Validation and reliability of The Childhood Executive Function Inventory (CHEXI) in Spanish primary school students

Validación y fiabilidad del Inventario de Función Ejecutiva Infantil (CHEXI) en alumnos españoles de primaria

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Abstract

Given the enormous influence of executive functions in school and life success, it is necessary to identify EF levels and address them in a reliable way with tools accessible to practitioners. Two studies were conducted. In study 1, the psychometric properties of the Spanish version *Children's Executive Functioning Inventory (CHEXI*) in a representative sample of 1230 primary school students from 9 to 12 years old was investigated. According to Barkley's hybrid model, CHEXI showed good fit indices on the two subscales: working memory and inhibition (X^2=949.32, $p < 0.001$, CFI = 0.98, TLI = 0.98, SRMR = 0.06, RMSEA = 0.05), as well as excellent internal consistency ($\omega \geq 0.84$–0.91; $\alpha \geq 0.84$–0.91). In study 2, the efficacy of the CHEXI for the observation of EF deficits related to ADHD symptoms in children was analysed. Significant differences in parent-reported scores were observed between typically developing students and students diagnosed with ADHD ($p = < 0.001$, $\eta^2 partial$ = 0.09 – 0.10). The results showed that the CHEXI is a reliable instrument for measuring EF in Spanish children, and, it could be a useful tool for the identification of ADHD in these ages.

Keywords: executive functions; CHEXI; inhibition; working memory;ADHD

Resumen

Dada la enorme influencia de las funciones ejecutivas (FE) en el bienestar y el éxito escolar del alumnado de Educación Primaria, resulta necesario utilizar instrumentos que midan tales variables que sean accesibles para todos los profesionales de la educación. Se realizaron dos estudios. En el estudio 1, se investigó las propiedades psicométricas de la versión española del Inventario de Funcionamiento Ejecutivo Infantil (CHEXI) en una muestra representativa de 1230 alumnos de primaria de 8 a 12 años. Siguiendo el modelo híbrido de Barkley, el CHEXI mostró unos buenos índices de ajuste en las dos subescalas: memoria de trabajo e inhibición (X^2=949.32, $p < 0.001$, CFI = 0.98, TLI = 0.98, SRMR = 0.06, RMSEA = 0.05), así como una excelente consistencia interna ($\omega \geq 0.84$–0.91; $\alpha \geq 0.84$–0.91). En el estudio 2, se analizó la eficacia del CHEXI para la observación de los déficits de EF relacionados con los síntomas del TDAH. Se observaron diferencias significativas en las puntuaciones informadas por los padres entre los estudiantes con desarrollo típico y los estudiantes diagnosticados con TDAH ($p = < 0.001$, $\eta^2 partial = 0.09 – 0.10$). Los resultados mostraron que el CHEXI es un instrumento fiable para medir las FEs en niños españoles, y podría ser una herramienta útil para la identificación del TDAH en estas edades.

Keywords: funciones ejecutivas; CHEXI; inhibición; memoria de trabajo; TDAH

Introduction

In recent decades, numerous research studies have been developed in the field of cognitive psychology in the area of child development. Its importance extends beyond the necessary theoretical understanding of the causes of child behaviour, but also to practical knowledge in the design of interventions aimed at optimizing the development, learning or well-being of children. Executive functions seem to be one of the key aspects for such optimization (Diamond, 2013; Miyake et al., 2000).

Executive functions are understood as those neurocognitive mechanisms that control thoughts and behaviours aimed at achieving a goal or objective (Diamond, 2013). Within the complexity of the construct, it seems that there is a general consensus that there are three principal concepts at the core of EF: inhibition, cognitive flexibility, and working memory (Diamond, 2013; Miyake et al., 2000). From these, other mechanisms emerge, which are also essential for children, such as reasoning, problem solving, and planning.

Inhibition (also known as inhibitory control) refers to the ability to prevent predominant or automated responses and do instead what is most appropriate or necessary. Several studies suggest that inhibitory control in the early stages of an individual's life can predict outcomes and success throughout life (e.g., see Moffitt et al., 2011). *Cognitive flexibility* is described as the capacity to shift between different mindsets, tasks, or purposes. This executive function helps children to accomplish fluid strategies that allow them to adjust to unexpected situations by thinking without stiffness and freeing themselves from inefficient automatisms (Diamond, 2013). Finally, *working memory (WM)* involves maintaining and using information appropriately even if it is not perceptually present (Baddeley & Hitch, 1994; Kent, 2016). That is, it is the cognitive ability that allows children to actively maintain information while mentally working on that content or on any other (D'Esposito & Postle, 2015; Engle & Kane, 2004). Deficits in this component are present in the majority of students with attention-deficit/hyperactivity disorder (ADHD) and have been shown to be longitudinally and experimentally consistent with the behavioural symptoms of ADHD (Karalunas et al., 2017; Kasper et al., 2012). However, there remains considerable debate about the magnitude of these deficits and the extent to which they reflect the underlying mechanisms that generate the behavioural symptoms of ADHD (Chacko et al., 2014; Kofler et al., 2020).

Each component of EF develops at its own pace throughout childhood and adolescence, reaching maturity at different ages (Ferguson et al., 2021). The 6 to 12-year-old stage is vital in the development of EF (Davidson et al., 2006; Ferguson et al., 2021), since neuronal plasticity is particularly high and the prefrontal cortex is especially sensitive to environmental influences (Bull et al., 2011).

In order to measure executive functions in the childhood, two main types are distinguished: performance-based tasks and questionnaires (Zelazo et al., 2016). EF questionnaires have been described as an effective way to measure the practice of EF skills in "everyday" contexts such as school or home (Gioia et al., 2000; Zelazo et al., 2016). Questionnaires used with children are usually completed by teachers and parents. In contrast, performance-based tasks measure EFs under controlled conditions and may not be indicative of a child's typical daily use of those skills. Moreover, as suggested by several authors, it seems that performance tasks do not present an adequate ecological and predictive validity of these functions (Soto et al., 2020). For example, several studies have found that performance tasks do not discriminate between control and ADHD students (Barkley, 2019; Barkley & Eme, 2019)

The main questionnaires used to measure EF are the Behavioral Rating Inventory of Executive Functions (BRIEF; Gioia et al., 2000, 2002) or recently revised as the BRIEF-2 (Gioia et al., 2016), the Barkley Deficits in Executive Functioning Scale (BDEFS-CA for children and adolescents; Barkley, 2012) and the Behavior Assessment System for Children (BASC-2 and 3; Reynolds & Kamphaus, 2015).

The Children's Executive Functioning Inventory (CHEXI) is another example of an EF measurement questionnaire that can be used with children (Thorell et al., 2010a; Thorell & Nyberg, 2008). The 24-item CHEXI has been translated into several languages (i.e., English, Swedish, French, Spanish or Taiwanese) and, most importantly, is freely available for large-scale use (see www.chexi.se). Although the CHEXI was designed to measure four dimensions of EF (inhibition, regulation, WM, and planning), its authors found that two factors (inhibition and WM) provide a more consistent representation of the EF construct (Catale et al., 2013). These two factors demonstrated acceptable levels of internal consistency (Cronbach's $\alpha > .85$), test–retest reliability ($r > .74$) and criterion validity with ADHD symptoms of hyperactivity/impulsivity ($r = .27$–$.36$) and inattention ($r = .13$–$.27$; Catale et al., 2013; Thorell & Nyberg, 2008). Although it was created recently, it has been observed how CHEXI has been used in educational contexts, for example, observing its correlation with academic achievement (Catale et al., 2015; Conesa & Duñabeitia, 2021; Thorell et al., 2013) or measuring its validity in identifying the role of neuropsychological deficits in Attention deficit hyperactivity disorder (ADHD; e.g., see Sjöwall & Thorell, 2019; Thorell et al., 2010). As suggested by several authors in preschool samples, CHEXI has shown good discrimination between children with symptoms consistent with a diagnosis of ADHD and those without symptoms (Thorell et al., 2010b; Thorell & Catale, 2014). And as suggested by Molina-Torres et al., (2022) in a recent review, the CHEXI can be included as a valid and useful tool for the assessment of ADHD in this age group.

Given the enormous influence of EF on school and life success, it is necessary to identify EF levels and address them in a reliable way with tools accessible to practitioners. CHEXI may be a suitable option for it. In preschool children, a Spanish validation was found with adequate psychometric properties (Giménez de la Peña et al., 2022). However, the reliability and validity of the Spanish version of the CHEXI in elementary school children has not yet been investigated. Moreover, the CHEXI has not yet been used in Spanish samples in children with ADHD and its validity for identifying ADHD-related neuropsychological deficits has not been examined. Therefore, two studies have been performed. The aim of the first study is to investigate the psychometric properties of the Spanish version of the CHEXI. Using confirmatory factor analysis, we hypothesise that the two-factor model provides a statistically significant improvement in fit over the four-factor model. We also hypothesized that the CHEXI has good consistency and reliability in a sample of Spanish primary school children and that its measurement properties are invariant across different subgroups. The aim of the second study is to analyze its utility for the identification of ADHD in children aged 9 to 12 years. We hypothesized that the CHEXI is a sensitive measure for discriminating between children who meet the diagnostic criteria for ADHD and children with normal development.

Study 1

Method

Participants

Study 1

In this cross-sectional study, we investigated 1230 primary school Spanish students from 9 to 12 years old (M_{age} =10.28, SD=0.88, 48.86 % females). The data collected in this research was part of a larger longitudinal research project. The sample included students of 26 public and private Spanish schools, in the last three years of Primary Education (4th, 5th, and 6th grades). 27% of the students were enrolled in 4th grade, 41% in 5th grade, and 32% in 6th grade. Although the initial sample was slightly larger, children with special educational needs (N = 97), were excluded from the analysis.

Study 2

The participants were 148 Primary Education students aged between 9 and 12 years old (*M* = 10.3, *SD* = 0.96, 49% girls). The control group included 74 students (*M* = 10.4 years, *SD* = 0.95; 54 % girls) and the group diagnosed with ADHD were 74 students (*M* = 10.2 years, *SD* = 0.96; 44% girls). For the control group, we randomly assigned the same number of participants as the experimental group through the available sample we found in study 1. The sample was collected through the educational psychologist at the school with the consent of the participants' families. These students were diagnosed by the school itself in collaboration with their respective child and youth mental health care institution. Among the 74 children, 21 met the criteria for the ADHD inattentive type (ADHD-I), 14 met for the ADHD hyperactive type (ADHD-H) and 39 met the criteria for the ADHD combined type (ADHD-C). The control group was randomly selected from the set of participants in study 1.

Instruments

Study 1

The Spanish version of *The Childhood Executive Function Inventory* (CHEXI; Catale et al., 2015) was used. Parents rated each item using a 5-point Likert rating scale (from 1 = definitely not true to 5 = definitely true). It consists of 24 items and assesses four aspects of the students' executive functioning: WM (9 items, e.g., "has difficulty remembering what he/she is doing, in the middle of an activity"), planning (4 items, e.g., "has difficulty telling a story about something that has happened so that others may easily understand"), inhibition (6 items, e.g., "has difficulty holding back his/her activity despite being told to do so"), and regulation (5 items, e.g., "has clear difficulties doing things he/she finds boring"). These scales correspond to the EF domains presented in Barkley's (2005) hybrid model as constituting the major deficits in ADHD. Factor analysis of either parent or teacher ratings (Thorell & Nyberg, 2008) has yielded two broad factors named WM (mean value of items measuring working memory and planning) and inhibition (mean value of items measuring inhibition and regulation). Previous studies have shown that the CHEXI has good internal consistency and factorial structure as well as good predictive capacity on school performance (Thorell et al., 2013). The items are described in an inverted way where it is established that a lower score of the participant in the corresponding subscales means better levels of EF.

Study 2

The CHEXI described in study 1 was administered to parents of the children in the Spanish sample.

Procedure

This study procedure was approved by the University of Murcia's Research Ethics Commission (Ref: 2989/2020). Three months before completing the instrument, private and public schools in several autonomous communities in Spain were asked by e-mail if they were interested in taking part. Since the sample was composed of underaged participants, parents were requested to sign a parental consent form. Under the supervision of their teacher, participants completed a 20-min online study programmed using Gorilla Experiment Builder (Anwyl-Irvine et al., 2020) in their respective classrooms. Students were informed that their responses would be confidential and used only for research purposes. Participation in the study was voluntary and participants could give up at any time.

Data Analysis

To complete the statistical analysis of this study, the open-source statistical software were JASP (Version 0.16.3) was used.

Study 1

Descriptive statistics, Pearson's correlations, reliability analysis and confirmatory factor analysis were conducted.

Firstly, a descriptive analysis of the 24 items in the questionnaire was carried out, considering the means and standard deviations, skewness and kurtosis. The assumption of univariate normality was examined by standardised values for univariate skewness and kurtosis coefficients.

That being so, a correlation analysis was performed for the four-factor model of the BPN-CS test. The Cronbach's alpha coefficient and Mc Donald's omega were used to analyse the reliability of the scale. In comparison with Cronbach's alpha, McDonald's omega has the advantage of taking into account the strength of association between items and constructs as well as item-specific measurement errors (Dunn et al., 2014). For both alpha and omega, the corresponding 95% CI confidence interval was included (Fan & Thompson, 2001). The Kaiser-Meyer-Olkin sample adequacy measure (KMO) and the Bartlett sphericity test were used to test the adequacy of the sample to the factor analysis.

A confirmatory factor analysis (CFA) was performed using a robust weighted least square (DWLS) estimator. DWLS was chosen because this estimator is more suitable due to the ordered-categorical nature of Likert scales, rather than the traditional maximum likelihood estimation (Beauducel & Herzberg, 2006; Forero et al., 2009), resulting in more precise estimates of key model-parameters.

The loading factors were analysed using two factor-model proposed by (Catale et al., 2015). According to suggestions (Hu & Bentler, 1998), goodness of fit was judged with different several fit indices: SRMR, CFI, TLI and RMSEA, with a confidence interval (CI) of 90%. Smaller values for RMSEA (ideally < 0.06) and SRMR (<0.08), while larger values for CFI and TLI (ideally > 0.90) are indicative of acceptable model fit of the data.

In order to explore measurement invariance across gender (group 1 = girls, group 2 = boys) and year (group 1 = 9-10 years, group 2 = 11-12 year), a multiple-group confirmatory factor analysis (MGCFA) was performed. The measurement invariance types considered in this study was a configural model, metric, scalar and strict invariance. A configured invariance model was conducted to test whether the groups associate the same subsets of items with the same constructs, with factor means set to zero. This is a necessary condition for testing invariance by comparing it with other invariance models based on fit indices. In order to check whether the factor loadings between each item and its factor are the same in all groups, a metric invariance was performed. The scalar invariance compares latent means; this indicates that none of the groups tends to respond systematically higher or lower to the items of scales than other groups. And the strict invariance is the equivalent of the residual items. This model analyses whether the error variance of the items is the same in the different groups. If this is not the case, it would indicate differences in measurement precision between the groups (Cheung & Rensvold, 2002; Schroeders & Gnambs, 2020). A MGCFA following these steps is widely accepted as the best approach for testing measurement invariance (Milfont & Fischer, 2010). Furthermore, as indicated by Chen, (2007), a change of -0.010 or more in the CFI and ≥0.015 in the RMSEA or a change of ≥0.030 in the SRMR was used as an indication of non-invariance when testing for metric invariance. To test for scalar and strict invariance, we use the same changes in the CFI and RMSEA, supplemented by a change of ≥0.010 in the SRMR, as an indication of non-invariance.

Finally, the temporal stability of parent ratings collected six months later was examined using bivariate correlations.

Study 2

As in study 1, descriptive statistics were conducted. Next, an analysis of variance (ANOVAs) was performed to identify if there were differences in each group (ADHD;

Control). The main effects and inter-group effects were analyzed, and we applied Tukey post hoc tests. Partial eta-squared (η^2) was used to estimate effect size. This is a considered as a descriptive index of strength of association between an experimental factor (main effect or interaction effect) and a dependent variable (Nouchi et al., 2013). Effect sizes were interpreted as following: $\eta^2 \leq 0.01$ is regarded as a small effect, $\eta^2 \leq 0.06$ was considered moderate, $\eta^2 \leq 0.14$ was considered large (Field, 2017). Regarding p-value, it ranges from 0 to 1. Higher values indicate less probability of committing a type II error. The level of significance was set at $p < .05$.

Results

Study 1

In this first study, the aim is to investigate the psychometric properties of the Spanish version of the CHEXI.

Descriptive Analysis

The means, standard deviations, skew and kurtosis of the two subscales of the 24-item CHEXI are presented according to gender in Table 1. Standardised values ranged from 0.02 to 0.30 for skewness and from -0.52 to -0.17 for kurtosis, sustaining the assumption of univariate normality (Field, 2017). In addition, as shown in table 2, the descriptive statistics of the sample are shown by year.

[See Table 1 at the end of manuscript]

[See Table 2 at the end of manuscript]

The KMO index showed a good value of 0.95 and the values of the Bartlett sphericity test were statistically significant ($\chi^2 = 7247$; $p<0.001$). The internal consistency of the scale was evaluated with two indexes: Cronbach's α and McDonald's ω (Dunn et al., 2014) and the corresponding 95% CI. In relation to the WM subscale, the results showed Cronbach's α-values of 0.91 (0.90-0.92) and McDonald's ω coefficients were 0.91 (0.90-0.92). The Inhibition subscale exhibited α-values of 0.84 (0.82-0.85) and ω coefficients of 0.84 (0.83-0.85). As expected, the two subscales were strongly and positively correlated with each other ($r = .72$; $p < .001$). In addition, the results showed adequate test-retest reliability for both subscales: $r = .77$, $p < .001$ for the WM subscale, $r = .71$, $p < .001$ for the Inhibition subscale. In both cases, the Shapiro-Wilk normality test and Levene's homogeneity test were met.

Confirmatory Factor Analysis

The factorial loadings of the individual items of the two sub-scales of the 24-item CHEXI are presented in Table 3. All the items were statistically significant within their respective factor, and factor loadings ranged from 0.50 (Item 16) to 0.75 (Item 14).

[See Table 3 at the end of manuscript]

In order to analyse the most optimal model, the above proposed two-factor model was compared with an initial four-factor (see Table 4). The four-factor model, initially developed by Thorell & Nyberg, (2008) was composed of the subscales of working memory (Q1, Q3, Q6, Q7, Q9, Q19, Q21, Q23, Q24), planning (Q12, Q14, Q17, Q20), inhibition (Q2, Q4, Q8, Q11, Q15) and regulation (Q5, Q10, Q13, Q16, Q18, Q22). The two-factor model proved to represent an excellent fit for the data (X^2=949.32, $p < 0.001$, CFI = 0.98, TLI = 0.98, SRMR = 0.06, RMSEA = 0.05). Although four-factor model also met the recommendations for an acceptable fit (X^2=1079.56, $p < 0.001$, CFI = 0.97, TLI = 0.97, SRMR = 0.08, RMSEA = 0.06), it had less adequate values than the two-factor model.

[See Table 4 at the end of manuscript]

Multiple-Group Confirmatory Factor Analysis

A multiple-group approach was used to test measurement invariance across gender and year. Before carrying out the invariance measurement, each group was tested separately to ensure that it was adequately fit. Configural invariance criteria was met, as noted by the models' good fit indices across gender or year (see model 1 in Table 5). Criteria for metric invariance (model 2) was also met, showing that the CHEXI was invariant across gender groups (*ΔCFI* = − 0.001; *ΔSRMR* = 0.001; *ΔRMSEA* = 0.001) and year (*ΔCFI* = - 0.001; *ΔSRMR* = 0.001; *ΔRMSEA* = 0.001). Regarding scalar invariance (model 3), no differences in latent means were observed between genders (*ΔCFI* = -0.001; *ΔSRMR* = - 0.001; *ΔRMSEA* = 0.000). The results showed that the criteria for scalar invariance (model 3) was fully met across year (*ΔCFI* = -0.001; *ΔSRMR* = 0.000; *ΔRMSEA* = 0.001). Criteria for strict invariance (model 4) were also met across gender groups (*ΔCFI* = 0.000; *ΔSRMR* = 0.001; *ΔRMSEA* = -0.001) and year (*ΔCFI* = 0.000; *ΔSRMR* = 0.000; *ΔRMSEA* = 0.001).

[See Table 5 at the end of manuscript]

After testing for measurement invariance, it was observed whether there were differences between the subscale differences in terms of gender and age. Regarding gender, significant differences were observed in both the WM subscale [t = -3.52, p = <.001] and the Inhibition subscale [t = -4.39, p = <.001]. In contrast, no differences were observed with regard to year. Finally, Pearson correlations were calculated to examine the temporal stability of parents' ratings after six months. The findings showed that temporal stability was adequate for the total score (r = 0.72, p < .001), as well as for the WM subscale (r = 0.72, p < .001) and the Inhibition subscale (r = .71, p < .001).

Study 2

As for the second study, the aim is to analyze its usefulness for the identification of ADHD in children aged 9 to 12 years. Descriptive analyses were completed first. The mean scores and standard deviations for both groups are shown in Table 6.

[See Table 6 at the end of manuscript]

As for the ANOVA results, for both subscales, a significant group effect was observed, with children with ADHD scoring significantly higher than children in the control group. It should be recalled that the CHEXI is an instrument with negative items, where the higher the score, the lower the level of executive functions.

In the CHEXI *working memory* scale, statistical differences were observed regarding Group [F (1, 11125) = 135.42, p = < 0.001, $\eta^2 partial$ = 0.09]. Through the *post hoc* analysis with Tukey's correction, a significant difference of 12.62 points with respect to the control group was demonstrated in the ADHD group [t = -11.64, p < 0.001, Cohen's d = -1.39]. In other words, the ADHD group scored higher than the control group on the working memory subscale and therefore, the ADHD group seems to have lower levels of working memory.

In the CHEXI *inhibition* scale, significant differences were also observed as a function of the Group factor [F (1, 7638) =140.92, p < 0.001, $\eta^2 partial$ = 0.10]. The ADHD group showed a significant difference of 10.46 points compared to the Control group [t = -11.87, p < 0.001; Cohen's d = -1.42]. As with the other subscale, the ADHD group scored higher than the control group on inhibition subscale and, accordingly, the ADHD group appears to report lower levels on inhibition.

Discussion

The aim of this study was to validate the Spanish version of the Childhood Executive Function Inventory (CHEXI) in a large sample of primary school students. CHEXI is a new questionnaire that is available free of charge whose main focus is the deficits in working memory and inhibition in children aged 8 to 12 years. The results supported the construct validity of this version and were consistent with other similar studies performed in other populations (Camerota et al., 2018; Catale et al., 2013, 2015).

Based on previous studies, two models were tested in a CFA: a four-factor model and a two-factor model. The results of this CFA confirmed the two-factor structure as the best model of the CHEXI, in line with the analyses conducted by the main authors of the instrument (Catale et al., 2013, 2015).

Regarding the reliability of the scale, the internal consistency analysis provided an excellent value for the Cronbach's alpha and Mc Donald's omega in each of the two subscales. This results are similar to those obtained in previous studies (Catale et al., 2015; Thorell & Nyberg, 2008). A multiple-group confirmatory factor analysis showed that the structure of the two-factor model, and was invariant with regards to gender and year. The present results of strong measurement invariance suggest that CHEXI factor scores can be directly compared for boys and girls, and for 8 or 12-year-olds.

The descriptive analysis suggested a significant distinction between inhibition and WM scores in students according to their gender, supporting several studies that showed how girls usually score higher on executive function questionnaires, and parents and teachers rated them higher than boys on EF measurements (Klenberg et al., 2010; Schirmbeck et al., 2020; Thorell et al., 2013; Wanless et al., 2013). The substantially lower WM and inhibition scores reported in our study by boys may place them at greater risk than females for may place them at greater risk than females for engagement in impulsive and inattentive behaviours in their school development. There is a substantial literature on this topic, which shows that the prevalence of both impulsive behaviours and symptoms in the domain of Attention Deficit Hyperactive (i.e., ADHD) in males is much higher than in females (Arnett et al., 2015; Quinn & Madhoo, 2014; Weafer & de Wit, 2014). Therefore, it may be convenient, among others, to use these questionnaires in order to observe possible developmental trajectories.

As in the study by Catale et al. (2015) with Belgian and Swedish children, we was also observed that there were significant differences in the scores registered by parents between typically-developing students and students diagnosed with ADHD. These results are especially interesting considering that the CHEXI is based on the Barkley's (2005) hybrid model. Furthermore, CHEXI does not include items written identically to those used by other scales in relation to the symptom criteria for ADHD as presented in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5;American Psychiatric Association, 2013) such as, for example, the BRIEF. The CHEXI can be of great use in identifying and observing EF deficits related to ADHD symptoms. However, it is worth mentioning that multifactorial causality is reflected in the heterogeneity of this disorder (Luo et al., 2019) and, therefore, this instrument can be used as a complement within a comprehensive analysis towards its diagnosis.

This instrument may be of interest to researchers and educational psychologists, since through its free use (see http://www.chexi.se), it can provide valuable information on the executive functioning of students. In fact, regarding skills that are critical for academic success, research has revealed that EF play a fundamental role (Cortés Pascual et al., 2019; Diamond & Ling, 2019; St Clair-Thompson & Gathercole, 2006; Usai et al., 2018; Zelazo et al., 2016). These EF have been shown to be a key element in the development of skills, as problem solving, reasoning or planning (Collins & Koechlin, 2012; Duncan et al., 2012), or skills related to reading (e.g., see Follmer, 2018; Gathercole et al., 2004). As such, it is important to have a scale with adequate psychometric properties that measures inhibition and working memory scores, the CHEXI could be used to it. These results invite future experimental research to corroborate the psychometric properties and expand the study variables. Due to its applicability, replicability and adaptability, this instrument can be useful, for example, to evaluate the effects of school intervention programs on executive functions in the classroom.

However, some particularities must be taken into consideration. The interpretation of the measurement of executive functions with this instrument should be taken with some caution. Firstly, CHEXI contains the working memory and inhibition subscale and considering the multifaceted construct of EF (Miyake et al., 2000), future studies should be directed to explore the validity of a new subscale such as cognitive flexibility. Secondly, literature has corroborated the complexity involved in measuring executive functions and, more specifically, the weak relationship between behavioral questionnaires and chronometric performance tests (Burgess et al., 2006; Toplak et al., 2013). Therefore, the importance of combining the two types of measurement is suggested in order to collect more complete information regarding the assessment, intervention and improvement of students' EFs (Toplak et al., 2009, 2013). Nevertheless, scores on questionnaires such as the CHEXI can represent the observable behaviors associated with that EF in everyday settings, such as the classroom. Thirdly, and due to its recent novelty, there is a lack of literature on the applicability and analysis of CHEXI in educational contexts. In terms of future lines of research, it is important to highlight the importance of presenting normative data from the instrument so that scores can be interpreted and compared in different contexts or educational stages. Also, it would be interesting to carry out experimental interventions aimed at improving EF using this questionnaire, and to observe its transfer to the academic, behavioural and emotional aspects of students in their daily lives (e.g., see Conesa & Duñabeitia, 2021).

This study tests the psychometric properties of the Childhood Executive Functioning Inventory Scale (CHEXI) in the Spanish context of Primary school. The results showed that the validity and reliability of the scores derived from the CHEXI and their subscales (Working Memory and Inhibition) were adequate and satisfactory. That, combined with the fact that it is available online and is considerably shorter than other rating scales, it suggests that CHEXI is an attractive and reliable instrument to measure the EF in Spanish children aged 8 to 12 years.

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Conflicto de intereses

Los autores de este trabajo declaran que no existe conflicto de intereses.

Figures / Tables

Table 1

Descriptive Statistics total Sample (n=1230), Girls (n=602) and Boys (n=628)

	WM			**Inhibition**		
	Total	**Girls**	**Boys**	**Total**	**Girls**	**Boys**
Mean	29.38	28.51	30.21	29.60	4.06	3.98
SD	8.90	8.87	8.86	7.42	7.24	7.48
Skewness	0.27	0.30	0.24	0.09	0.15	0.02
Kurtosis	-0.44	-0.52	-0.34	-0.21	-0.23	-0.17
Min	13	13	13	11	11	11
Max	55	54	55	52	51	52

**Note. SD = standard deviation, Min = minimum, Max = maximum*

Table 2

Descriptive statistics of the sample (n = 1230) according to age (9 years =264; 10 years = 446; 11 years = 440; 12 years = 82)

	Working Memory				Inhibition			
	9 years	**10 years**	**11 years**	**12 years**	**9 years**	**10 years**	**11 years**	**12 years**
Mean	29.05	30.04	28.57	31.71	29.89	29.71	29.08	30.87
SD	8.54	9.05	9.10	8.90	7.31	6.99	7.85	7.55
Skewness	0.34	0.28	0.48	-0.17	0.17	0.02	0.19	-0.31
Kurtosis	-0.24	-0.20	0.04	-0.34	-0.47	-0.44	0.03	0.12
Min	13	13	13	13	12	11	11	11
Max	53	65	64	52	48	47	52	47

**Note. SD = standard deviation, Min = minimum, Max = maximum*

Table 3

Results from a Factor Analysis of the CHEXI Questionnaire

CHEXI item	Factor loading	
	WM	INH
Factor 1: WM		
Item 1	**.72**	–
Item 3	**.66**	–
Item 6	**.69**	–
Item 7	**.64**	–
Item 9	**.61**	–
Item 12	**.64**	–
Item 14	**.75**	–
Item 17	**.54**	–
Item 19	**.67**	–
Item 20	**.71**	–
Item 21	**.68**	–
Item 23	**.61**	–
Item 24	**.69**	–
Factor 2: INH		
Item 2	–	**.65**
Item 4	–	**.74**
Item 5	–	**.66**
Item 8	–	**.68**
Item 10	–	**.65**
Item 11	–	**.69**
Item 13	–	**.62**
Item 15	–	**.75**
Item 16	–	**.50**
Item 18	–	**.61**
Item 22	–	**.53**

Note. N = 1320. Factor loadings above .30 are in bold. All regression weights are significantly different from zero at $p < 0.001$.

Table 4

Fit indices for the two models (n = 1320)

Model	X^2	df	p	CFI	TLI	SRMR	RMSEA (90% CI)
Two-factor model	949.32	246	< .001	0.98	0.98	0.06	0.05 (0.05-0.06)
Four-factor model	1079.56	229	< .001	0.97	0.97	0.08	0.06 (0.06-0.07)

**Note.* χ^2 = Chi Squared; df = Degree of Freedom; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; SRMR = Standardized Root Mean-Square; RMSEA = Root-Mean-Square Error of Approximation; 90% CI = 90% Confident Interval

Table 5

Model fit and measurement invariance between groups according to gender and year

Model	**X² (df)**	**p**	**CFI** (ΔCFI)	**TLI**	**SRMR** (ΔSRMR)	**RMSEA (90% C.I.)** (ΔRMSEA)
Gender						
Model 1: Configural invariance	1033.07 (492)	<.001	0.986	0.984	0.059	0.042 (0.039-0.046)
Model 2: Metric invariance	1089.73 (512)	<.001	0.985 (-0.001)	0.983	0.060 (0.001)	0.043 (0.039-0.046) (0.001)
Model 3: Scalar Invariance	1135.14 (532)	< .001	0.984 (-0.001)	0.983	0.059 (-0.001)	0.043 (0.039-0.046) (0.000)
Model 4: Strict Invariance	1152.50 (556)	< .001	0.984 (0.000)	0.984	0.060 (+0.001)	0.042(0.038-0.045) (-0.001)
Year						
Model 1: Configural invariance	1075.72 (492)	< .001	0.985	0.983	0.060	0.044 (0.040-0.047)
Model 2: metric invariance	1147.14 (512)	< .001	0.984 (-0.001)	0.982	0.061 (0.001)	0.045 (0.041-0.048) (0.001)
Model 3: scalar invariance	1171.82 (532)	< .001	0.983 (-0.001)	0.983	0.061 (0.000)	0.044 (0.041-0.048) (0.001)
Model 4: Strict Invariance	1191.18 (556)	< .001	0.983 (0.000)	0.982	0.061 (0.000)	0.045 (0.041-0.048) (0.001

**Note.* χ^2 = Chi Squared; df = Degree of Freedom; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; SRMR = Standardized Root Mean-Square; RMSEA = Root-Mean-Square Error of Approximation; 90% CI = 90% Confident Interval; ΔCFI = Change in Comparative Fit Index, ΔRMSEA = Change in Root-Mean-Square Error of Approximation,

Table 6

Mean scores by group in the CHEXI Scores

	ADHD Group	**Control Group**
CHEXI Scores		
Working Memory	41.97 (9.89)	29.31 (9.51)
Inhibition	39.96 (7.61)	29.47 (7.39)

**Note*. Standard deviations are in parentheses.