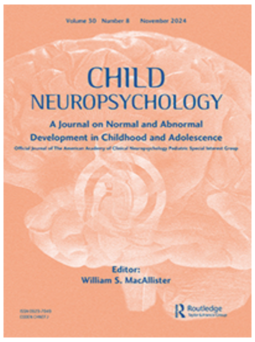

Child Neuropsychology

A Journal on Normal and Abnormal Development in Childhood and Adolescence

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ncny20

Factor structure and measurement invariance of the Childhood Executive Functioning Inventory (CHEXI) across parents and teachers in Portuguese children

Octávio Moura, Marcelino Pereira, Cristina P. Albuquerque & Mário R. Simões

To cite this article: Octávio Moura, Marcelino Pereira, Cristina P. Albuquerque & Mário R. Simões (18 Jan 2025): Factor structure and measurement invariance of the Childhood Executive Functioning Inventory (CHEXI) across parents and teachers in Portuguese children, Child Neuropsychology, DOI: 10.1080/09297049.2025.2455469

To link to this article: https://doi.org/10.1080/09297049.2025.2455469

Published online: 18 Jan 2025.

CHILD NEUROPSYCHOLOGY
https://doi.org/10.1080/09297049.2025.2455469

Factor structure and measurement invariance of the Childhood Executive Functioning Inventory (CHEXI) across parents and teachers in Portuguese children

Octávio Moura [a,b], Marcelino Pereira [a,b], Cristina P. Albuquerque [a,b] and Mário R. Simões [a,b]

[a]Center for Research in Neuropsychology and Cognitive and Behavioural Intervention, Faculty of Psychology and Educational Sciences, University of Coimbra, Coimbra, Portugal; [b]Psychological Assessment and Psychometrics Laboratory (PsyAssessmentLab), Faculty of Psychology and Educational Sciences, University of Coimbra, Coimbra, Portugal

ABSTRACT

The Childhood Executive Functioning Inventory (CHEXI) is a rating scale that evaluates everyday behaviors associated with executive functions in children. This study aimed to investigate the factor structure and the measurement invariance across parents and teachers of the CHEXI in a sample of 279 Portuguese typically developing children (6 to 12 years old, $n = 160$ girls and $n = 119$ boys). Most studies only analyzed the original two-factor model, and the few that investigated the four-factor model found a nearly identical fit between both factor structures. Confirmatory factor analysis was used to test five competing factor models and the four-factor models (slightly better than the two-factor model) demonstrated the most adequate fit to the data for both parents and teachers. The CHEXI showed adequate reliability and convergent validity with the BRIEF2. The measurement invariance of the four-factor model across parents and teachers was fully supported (configural, metric, and scalar invariance). Overall, the CHEXI showed adequate psychometric properties, suggesting that is a useful instrument to assess executive functioning based on reports of behaviors observed by parents and teachers in Portuguese typically developing children.

ARTICLE HISTORY
Received 12 July 2024
Accepted 14 January 2025

KEYWORDS
Executive functions; confirmatory factor analysis; measurement invariance; parents; teachers

Executive functions (EF) are a complex, multidimensional construct that encompasses cognitive processes required for conscious, top-down control of behaviors, thoughts, and emotions. It refers to metacognitive capacities that allow an individual to perceive stimuli, respond adaptively, establish goals, flexibly change actions, monitor results, and respond in an integrated way (Baron, 2018). That is, EF is an umbrella term comprising a wide range of higher-order cognitive processes necessary for goal-directed behavior, such as flexibility/shifting, inhibition, planning, problem-solving, working memory, updating, and initiation, among others (Friedman & Miyake, 2017; Jurado & Rosselli, 2007; Wasserman & Wasserman, 2013).

CONTACT Octávio Moura octaviomoura@gmail.com Center for Research in Neuropsychology and Cognitive and Behavioural Intervention, Faculty of Psychology and Educational Sciences, University of Coimbra, Rua Do Colégio Novo, Coimbra 3000-115, Portugal

Neurodevelopmental studies have shown that EF emerges in early childhood and develops significantly throughout childhood and adolescence, and that adult-level performance on the most complex EF tasks does not occur until adolescence or even early adulthood (Best & Miller, 2010; Davidson et al., 2006). The influence of age on EF task performance has been associated with the maturation of the brain, specifically the frontal lobe (Blakemore & Choudhury, 2006; Tamnes et al., 2010). Neuroimaging studies with healthy individuals and patients with brain damage have found that various brain regions (frontal, parietal, cerebellar) correlate with performance in EF tasks (Collette et al., 2006; Demakis, 2004; Nowrangi et al., 2014). EF depends on extensive brain networks, and the neural correlates of EF seem to be similar between various clinical groups (Baron, 2018; Nowrangi et al., 2014).

EF are relevant cognitive phenotypes for a variety of neurodevelopmental disorders (e.g., developmental dyslexia, attention-deficit/hyperactivity disorder [ADHD], autism spectrum disorder; Marzocchi et al., 2008; May & Kana, 2020; Moura et al., 2014, 2017; Roberts et al., 2017; Willcutt et al., 2005), neurological disorders (e.g., epilepsy; Zanaboni et al., 2021), and play an important role in school readiness (Blair & Raver, 2015), reading comprehension (Spencer et al., 2020), math skills (Emslander & Scherer, 2022; Schmitt et al., 2017), academic performance (Muñoz & Filippetti, 2021), behavior problems (Schoemaker et al., 2013; Yang et al., 2022), among others.

Performance-based tests and rating scales are commonly used to assess EF in neuropsychological evaluations. The relevance of considering both instruments relies on existing evidence suggesting that these measures capture different underlying executive functioning constructs (Ten Eycke & Dewey, 2016; Toplak et al., 2009, 2013). Performance-based tests are administered in highly standardized conditions and their performance is typically measured by accuracy scores, response time, or speeded responding under a time constraint (e.g., Trail Making Test, Wisconsin Card Sorting Test, Stroop Color and Word Test, Tower of London). Performance-based tests are more related to the efficiency of cognitive abilities and the so-called "cool" EF used in relatively neutral emotional and motivational contexts (Toplak et al., 2013; Zelazo, 2020).

Rating scales were developed to provide an ecologically valid indicator of competence in complex problem-solving situations and behavioral regulation (e.g., Behavior Rating Inventory of Executive Function [BRIEF (Gioia et al., 2000, 2015)], Barkley Deficits in Executive Functioning Scale – Children and Adolescents [BDEFS-CA (Barkley, 2012)], Childhood Executive Functioning Inventory [CHEXI (Thorell & Nyberg, 2008)]. Rating scales are more related to real-life situations and the so-called "hot" EF used in emotional and motivational contexts (Shum et al., 2021; Zelazo, 2020; Zelazo & Carlson, 2012). Parent and teacher rating scales are relevant predictors of ADHD status and account for a significant amount of variance in the behavioral problems associated with ADHD (Aita et al., 2022; Jacobson et al., 2020; Shum et al., 2021; Toplak et al., 2009).

Considering that EF play a significant role in typical and atypical cognitive, behavioral, social, and academic outcomes, the present study aimed to investigate the psychometric properties of the CHEXI in Portuguese typically developing children.

CHEXI factorial structure

The CHEXI is a rating instrument for parents and teachers developed by Thorell and Nyberg (2008) to measure executive functioning in children aged 4–12. The preliminary version of the CHEXI included 26 items, but two items were excluded from the factor analysis (and were also dropped out from the final version) due to low shared variance. Thus, the final version comprised 24 items that are organized into four subscales (Working Memory, Planning, Regulation, and Inhibition), and two scales: Working Memory (Working Memory and Planning subscales) and Inhibition (Regulation and Inhibition subscales). Their items were based on Barkley's (1997) hybrid model of EF deficits in children with ADHD, and Baddeley and Hitch's (1974) working memory framework. During their development, the authors tried to avoid a semantic overlap between the EF and ADHD symptoms (as found in other rating scales: e.g., BRIEF), including items that only reflected executive functioning (core functions such as working memory, inhibition, and self-regulation) and excluding those that are related to ADHD symptoms. The CHEXI has the advantage of capturing everyday behavior over an extended period, it is easy and quick to administer, it is freely available in several languages (https://chexi.se), and it seems to be a valuable screening instrument for identifying children with ADHD (Alyami, 2023; Catale et al., 2015; Thorell et al., 2010).

In the original study with Swedish kindergarten children, Thorell and Nyberg (2008) performed an exploratory factor analysis with oblique rotation and found that a two-factor solution best fit the data. The first factor (Working Memory scale) comprised the items from the Working Memory and Planning subscales, whereas the second factor (Inhibition scale) included the items from the Inhibition and Regulation subscales. Since then, the factorial structure of the CHEXI has been investigated by a large number of studies in different countries (e.g., Argentina, Belgium, Brazil, Iran, Saudi Arabian, Spain, Sweden, United States of America) with typically developing children (Camerota et al., 2018; Catale et al., 2013; Conesa, 2023; Gutierrez et al., 2021; Mashhadi et al., 2023; Trevisan et al., 2017) and children with ADHD (Alyami, 2023; Catale et al., 2015).

Catale et al. (2013) reproduced the original two-factor model in a sample of parents, through confirmatory factor analysis (CFA), and found an adequate fit: comparative fit index (CFI) = .96, root mean square error of approximation (RMSEA) = .076, and standardized root mean square residual (SRMR) = .07. In a sample of parents of children with ADHD, Alyami (2023) also found support for the two-factor structure (CFI = .93, RMSEA = .07, SRMR = .05).

Surprisingly, few studies compared other factor solutions than the original two-factor model. Gutierrez et al. (2021) analyzed the one- and two-factor models and concluded that the latter showed a better fit to the data (parents' form: CFI = .97, RMSEA = .062; teachers' form: CFI = .99 RMSEA = .081). Camerota et al. (2018) was the first study that compared the two- (Working Memory and Inhibition scales) and four-factor models (Working Memory, Planning, Regulation, and Inhibition subscales) for parents and concluded that both models were nearly identical and redundant (CFI = .94, RMSEA = .04, SRMR = .04, for both models). Mashhadi et al. (2023) contrasted three-factor solutions (one-, two-, and four-factor models for parents) and found that the two-factor model (CFI = .96, RMSEA = .06, SRMR = .04) was slightly better than the four-factor model (CFI = .95, RMSEA = .08, SRMR = .05), and the unitary model was not adequate (CFI = .69, RMSEA = .13, SRMR = .07). Similarly, Conesa (2023) also found that both models revealed good goodness-of-fit indices, but the two-factor model (parents' form) showed a better fit (two-factor model: CFI = .98, RMSEA = .05, SRMR = .06; four-factor model: CFI = .95, RMSEA = .08, SRMR = .05).

The CHEXI demonstrated adequate reliability (e.g., Catale et al., 2013: α ≥ .89; Conesa, 2023: α ≥ .84 and McDonald's ω ≥ .84; Gutierrez et al., 2021: McDonald's ω ≥ .84) and the convergent validity has been also confirmed. For example, Mashhadi et al. (2023) found correlation coefficients greater than .55 between the CHEXI scales and the BDEFS-CA in Iranian typically developing children (parents' form). In a sample of children with ADHD (parents' form), Parhoon et al. (2022) found correlation coefficients ranging from .71 (Working Memory) to .89 (Inhibition) between the CHEXI subscales and the BRIEF2 Global Executive Composite.

Surprisingly, no studies have investigated the measurement invariance of the CHEXI across parents and teachers. Measurement invariance concerns the extent to which the psychometric properties of the observed indicators can be generalizable across groups or conditions (Sideridis et al., 2015; Vandenberg & Lance, 2000). Thus, testing measurement invariance is an important step in the validation process of a psychological test because most of the research and clinical practice involves between-group comparisons with the implicit assumption (rarely tested) that the constructs/tests are measured in similar terms across groups or populations (Sideridis et al., 2015). However, if the measurement invariance is not achieved for a particular (cognitive) test, the latent (cognitive) ability that the test is supposed to measure does not explain all observed group differences on that test (i.e., the mean group differences are not solely explained by the latent [cognitive] ability), negatively affecting the quality of assessment and decisions made based on the test scores (Moura et al., 2018, 2023; Wicherts, 2016). In the specific case of the CHEXI, if the measurement invariance is achieved, it means that researchers and clinicians can compare subscale/scale scores reliably across the parents and teachers forms.

The present study

The main objective of this study is to investigate the psychometric properties (reliability, factor structure, measurement invariance, and convergent validity) of the CHEXI in a sample of parents and teachers of Portuguese typically developing children. Even though Portuguese is the sixth most spoken language in the world (Lewis et al., 2015), this is the first study that explores the factor structure of the CHEXI in European Portuguese-speaking children. To the best of our knowledge, this is also the first study that explores the measurement invariance of the CHEXI across parents and teachers, and compares various factor solutions (one-, two-, and four-factor models; correlated and hierarchical models).

Based on the existing literature, we hypothesized that the two- and/or four-factor model would be the most interpretable and parsimonious factor solutions for both parents' and teachers' forms (Camerota et al., 2018; Conesa, 2023; Mashhadi et al., 2023), with adequate reliability (Alyami, 2023; Catale et al., 2015; Conesa, 2023; Trevisan et al., 2017), and convergent validity (Mashhadi et al., 2023; Parhoon et al., 2022). Although no studies have investigated the measurement equivalence across parents and teachers, we hypothesized that both respondents would be invariant at the number and pattern of factors, factor loadings, and intercepts. As suggested by Sideridis et al. (2015), unless invariance is present at least at the factor loading level (i.e., metric invariance), all subsequent between-group comparisons (e.g., parents vs. teachers) may likely be suspect or invalid.

Method

Participants

The participants were 279 Portuguese children ($n = 160$ girls and $n = 119$ boys) from 6 to 12 years old ($M = 8.59$, $SD = 2.03$; 6y $n = 60$, 7y $n = 53$, 8y $n = 24$, 9y $n = 32$, 10y $n = 47$, 11y $n = 39$, and 12y $n = 24$), attending school from the first to seventh grade. Participants were recruited from nine public schools in urban (59.2%), moderately urban (10.1%), and rural (30.7%) areas. Most of the participants were from families of middle socioeconomic status (lower = 35.6%, middle = 54.8%, and higher = 9.6%). The participants' urban typology and socioeconomic status are close to the Portuguese distribution (Instituto Nacional de Estatística, 2022; OECD, 2019; Pordata, 2018).

Parents and teachers were invited to complete the CHEXI. We collected 279 questionnaires from parents and 191 questionnaires from teachers (primary school $n = 130$, and 5th to 6th $n = 61$), with 179 questionnaires completed from both parents and teachers of the same child. Twelve parents' questionnaires were dropped out due to missing values in several items (no questionnaires were dropped out for teachers). In the absence of information from the original authors (Thorell & Nyberg, 2008) on how to deal with missing data, we chose to exclude these parents to avoid biased data (parents' final sample: $n = 267$). Most of them were completed by the mother (mother = 86.7%, father = 11.0%, both parents = 1.2%, and others = 1.1%). Most of the mothers had a university degree (elementary = 17.7%, secondary = 37.8%, and university = 44.5%), whereas most of the fathers had an elementary or secondary degree of education (elementary = 36.2%, secondary = 34%, and university = 29.8%).

The participants had to fulfill the following inclusion criteria: (i) aged 6 to 12 years old; and (ii) no history of a diagnosis of neurodevelopmental disorders (e.g., ADHD, specific learning disorder, autism spectrum disorder), neurological disorders (e.g., epilepsy, traumatic brain injury), psychopathology (e.g., depressive disorders, anxiety disorders), disruptive, impulse-control, and conduct disorders (e.g., oppositional defiant disorder, conduct disorder), or special needs.

Measures

Childhood Executive Functioning Inventory (CHEXI)

The CHEXI (Thorell & Nyberg, 2008) consists of 24 items that are organized into four subscales (Working Memory [nine items], Planning [four items], Regulation [five items], and Inhibition [six items]), and two scales (Working Memory [Working Memory and Planning subscales], and Inhibition [Regulation and Inhibition subscales]). Parents and teachers indicated how often their child has displayed a specific behavior on a 5-point Likert scale ("definitely not true" to "definitely true"), with higher scores indicating poorer EF. We used the Portuguese version of the CHEXI available on the official website (https://chexi.se).

Behavior Rating Inventory of Executive function – 2nd edition (BRIEF2)

The BRIEF2 (Gioia et al., 2015) consists of 63 items that are organized into a unitary Global Executive Composite (GEC), three composite indexes (Behavior Regulation Index [BRI], Emotion Regulation Index [ERI], and Cognitive Regulation Index [CRI]), and nine scales (BRI: Inhibit, and Self-Monitor scales; ERI: Shift, and Emotional Control scales; and CRI: Initiate, Working Memory, Plan/Organize, Task-Monitor, and Organization of Materials scales). Parents and teachers indicated how often their child has displayed a specific behavior on a 3-point Likert scale ("never," "sometimes," and "often"), with higher scores indicating poorer EF. The Portuguese version of BRIEF2 has adequate psychometric properties: internal consistency with Cronbach's α ranging from .738 to .953; and CFI = .976, SRMR = .030, RMSEA = .078 for the three-correlated-factor model (Moura et al., 2023).

Procedures

This research has approved by the Directorate-General for Education of the Portuguese Ministry of Education (number 0613500003), the Ethics Commission of the Faculty of Psychology and Educational Sciences of the University of Coimbra (CEDI/FPCEUC: 53-7-July 21 2021), and for each of the participants' school board. In each of the nine schools, classrooms were randomly selected. The parents of the selected classrooms were contacted by letter and invited to participate in the study. The aims of the study were fully explained, and written informed consent was obtained from the parents before the inclusion of participants in the study. Voluntary participation was requested from all parents and teachers, and participants did not receive any fees or compensation.

Statistical analyses

Raw scores were used in all the statistical analyses. Descriptive statistics, correlations, and internal consistency were performed with IBM SPSS Statistics version 29. The factor structure of the CHEXI was conducted through a CFA using Mplus 8. The weighted least square mean and variance adjusted estimator (WLSMV) based on polychoric correlation matrices was used in CFA and measurement invariance because it has been recommended for ordered categorical data and nonnormal indicators (Beauducel & Herzberg, 2006; Brown, 2015; Li, 2016). Simulation studies have found that WLSMV was less biased and more accurate than maximum likelihood estimators (e.g., ML, MLR) in estimating the factor loadings for ordinal data (Beauducel & Herzberg, 2006; Li, 2016).

The CFI, SRMR, and RMSEA were used to determine the model fit. A CFI > .95, a SRMR < .08, and a RMSEA < .06 (other cutoff values: < .05 good fit, .05–.08 acceptable fit, .08–.10 mediocre fit, and > .10 poor fit) were considered a good model fit (Byrne, 2012; Hu & Bentler, 1999; Schreiber et al., 2006). These cutoff values for the fit indices should not be used as rules of thumb, that is more stringent cutoff values are recommended for simple models, and less stringent cutoff values are recommended for more complex models (Marsh et al., 2004).

To study if the factor structure of the CHEXI would be equivalent across parents and teachers a multiple-group analysis (measurement invariance) was conducted. It involves a hierarchical set of steps in which increasingly more stringent levels of constrained equivalence across groups are explored. Three levels of measurement invariance were tested: (1) *configural invariance*, no equality constraints were imposed on the parameters across parents and teachers; (2) *metric invariance* ("weak factorial invariance"), factor loadings were constrained to be equal across parents and teachers; and (3) *scalar invariance* ("strong factorial invariance"), factor loadings and intercepts were constrained to be equal across parents and teachers. It is commonly accepted that evidence for invariance is obtained if: (i) the multigroup model exhibits an adequate fit to the data; and (ii) the difference value between the nested models for the fit indices is ΔCFI < −.010 and ΔRMSEA > .010 or > .015 (Byrne, 2012; Chen, 2007; Cheung & Rensvold, 2002). We did not include $\Delta\chi^2$ for evaluating measurement invariance because it is oversensitivity for sample size (as well noted in the literature; e.g., Beribisky & Hancock, 2024; Cheung & Rensvold, 2002; Counsell et al., 2020) when even trivial deviations from perfect fit can lead the $\Delta\chi^2$ to be statistically significant.

Results

Descriptive statistics, correlation coefficients, and reliability

Tables 1 and 2 show the descriptive statistics, correlation coefficients, and internal consistency of the CHEXI for parents and teachers. All the subscales and scales showed skewness and kurtosis values < 1 suggesting the normality of the data distribution.

According to Cohen's guidelines (Cohen, 1988; small $r = .1$, medium $r = .3$, and large $r = .5$), large Pearson correlation coefficients were observed between the subscales and scales. As expected, the Working Memory subscale was highly correlated with the Planning subscale ($r = .833$ for parents, and $r = .951$ for teachers), and the Inhibition subscale was highly correlated with the Regulation subscale ($r = .719$ for parents, and $r = .740$ for teachers). At the scale level, a large correlation coefficient was observed between the Working Memory and Inhibition scales for parents and teachers ($r = .780$ and $r = .760$ respectively).

The subscales and scales revealed acceptable to very good internal consistency with Cronbach's α ranging from .765 to .930 for parents and .869 to .974 for teachers.

Table 1. Descriptive statistics and reliability for parents and teachers.

	Descriptive statistics				Reliability		Percentile rank				
	M	*SD*	Skewness	Kurtosis	Inter-item correlation	α	5	25	50	75	95
Parents (*n* = 267)											
Working Memory subscale	19.31	6.50	.517	−.067	.516	.905	9	14	19	24	32
Planning subscale	8.15	2.94	.891	.999	.508	.803	4	6	8	10	14
Regulation subscale	13.77	4.45	.327	−.184	.573	.869	6	11	14	16	22
Inhibition subscale	15.12	4.27	.190	−.016	.355	.765	8	12	15	18	22
Working Memory scale	27.46	9.10	.618	.262	.510	.930	14	22	26	33	44
Inhibition scale	28.90	8.08	.278	.040	.418	.887	14	24	28	34	43
Teachers (*n* = 191)											
Working Memory subscale	19.13	8.65	.831	.193	.745	.963	9	12	18	25	36
Planning subscale	8.51	3.91	.686	−.259	.727	.915	4	5	8	11	16
Regulation subscale	11.06	5.14	.771	−.212	.789	.948	5	7	10	14	21
Inhibition subscale	11.74	4.45	.803	.239	.529	.869	6	9	11	14	20
Working Memory scale	27.65	12.43	.786	.041	.744	.974	13	16	26	35	52
Inhibition scale	22.81	8.96	.643	−.285	.576	.938	11	16	21	28	39

Table 2. Pearson correlation coefficients for parents and teachers.

	CHEXI						BRIEF2			
CHEXI	1	2	3	4	5	6	BRI parents (teachers)	ERI parents (teachers)	CRI parents (teachers)	GEC parents (teachers)
1. Working Memory subscale	–	.833	.777	.660	.984	.777	.498 (.428)	.522 (.660)	.711 (.847)	.693 (.796)
2. Planning subscale	.951	–	.685	.603	.919	.696	.424 (.415)	.488 (.636)	.667 (.817)	.639 (.768)
3. Regulation subscale	.811	.791	–	.719	.777	.930	.580 (.637)	.590 (.730)	.704 (.841)	.730 (.867)
4. Inhibition subscale	.580	.584	.740	–	.667	.924	.702 (.781)	.563 (.704)	.550 (.599)	.659 (.756)
5. Working Memory scale	.995	.976	.814	.588	–	.780	.493 (.428)	.531 (.659)	.724 (.847)	.701 (.796)
6. Inhibition scale	.755	.745	.942	.922	.760	–	.690 (.753)	.623 (.769)	.680 (.777)	.750 (.870)

All correlations are significant at $p < .001$. Above the diagonal, the values concern to the parents. Below the diagonal and within parentheses, the values concern to the teachers. BRI = Behavior Regulation Index. ERI = Emotion Regulation Index. CRI = Cognitive Regulation Index. GEC = Global Executive Composite.

Confirmatory factor analysis

CFAs at the item level (i.e., items were treated as ordinal indicators) were performed to test five competing factor structures for parents and teachers, separately (WLSMV estimator): (i) a one-factor model (a general executive factor in line with the view of EF as a unitary construct) with the 24 items in one factor; (ii) a two-correlated-factor model with the two scales (Working Memory and Inhibition); (iii) a hierarchical two-factor model with a general factor (second-order factor) and the two scales as first-order factors (Working Memory and Inhibition); (iv) a four-correlated-factor model with the four subscales (Working Memory, Planning, Regulation, and Inhibition); and (v) a hierarchical four-factor model with two second-order factors and the four subscales as first-order factors (Working Memory: Working Memory and Planning subscales; and Inhibition: Regulation and Inhibition subscales). No error covariances were added to the models.

For parents, the two-correlated-factor model and the four-factor model (correlated and hierarchical) are nearly identical, showing adequate goodness-of-fit indices (the four-factor models were slightly better). For teachers, the four-factor models (the correlated and hierarchical) showed a better model fit than the other competing models. The hierarchical two-factor model revealed a poor fit (see Table 3). Table 4 shows the factor loadings, latent factor correlations, and reliability (McDonald's ω) of the four-correlated-factor model for both parents and teachers. In general, the four latent factors were highly correlated ($\varphi \geq .658$), revealing adequate factor loadings ($\lambda \geq .551$) and reliability ($\omega \geq .812$).

Measurement invariance across parents and teachers

Given that the four-factor model showed the best fit in both parents and teachers, we performed a multiple-group analysis to evaluate whether the factor structure (four-correlated-factor model) of the CHEXI would be equivalent across groups (parents n = 267 and teachers n = 191).

The configural model had adequate fit, which suggested that both the number and pattern of factors were equivalent across groups (see Table 5). Metric invariance was

Table 3. CFA (WLSMV estimator) of the CHEXI for parents and teachers.

	Parents ($n = 267$)					Teachers ($n = 191$)				
	CFI	SRMR	RMSEA (90%CI)	χ^2 (df)	χ^2/df	CFI	SRMR	RMSEA (90%CI)	χ^2 (df)	χ^2/df
1-factor	.943	.069	.090 (.082–.098)	696.081 (252)	2.76	.949	.094	.127 (.119–.134)	1129.807 (252)	4.48
2-correlated-factor	.956	.062	.079 (.071–.087)	592.477 (251)	2.26	.972	.062	.095 (.087–.103)	738.564 (251)	2.94
hierarchical 2-factor	.460	.204	.278 (.270–.285)	4464.083 (252)	17.71	.725	.186	.294 (.287–.301)	4988.362 (252)	19.79
4-correlated-factor	.959	.060	.078 (.069–.086)	568.748 (246)	2.31	.981	.049	.079 (.070–.087)	575.965 (246)	2.34
hierarchical 4-factor	.959	.060	.078 (.069–.086)	569.389 (247)	2.30	.981	.050	.079 (.071–.087)	581.582 (247)	2.35

CFI = Comparative Fit Index. SRMR = Standardized Root Mean Square Residual. RMSEA (90% CI) = Root Mean Square Error of Approximation (90% confidence interval). χ^2 = chi-square. *df* = degrees of freedom.

Table 4. Factor loadings, factor correlations, and reliability of the four-correlated-factor model for parents and teachers.

	Parents					Teachers				
	WM	Plan	Reg	Inh	φ	WM	Plan	Reg	Inh	φ
Loadings										
Item 1	.764					.914				
Item 3	.771					.877				
Item 6	.797					.904				
Item 7	.778					.877				
Item 9	.751					.837				
Item 19	.737					.841				
Item 21	.841					.901				
Item 23	.757					.885				
Item 24	.863					.933				
Item 12		.748					.910			
Item 14		.698					.904			
Item 17		.688					.815			
Item 20		.868					.921			
Item 2			.720					.895		
Item 4			.777					.925		
Item 8			.856					.856		
Item 11			.821					.893		
Item 15			.838					.922		
Item 5				.762					.910	
Item 10				.551					.644	
Item 13				.639					.759	
Item 16				.681					.668	
Item 18				.715					.747	
Item 22				.659					.807	
Factor correlations										
WM – Plan					.922					.926
WM – Reg					.900					.838
WM – Inh					.829					.658
Plan – Reg					.855					.811
Plan – Inh					.805					.686
Reg – Inh					.886					.843
Reliability										
McDonald's ω	.923	.840	.896	.812		.958	.919	.935	.877	

WM = Working Memory subscale. Plan = Planning subscale. Reg = Regulation subscale. Inh = Inhibition subscale.

Table 5. Measurement invariance analysis.

	CFI	RMSEA (90% CI)	ΔCFI	ΔRMSEA
Configural	.980	.080 (.074–.086)		
Metric	.979	.080 (.075–.086)	−.001	.000
Scalar	.978	.077 (.072–.083)	−.002	−.003

CFI = Comparative Fit Index. RMSEA (90% CI) = Root Mean Square Error of Approximation (90% confidence interval). ΔCFI and ΔRMSEA were the differences between each alternative and the configural model.

tested, and the constraint of factor loadings (regression slopes) did not yield a significantly worse model fit compared with the configural model (ΔCFI = −.001 and ΔRMSEA = .000), supporting metric invariance. Scalar invariance was then examined, and the constraint of factor loadings (regression slopes) and intercepts did not result in a significantly worse model fit compared with the configural model (ΔCFI = −.002 and ΔRMSEA = −.003). These findings seem to support the measurement equivalence across parents and teachers (strong factorial invariance).

After confirming measurement invariance across groups, we analyzed the differences between parents and teachers on the four subscales ($n = 179$). Paired samples t-test were performed and revealed statistically significant group differences in Regulation ($t = 7.239$, $p < .001$, $d = .541$) and Inhibition ($t = 8.590$, $p < .001$, $d = .642$) subscales, with parents reporting higher scores (i.e., poorer EF).

Convergent validity with the BRIEF2

The subscales and scales of CHEXI are moderate to strongly correlated with the BRIEF2 index scores (see Table 2). As expected, the Working Memory and Planning subscales showed higher correlation coefficients with CRI (it includes the Working Memory and Plan/Organize scales of BRIEF2; parents: $r = .711$ and $r = .667$, respectively; teachers: $r = .847$ and $r = .817$, respectively), whereas Inhibition subscale revealed higher correlation coefficient with the BRI (it includes the Inhibit scale of BRIEF2; parents: $r = .702$; teachers: $r = .781$).

Discussion

The CHEXI is a rating scale that evaluates everyday behaviors associated with EF in children aged 4–12 years in home and educational environments. This study aimed to investigate the psychometric properties of the CHEXI in Portuguese typically developing children.

The first main objective of the present study was to determine whether the CHEXI is best represented by two (Working Memory and Inhibition) or four (Working Memory, Planning, Regulation, and Inhibition) latent factors. Exploratory and confirmatory factor analysis studies have found support for the two-correlated-factor model (Alyami, 2023; Catale et al., 2013, 2015; Gutierrez et al., 2021; Thorell & Nyberg, 2008; Trevisan et al., 2017) or a nearly identical fit between the two- and the four-correlated-factor models (Camerota et al., 2018; Mashhadi et al., 2023). It is important to note that most of the studies only analyzed the two-correlated-factor model (i.e., no other competing factor structures were compared) (e.g., Alyami, 2023; Catale et al., 2013, 2015) and few compared the two- and four-factor models (e.g., Camerota et al., 2018; Mashhadi et al., 2023) or the factor structure in a sample of teachers (Gutierrez et al., 2021). For example, Camerota et al. (2018) found that the four-correlated-factor model (parents' form) revealed a better fit in the chi-square difference tests and equivalent fit indices than the two-correlated-factor model, but it yielded a high latent factor correlation between Working Memory and Planning ($\varphi = .98$). Based on these findings they suggested that both factor models are nearly identical, but the two-correlated-factor model may be the most interpretable and parsimonious factor solution in a sample of parents of US preschoolers. Mashhadi et al. (2023) compared the one-, two-, and four-factor models (parents' form) and found that the two-factor model was slightly better than the four-factor model (the one-factor model was not adequate).

This study extends the current knowledge about the factor structure of the CHEXI and surpasses some of the existing literature limitations, by attending to both parents and teachers, and comparing different factor models (unitary, correlated, and hierarchical). We tested five competing factor structures for both parents and teachers. CFAs have shown that the four-factor (correlated and hierarchical) models were the most parsimonious factor solutions, albeit the two-correlated-factor model also showed adequate goodness-of-fit indices. Thus, the CHEXI was best operationalized with four subscales (i.e., four-correlated-factor model; Working Memory, Planning, Regulation, and Inhibition subscales) or two scales and four subscales (i.e., hierarchical four-factor model with two second-order factors; Working Memory scale: Working Memory and Planning subscales, and Inhibition scale: Regulation and Inhibition subscales). These findings gave support for the four-factor structure of the CHEXI in a sample of Portuguese typically developing children.

Some reasons may explain the different factor structures for CHEXI found in the literature. First, few studies have analyzed the four-factor solution for parents (Camerota et al., 2018; Conesa, 2023; Mashhadi et al., 2023), and no studies have investigated it for teachers. If studies also examined the four-factor model (and other models), they could find which factor structure fits the data better. Second, most studies used the maximum likelihood estimation in the CFA of the CHEXI (except, Conesa, 2023), but it has been suggested that WLSMV has advantages over maximum likelihood estimation for ordinal indicators (Beauducel & Herzberg, 2006; Brown, 2015; Li, 2016). Lastly, some studies included the two problematic items identified in preliminary analyses that were dropped from the final version of the CHEXI (Camerota et al., 2018; Catale et al., 2013, 2015; Trevisan et al., 2017).

We found a large latent factor correlation between Working Memory and Planning subscales ($\varphi = .922$ for parents and $\varphi = .926$ for teachers), which is also observed in another study (Camerota et al., 2018). This finding is expected because working memory and planning may share some underlying cognitive processes and given the nature of the items from both subscales (e.g., item 3 [Working Memory subscale]: *"Has difficulty remembering what he/she is doing, in the middle of an activity"*; and item 12 [Planning subscale]: *"Has difficulty planning for an activity [e.g., remembering to bring everything necessary for a field trip or things needed for school]"*). The high correlation coefficient between working memory and planning is also observed in BRIEF2 in typically developing children: $r = .76$ (Moura et al., 2023) or $r \geq .82$ (Gioia et al., 2015).

The CHEXI demonstrated adequate reliability at the subscale and scale levels for both parents and teachers ($\alpha = .765$ to $.974$, McDonald's $\omega = .812$ to $.958$), which are close to those found in other studies: $\alpha \geq .84$ (Conesa, 2023) and McDonald's $\omega \geq .84$ (Gutierrez et al., 2021). Convergent validity was also confirmed with large correlation coefficients between the CHEXI and the composite scores of the BRIEF2 (cf., Mashhadi et al., 2023; Parhoon et al., 2022).

The second main objective of the present study was to examine the measurement invariance across parents and teachers. During the validation process of cognitive measures is important to analyze measurement invariance because most of the psychological research and clinical practice involves between-group comparisons (Moura et al., 2018, 2023; Sideridis et al., 2015; Wicherts, 2016). Surprisingly, we did not find studies that performed a multiple-group analysis across parents and teachers even though the interpretation of the everyday behaviors associated with EF in both contexts (i.e., home and school) is relevant in clinical evaluation and decision-making process.

The findings from the measurement invariance supported strong invariance of the CHEXI across parents' and teachers' respondents. That is, the number and pattern of factors (configural invariance), and the strength of the relation between the items and their latent factors (metric invariance) were equivalent across respondents. Scalar invariance was also met, suggesting that those who have the same score on a latent factor (subscale) would obtain the same score on the observed variable (item) regardless of their group membership (parents or teachers). Thus, the results from the multiple-group analysis support the interpretation of subscale scores across parents and teachers. Previous studies with the CHEXI (parents) established strong or strict invariance across gender, age, and household income level (Camerota et al., 2018; Conesa, 2023; Mashhadi et al., 2023).

The present study has some limitations that should be addressed in future studies. First, the sample of this study did not include children with 4 and 5 years old for which the CHEXI is also intended (i.e., 4–12 years), and it contains more girls. Second, children were not recruited from a large representative sample, which limits the generalizability of the findings. Third, we did not examine the convergent validity with performance-based measures of EF (e.g., Trail Making Test, Wisconsin Card Sorting Test, Stroop Color and Word Test, Tower of London), although the literature suggests that rating scales and performance-based tests capture different underlying EF constructs and were not highly correlated (Gutierrez et al., 2021; Ten Eycke & Dewey, 2016; Thorell & Nyberg, 2008; Toplak et al., 2009, 2013). Fourth, we did not explore the equivalence of the factor structure in clinical samples (e.g., ADHD, autism spectrum disorder, specific learning disorder, oppositional defiant disorder, conduct disorder). Including clinical groups would be relevant to analyze how the factor structure found in typically developing children would operate in children that frequently show a profile of high scores (i.e., negative skewness). Fifth, future studies should explore the derivation of standardized/normed scores across age and/or sex to expand the clinical utility of the CHEXI, as well as their diagnostic accuracy (e.g., ROC curve, logistic regression) in neurodevelopmental disorders. Some studies found sensitivity and specificity values greater than .80, suggesting that the CHEXI is a promising measure for identifying children with ADHD (Catale et al., 2015; Thorell et al., 2010). Lastly, it is also important to note that respondent bias (e.g., emotional involvement in the daily life of the child, the frequency with which the respondent interacts with the child, positive and negative halo effects) is an issue that always needs to be taken into consideration when using questionnaires (Denckla, 2002; Thorell & Nyberg, 2008).

In conclusion, this study provides evidence regarding the adequate psychometric properties of the CHEXI as a useful instrument for assessing executive functioning based on reports of behaviors observed by parents and teachers in Portuguese children. The fact that this study supports the four-factor model (slightly better than the two-factor model) is not surprising given some inconsistent findings found across studies. It is important to continue studying the CHEXI factor structure, including in larger samples of typically developing children and clinical samples.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

ORCID

Octávio Moura http://orcid.org/0000-0002-5857-6200
Marcelino Pereira http://orcid.org/0000-0002-1468-2124
Cristina P. Albuquerque http://orcid.org/0000-0001-9055-9673
Mário R. Simões http://orcid.org/0000-0002-1311-1338

References

Aita, S. L., Holding, E. Z., Greene, J., Carrillo, A., Moncrief, G. G., Isquith, P. K., Gioia, G. A., & Roth, R. M. (2022). Multivariate base rates of score elevations on the BRIEF2 in children with ADHD, autism spectrum disorder, or specific learning disorder with impairment in reading. *Child Neuropsychology*, *28*(7), 979–996. https://doi.org/10.1080/09297049.2022.2060201

Alyami, I. Q. (2023). Psychometric analysis of Childhood Executive Functioning Inventory (CHEXI) in Saudi Arabian ADHD children: Calibration with Rasch model. *Applied Neuropsychology: Child*. https://doi.org/10.1080/21622965.2023.2208698

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. A. Bower (Ed.), *The psychology of learning and motivation* (pp. 47–89). Academic Press.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–94. https://doi.org/10.1037/0033-2909.121.1.65

Barkley, R. A. (2012). *Barkley deficits in Executive functioning scale-children and adolescents (BDEFS-CA)*. The Guilford Press.

Baron, I. S. (2018). *Neuropsychological evaluation of the child: Domains, methods, & case studies* (2nd ed.). Oxford University Press.

Beauducel, A., & Herzberg, P. Y. (2006). On the performance of maximum likelihood versus means and variance adjusted weighted least squares estimation in CFA. *Structural Equation Modeling*, *13*(2), 186–203. https://doi.org/10.1207/s15328007sem1302_2

Beribisky, N., & Hancock, G. R. (2024). Comparing rmsea-based indices for assessing measurement invariance in confirmatory factor models. *Educational and Psychological Measurement*, *84*(4), 716–735. https://doi.org/10.1177/00131644231202949

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development*, *81*(6), 1641–1660. https://doi.org/10.1111/j.1467-8624.2010.01499.x

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology*, *66*(1), 711–731. https://doi.org/10.1146/annurev-psych-010814-015221

Blakemore, S. J., & Choudhury, S. (2006). Development of the adolescent brain: Implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry*, *47*(3–4), 296–312. https://doi.org/10.1111/j.1469-7610.2006.01611.x

Brown, T. A. (2015). *Confirmatory factor analysis for applied research* (2nd ed.). The Guilford Press.

Byrne, B. M. (2012). *Structural equation modeling with Mplus: Basic concepts, applications, and programming*. Routledge.

Camerota, M., Willoughby, M. T., Kuhn, L. J., & Blair, C. B. (2018). The childhood Executive functioning inventory (CHEXI): Factor structure, measurement invariance, and correlates in US preschoolers. *Child Neuropsychology*, *24*(3), 322–337. https://doi.org/10.1080/09297049.2016.1247795

Catale, C., Lejeune, C., Merbah, S., & Meulemans, T. (2013). French adaptation of the Childhood Executive Functioning Inventory (CHEXI): Confirmatory factor analysis in a sample of young French-speaking Belgian children. *European Journal of Psychological Assessment*, *29*(2), 149–155. https://doi.org/10.1027/1015-5759/a000141

Catale, C., Meulemans, T., & Thorell, L. B. (2015). The childhood Executive function inventory: Confirmatory factor analyses and cross-cultural clinical validity in a sample of 8- to 11-year-old children. *Journal of Attention Disorders*, *19*(6), 489–495. https://doi.org/10.1177/1087054712470971

Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling*, *14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling*, *9*(2), 233–255. https://doi.org/10.1207/S15328007SEM0902_5

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Academic Press.

Collette, F., Hogge, M., Salmon, E., & Van der Linden, M. (2006). Exploration of the neural substrates of executive functioning by functional neuroimaging. *Neuroscience*, *139*(1), 209–221. https://doi.org/10.1016/j.neuroscience.2005.05.035

Conesa, P. J. (2023). Validation and reliability of the childhood Executive function inventory (CHEXI) in Spanish primary school students. *Revista de Psicología Clínica con Niños y Adolescentes*, *10*(3). https://doi.org/10.21134/rpcna.2023.10.3.6

Counsell, A., Cribbie, R. A., & Flora, D. B. (2020). Evaluating equivalence testing methods for measurement invariance. *Multivariate Behavioral Research*, *55*(2), 312–328. https://doi.org/10.1080/00273171.2019.1633617

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*(11), 2037–2078. https://doi.org/10.1016/j.neuropsychologia.2006.02.006

Demakis, G. J. (2004). Frontal lobe damage and tests of executive processing: A meta-analysis of the category test, stroop test, and trail-making test. *Journal of Clinical and Experimental Neuropsychology*, *26*(3), 441–450. https://doi.org/10.1080/13803390490510149

Denckla, M. (2002). The behavior rating inventory of Executive function: Commentary. *Child Neuropsychology*, *8*(4), 304–306. https://doi.org/10.1076/chin.8.4.304.13512

Emslander, V., & Scherer, R. (2022). The relation between executive functions and math intelligence in preschool children: A systematic review and meta-analysis. *Psychological Bulletin*, *148*(5–6), 337–369. https://doi.org/10.1037/bul0000369

Friedman, N. P., & Miyake, A. (2017). Unity and diversity of executive functions: Individual differences as a window on cognitive structure. *Cortex, A Journal Devoted to the Study of the Nervous System and Behavior*, *86*, 186–204. https://doi.org/10.1016/j.cortex.2016.04.023

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). *BRIEF: Behavior rating inventory of Executive function* (1st ed.). PAR.

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2015). *BRIEF2: Behavior rating inventory of Executive function* (2nd ed.). PAR.

Gutierrez, M., Filippetti, V. A., & Lemos, V. (2021). The Childhood Executive Functioning Inventory (CHEXI) parent and teacher form: Factor structure and cognitive correlates in Spanish-speaking children from Argentina. *Developmental Neuropsychology*, *46*(2), 136–148. https://doi.org/10.1080/87565641.2021.1878175

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Instituto Nacional de Estatística. (2022). *Censos, 2021: Resultados definitivos*. Instituto Nacional de Estatística.

Jacobson, L. A., Pritchard, A. E., Koriakin, T. A., Jones, K. E., & Mahone, E. M. (2020). Initial examination of the BRIEF2 in clinically referred children with and without ADHD symptoms. *Journal of Attention Disorders*, *24*(12), 1775–1784. https://doi.org/10.1177/1087054716663632

Jurado, M. B., & Rosselli, M. (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychology Review*, *17*(3), 213–233. https://doi.org/10.1007/s11065-007-9040-z

Lewis, M. P., Simons, G. F., & Fennig, C. D. (2015). *Ethnologue: Languages of Africa and Europe* (18th ed.). SIL International.

Li, C.-H. (2016). Confirmatory factor analysis with ordinal data: Comparing robust maximum likelihood and diagonally weighted least squares. *Behavior Research Methods*, *48*(3), 936–949. https://doi.org/10.3758/s13428-015-0619-7

Marsh, H. W., Hau, K., & Wen, Z. (2004). In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. *Structural Equation Modeling*, *11*(3), 320–341. https://doi.org/10.1207/s15328007sem1103_2

Marzocchi, G. M., Oosterlaan, J., Zuddas, A., Cavolina, P., Geurts, H., Redigolo, D., Vio, C., & Sergeant, J. A. (2008). Contrasting deficits on executive functions between ADHD and reading disabled children. *Journal of Child Psychology and Psychiatry*, *49*(5), 543–552. https://doi.org/10.1111/j.1469-7610.2007.01859.x

Mashhadi, A., Maleki, Z. H., Hasani, J., Rasoolzadeh Tabatabaei, K., & Saleh, S. (2023). Psychometric properties of the Childhood Executive Functioning Inventory (CHEXI): A confirmatory factor analysis and measurement invariance by sex and age in Iranian children. *Neuropsychological Rehabilitation*, *33*(3), 409–427. https://doi.org/10.1080/09602011.2021.2021952

May, K. E., & Kana, R. K. (2020). Frontoparietal network in executive functioning in autism spectrum disorder. *Autism Research*, *13*(10), 1762–1777. https://doi.org/10.1002/aur.2403

Moura, O., Albuquerque, C. P., Pereira, M., Major, S., Lopes, A. F., Vilar, M., Seabra-Santos, M. J., & Simões, M. R. (2023). Factor structure and measurement invariance of the BRIEF2 Parent form across gender in a Portuguese sample. *Child Neuropsychology*, *29*(4), 628–643. https://doi.org/10.1080/09297049.2022.2105313

Moura, O., Albuquerque, C. P., Pinho, M. S., Vilar, M., Lopes, A. F., Alberto, I., Pereira, M., Santos, M. J. S., & Simões, M. R. (2018). Factor structure and measurement invariance of the Coimbra Neuropsychological Assessment Battery (BANC). *Archives of Clinical Neuropsychology*, *33*(1), 66–78. https://doi.org/10.1093/arclin/acx052

Moura, O., Pereira, M., Alfaiate, C., Fernandes, E., Fernandes, B., Nogueira, S., Moreno, J., & Simões, M. R. (2017). Neurocognitive functioning in children with developmental dyslexia and attention-deficit/hyperactivity disorder: Multiple deficits and diagnostic accuracy. *Journal of Clinical and Experimental Neuropsychology*, *39*(3), 296–312. https://doi.org/10.1080/13803395.2016.1225007

Moura, O., Simões, M. R., & Pereira, M. (2014). Executive functioning in children with developmental dyslexia. *The Clinical Neuropsychologist*, *28*(S1), 20–41. https://doi.org/10.1080/13854046.2014.964326

Muñoz, M. P., & Filippetti, V. A. (2021). Confirmatory factor analysis of the BRIEF-2 parent and Teacher form: Relationship to performance-based measures of executive functions and academic achievement. *Applied Neuropsychology: Child*, *10*(3), 219–233. https://doi.org/10.1080/21622965.2019.1660984

Nowrangi, M. A., Lyketsos, C., Rao, V., & Munro, C. A. (2014). Systematic review of neuroimaging correlates of executive functioning: Converging evidence from different clinical populations. *Journal of Neuropsychiatry and Clinical Neurosciences*, *26*(2), 114–125. https://doi.org/10.1176/appi.neuropsych.12070176

OECD. (2019). Under pressure: The squeezed middle class. https://doi.org/10.1787/689afed1-en

Parhoon, K., Moradi, A., Alizadeh, H., Parhoon, H., Sadaphal, D. P., & Coolidge, F. L. (2022). Psychometric properties of the behavior rating inventory of Executive function, second edition (BRIEF2) in a sample of children with ADHD in Iran. *Child Neuropsychology*, *28*(2), 427–436. https://doi.org/10.1080/09297049.2021.1975669

Pordata. (2018). *População residente segundo os Censos: Total e por dimensão dos lugares*. Fundação Francisco Manuel dos Santos.

Roberts, B. A., Martel, M. M., & Nigg, J. T. (2017). Are there executive dysfunction subtypes within ADHD? *Journal of Attention Disorders*, *21*(4), 284–293. https://doi.org/10.1177/1087054713510349

Schmitt, S. A., Geldhof, G. J., Purpura, D. J., Duncan, R., & McClelland, M. M. (2017). Examining the relations between executive function, math, and literacy during the transition to kindergarten: A multi-analytic approach. *Journal of Educational Psychology*, *109*(8), 1120–1140. https://doi.org/10.1037/edu0000193

Schoemaker, K., Mulder, H., Deković, M., & Matthys, W. (2013). Executive functions in preschool children with externalizing behavior problems: A meta-analysis. *Journal of Abnormal Child Psychology*, *41*(3), 457–471. https://doi.org/10.1007/s10802-012-9684-x

Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, J. (2006). Reporting structural equation modeling and confirmatory factor analysis results: A review. *Journal of Educational Research*, *99*(6), 323–338. https://doi.org/10.3200/JOER.99.6.323-338

Shum, K. K.-M., Zheng, Q., Chak, G. S., Kei, K. T.-L., Lam, C. W.-C., Lam, I. K.-Y., Lok, C. S. W., & Tang, J. W.-Y. (2021). Dimensional structure of the BRIEF2 and its relations with ADHD symptoms and task performance on executive functions in Chinese children. *Child Neuropsychology*, *27*(2), 165–189. https://doi.org/10.1080/09297049.2020.1817355

Sideridis, G. D., Tsaousis, I., & Al-Harbi, K. A. (2015). Multi-population invariance with dichotomous measures: Combining multi-group and MIMIC methodologies in evaluating the General aptitude test in the Arabic language. *Journal of Psychoeducational Assessment*, *33*(6), 568–584. https://doi.org/10.1177/0734282914567871

Spencer, M., Richmond, M. C., & Cutting, L. E. (2020). Considering the role of executive function in reading comprehension: A structural equation modeling approach. *Scientific Studies of Reading*, *24*(3), 179–199. https://doi.org/10.1080/10888438.2019.1643868

Tamnes, C. K., Østby, Y., Walhovd, K. B., Westlye, L. T., Due-Tønnessen, P., & Fjell, A. M. (2010). Neuroanatomical correlates of executive functions in children and adolescents: A magnetic resonance imaging (MRI) study of cortical thickness. *Neuropsychologia*, *48*(9), 2496–2508. https://doi.org/10.1016/j.neuropsychologia.2010.04.024

Ten Eycke, K. D., & Dewey, D. (2016). Parent-report and performance-based measures of executive function assess different constructs. *Child Neuropsychology*, *22*(8), 889–906. https://doi.org/10.1080/09297049.2015.1065961

Thorell, L. B., Eninger, L., Brocki, K. C., & Bohlin, G. (2010). Childhood Executive function inventory (CHEXI): A promising measure for identifying young children with ADHD? *Journal of Clinical and Experimental Neuropsychology*, *32*(1), 38–43. https://doi.org/10.1080/13803390902806527

Thorell, L. B., & Nyberg, L. (2008). The Childhood Executive Functioning Inventory (CHEXI): A new rating instrument for parents and teachers. *Developmental Neuropsychology*, *33*(4), 536–552. https://doi.org/10.1080/87565640802101516

Toplak, M. E., Bucciarelli, S. M., Jain, U., & Tannock, R. (2009). Executive functions: Performance-based measures and the behavior rating inventory of Executive function (BRIEF) in adolescents with attention deficit/hyperactivity disorder (ADHD). *Child Neuropsychology*, *15*(1), 53–72. https://doi.org/10.1080/09297040802070929

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct?: Performance-based and rating measures of EF. *Journal of Child Psychology and Psychiatry*, *54*(2), 131–143. https://doi.org/10.1111/jcpp.12001

Trevisan, B. T., Dias, N. M., Berberian, A. A., & Seabra, A. G. (2017). Childhood Executive Functioning Inventory: Adaptação e propriedades psicométricas da versão Brasileira. *Psico-USF*, *22*(1), 63–74. https://doi.org/10.1590/1413-82712017220106

Vandenberg, R. J., & Lance, C. E. (2000). A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational Research Methods*, *3*(1), 4–70. https://doi.org/10.1177/109442810031002

Wasserman, T., & Wasserman, L. D. (2013). Toward an integrated model of executive functioning in children. *Applied Neuropsychology: Child*, *2*(2), 88–96. https://doi.org/10.1080/21622965.2013.748394

Wicherts, J. M. (2016). The importance of measurement invariance in neurocognitive ability testing. *The Clinical Neuropsychologist*, *30*(7), 1006–1016. https://doi.org/10.1080/13854046.2016.1205136

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: A meta-analytic review. *Biological Psychiatry*, *57*(11), 1336–1346. https://doi.org/10.1016/j.biopsych.2005.02.006

Yang, Y., Shields, G. S., Zhang, Y., Wu, H., Chen, H., & Romer, A. L. (2022). Child executive function and future externalizing and internalizing problems: A meta-analysis of prospective longitudinal studies. *Clinical Psychology Review*, *97*, 102194. https://doi.org/10.1016/j.cpr.2022.102194

Zanaboni, M. P., Varesio, C., Pasca, L., Foti, A., Totaro, M., Celario, M., Provenzi, L., & De Giorgis, V. (2021). Systematic review of executive functions in children with self-limited epilepsy with centrotemporal spikes. *Epilepsy & Behavior*, *123*, 108254. https://doi.org/10.1016/j.yebeh.2021.108254

Zelazo, P. D. (2020). Executive function and psychopathology: A neurodevelopmental perspective. *Annual Review of Clinical Psychology*, *16*(1), 431–454. https://doi.org/10.1146/annurev-clinpsy-072319-024242

Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and plasticity. *Child Development Perspectives*, *6*(4), 354–360. https://doi.org/10.1111/j.1750-8606.2012.00246.x