inclui três domínios: inibição, flexibilidade e controle emocional; enquanto o índice de 'Metacognição' inclui cinco domínios: iniciativa, MT, planejamento/organização, organização do material e monitoramento.

O tempo previsto para o preenchimento de cada um dos questionários (pais, professores e a versão pessoal) é de aproximadamente 10 a 15 minutos. Idealmente, os questionários devem ser preenchidos em ambiente calmo. Os escores dos questionários são expressos em escores padrão *eranksde percentis*. Todas as medidas do BRIEF são convertidas em escore T, permitindo comparar os resultados do sujeito em relação ao grupo normativo.

Annex 4 - Description of the subtests Matrix Reasoning and Vocabulary of WISC-IV

4.1 Subtestes Raciocínio Matricial e Vocabulário da WISC-IV

Raciocínio Matricial é um subteste que avalia habilidades do domínio da inteligência fluída, ou seja, a capacidade de raciocinar em situações novas e pouco estruturadas que requerem autonomia intelectual, reconhecimento e formação de conceitos, compreensão de implicações, resolução de problemas, extrapolação, reorganização ou transformação de informações. Trata-se de um teste de caráter não verbal que é considerado o subteste principal do índice de organização perceptual.

Por outro lado, o subteste Vocabulário tem como objetivo mensurar o conhecimento de palavras e a formação de conceitos verbais, bem como a aprendizagem, a memória de longo prazo, a abstração, a expressão verbal e o nível de desenvolvimento linguístico. É o subteste principal da índice de compreensão verbal.

Annex 5 - Sociodemographic questionnaire

VULNERABILIDADE, RISCO E ESTRESSE: IMPLICAÇÕES PARA O DESENVOLVIMENTO DAS FUNÇÕES EXECUTIVAS E AQUISIÇÃO DE HABILIDADES ESCOLARES

QUESTIONÁRIO SÓCIO-ECONÔMICO

Identificação da Criança

Nome:________________________ Sobrenome:_________________________

Data de Nascimento:_______________________ Idade: ______________________

Sexo ( ) Feminino ( ) Masculino

Informações Familiares

Profissão dos Pais (ou tutores legais)

Mãe: ____

Pai: ____

Escolaridade dos Pais (grau mais elevado obtido)

Mãe: ____

Pai: ____

Número de irmãs e irmãos da criança: ______________________________

Renda familiar (em salários mínimos):_______________________________

Escolaridade da Criança

Série Atual:____

Repetência(s):

( ) Sim ( ) Não

Se sim, qual série?____

Salto(s) de série:

( ) Sim ( ) Não

Se sim, qual série?____

Apoio Escolares:

( ) Sim ( ) Não

Se sim, especificar:
Disciplina: ____________________ Série (especificar o período): ________________________
Frequência (ex. 2 horas por semana): ___________________

Apoio extra-escolar
( ) Sim ( ) Não
Se sim, especificar:
Disciplina: ____________________ (psicólogo, fonoaudiólogo...)
Série: ________________________ (especificar o período)
Frequência: ___________________ (ex. 2 horas por semana)

Desenvolvimento – saúde da criança

Problemas particular durante a gravidez ou parto?

( ) Sim ( ) Não

Se sim, Qual?____

Utilização de Medicação (atual)

( ) Sim ( ) Não

Se sim, Qual?____

Antecedentes de patologia neurológica diagnosticada

( ) Sim ( ) Não

Se sim, Qual?____

Antecedentes de patologia psiquiátrica diagnosticada

( ) Sim ( ) Não

Se sim, Qual?____

Antecedentes de dificuldade de aprendizagem diagnosticada (dislexia, disfasia, TDA, ...)

( ) Sim ( ) Não

Se sim, Qual?____

Transtorno sensorial (auditivo, visual) incompatível com a realização dos testes

( ) Sim ( ) Não

Se sim, Qual?____

Annex 6 - Term of Consent

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO – TCLE

Esclarecimentos

Estamos solicitando a você a autorização para que a criança pela qual você é responsável participe da pesquisa: VULNERABILIDADE, RISCO E ESTRESSE: IMPLICAÇÕES PARA O DESENVOLVIMENTO DAS FUNÇÕES EXECUTIVAS E AQUISIÇÃO DE HABILIDADES ESCOLARES, que tem como pesquisador responsável a Prof(a) Drª Izabel Hazin do Departamento de Psicologia da UFRN.

Esta pesquisa pretende avaliar o impacto das questões sociais no desenvolvimento de algumas funções cognitivas que são importantes para o processo de desenvolvimento e aprendizagem.

O motivo que nos leva a fazer este estudo é a possibilidade de compreender como as crianças e adolescentes aprendem e assim poder auxiliar os professores com métodos de ensino, buscando um maior aproveitamento em sala de aula.

Caso você decida autorizar, iremos fazer algumas atividades com a criança, algumas são semelhantes as feitas em sala de aula e outras parecidas com jogos. Os encontros com a criança durarão em média 1h e 30 min e ocorrerão 2 vezes. Todos os testes serão realizados nas dependências da escola, durante o período escolar regular, com autorização prévia da Diretoria. Além das atividades com as crianças também será feito um questionário com os responsáveis, para responder esse questionário será marcado um horário e local de melhor conveniência para ambas as partes. Como a pesquisa tem enfoque nas questões escolares, também será feito um questionário com o professor da turma da criança.

Os testes não oferecem riscos, mas podem causar cansaço, no caso disso acontecer os testes poderão ser remarcados, para que a criança não se sinta mal, ou até mesmo cancelados pelo participante.

Além do benefício amplo da pesquisa para o processo de aprendizagem na cidade de Natal, ao final os participantes receberão um relatório que falará do desempenho individual ao longo da pesquisa. Que poderá auxiliar pais e professores a compreender o funcionamento cognitivo da criança.

Em caso de algum problema que ele(a) possa ter, relacionado com a pesquisa, ele(a) terá direito a assistência gratuita que será prestada, pelo Serviço Aplicado de Psicologia da UFRN. Durante todo o período da pesquisa você poderá tirar suas dúvidas ligando para Profa. Izabel Hazin pelo telefone (84) 3342-2236 (ramal 332). Qualquer dúvida sobre a ética dessa pesquisa você deverá ligar para o Comitê de Ética em Pesquisa da Universidade Federal do Rio Grande do Norte, telefone 3215-3135.

Você tem o direito de recusar sua autorização, em qualquer fase da pesquisa, sem nenhum prejuízo para você e para ele(a).

Os dados que ele(a) irá nos fornecer serão confidenciais e serão divulgados apenas em congressos ou publicações científicas, não havendo divulgação de nenhum dado que possa identificá-lo(a).

Esses dados serão guardados pelo pesquisador responsável por essa pesquisa em local seguro e por um período de 5 anos.

Se você tiver algum gasto pela participação dele(a) nessa pesquisa, ele será assumido pelo pesquisador e reembolsado para você.

Se ele(a) sofrer algum dano comprovadamente decorrente desta pesquisa, ele(a) será indenizado.

Qualquer dúvida sobre a ética dessa pesquisa você deverá ligar para o Comitê de Ética em Pesquisa da Universidade Federal do Rio Grande do Norte, telefone 3215-3135.

Este documento foi impresso em duas vias. Uma ficará com você e a outra com o pesquisador responsável Profª Drª Izabel Hazin.

Consentimento Livre e Esclarecido

Eu, ____, representante legal do menor ____, autorizo sua participação na pesquisa VULNERABILIDADE, RISCO E ESTRESSE: IMPLICAÇÕES PARA O DESENVOLVIMENTO DAS FUNÇÕES EXECUTIVAS E AQUISIÇÃO DE HABILIDADES ESCOLARES

Esta autorização foi concedida após os esclarecimentos que recebi sobre os objetivos, importância e o modo como os dados serão coletados, por ter entendido os riscos, desconfortos e benefícios que essa pesquisa pode trazer para ele(a) e também por ter compreendido todos os direitos que ele(a) terá como participante e eu como seu representante legal.

Autorizo, ainda, a publicação das informações fornecidas por ele(a) em congressos e/ou publicações científicas, desde que os dados apresentados não possam identificá-lo(a).

Natal, Março de 2016.

Assinatura do representante legal

____

Assinatura do pesquisador responsável

____

Impressão datiloscópica do representante legal

Annex 7 - Convergent validity analysis

		5 digits test				**Digit span**		**Corsi block-tapping test**		**WISC-IV**	
		Non-executive measures		Executive measures		Non-executive measures	Executive measures	Non-executive measures	Executive measures	Non-executive measures	
		Counting	*Reading*	*Choosing*	*Shifting*	*Forward score*	*Backward score*	*Forward score*	*Backward score*	*Vocabulary*	*Matrix Reasoning*
Executive measures	**Stroop -** *Interference*	.27	.13	.28	.38*	-.01	-.23	-.21	-.33	.31	.19
	Tapping										
	Go/No-Go Time	.20	.38*	.49**	.43*	.21	-.13	-.35*	-.21	.13	-.14
	Conflict Time	.40*	.40*	.57**	.52**	-.40*	-.49 **	-.59**	-.59*	.12	-.13
	Barre Joe	.08	.05	.25	.23	-.18	-.05	.17	-.34	-.03	.26
	Updating tests										
	Verbal score	-.33	-.64**	-.29	-.46	.48	.58*	-.09	.02	.50	.30
	Visuospatial score	-.38	-.26	-.10	-.25	.16	-.28	.27	.13	-.20	.02
	Double task										
	Evolution digit span	.13	.03	.13	.16	.10	-.024	-.36*	-.08	.36	.05
	Evolution clowns	-.25	-.14	-.10	-.14	-.23	.06	-.04	.19	.01	-.05
	KCST - *Time*	.60**	.34	.61**	.50**	.11	-.20	-.42*	-.60**	.26	.32
	TMT - *Time*	.42*	.32	.45*	.52**	-.34	-.43*	-.09	-.50**	-.40	-.06
	Frog test -*Time*	.29	.05	.36	.26	-.11	-.17	-.51**	-.43*	-.01	-.02
	8 mazes – *Time*	-.04	.24	.35	.52**	-.07	.13	.18	-.11	-.23	-.17
	Scripts – *Time*	.12	-.01	.08	.36	-.07	-.20	-.25	-.16	.13	.07
	ROCF – *Planning Index*	.39	.03	.19	.17	-.03	.03	-.31	-.20	-.03	.02

		Non-executive measures								
		Stoop		**Tapping**	**Updating tests**		**Double task**		**TMT**	
		Naming	*Reading*	*Simple conditioning*	*Verbal baseline*	*Visuospatial baseline*	*Span task*	*Visuomotor clown*	*Numbers*	*Letters*
Executive measures	**Stroop -** *Interference*	.30	.18	-.02	-.16	-.13	-.20	.13	.10	.08
	Tapping									
	Go/No-Go Time	.11	.27	.51	-.16	-.17	-.24	-.01	.11	,17
	Conflict Time	.12	.15	.31	-.01	-.04	-.14	.07	.10	.18
	Barre Joe - *Time*	.21	.16	.05	-.02	-.09	-.23	-.04	.24	.14
	Updating tests									
	Verbal score	-.15	-.21	.02	.44	.20	.17	.08	-.28	-.33
	Visuospatial score	-.20	-.12	-.10	.20	.28	.19	-.11	-.22	-.16
	Double task									
	Evolution digit span	-.02	-.01	.10	-.07	-.04	.02	-.06	-.01	-.03
	Evolution clowns	.17	.03	-.01	-.06	.04	-.18	.11	.01	-.01
	KCST - *Time*	.18	.20	.11	-.13	-.17	-.32	.04	.06	.21
	TMT - Alternance	.27	.20	.19	-.19	-.15	-.24	.12	.37	.42
	Frog test -*Time*	.18	.18	.11	-.07	-.14	-.13	.09	.16	.15
	8 mazes – *Time*	.25	.19	.09	-.26	-.20	-.24	-.07	.52	.29
	Scripts – *Time*	.25	.44	.16	-.23	-.26	-.20	.04	.19	.22
	ROCF – *Planning Index*	.05	.11	-.01	-.09	-.15	-.12	.01	.14	.08