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The Childhood Executive Function Inventory: Confirmatory Factor Analyses and Cross-Cultural Clinical Validity in a Sample of 8- to 11-Year-Old Children

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Abstract

Objective: The aim was to investigate the psychometric characteristics of the French adaptation of the Childhood Executive Functioning Inventory (CHEXI) in children and to explore the cross-cultural validity of the CHEXI in discriminating between children with ADHD and controls in two culturally different samples (Belgian and Swedish). **Method:** Study I included normally developing children (*n* = 242), whereas Study II included both children diagnosed with ADHD (*n* = 87) and controls (*n* = 87). CHEXI ratings were collected from parents. **Results:** Confirmatory factor analyses replicated the two-factor solution, referred to as inhibition and working memory, which had been identified previously. Both subscales had good psychometric properties. Furthermore, the CHEXI was found to discriminate, with high sensitivity and specificity, between children with ADHD and controls in both cultural samples. **Conclusion:** The CHEXI can be considered as a valuable screening measure for ADHD in children, but the cross-cultural clinical implications of ratings have to be considered. *(J. of Att. Dis. 2015; 19(6) 489-495)*

Keywords

executive function, inventory, children, cross-cultural validity, ADHD

Introduction

Executive functioning (EF) is an umbrella term referring to the complex cognitive processes required when a predominant response must be inhibited or a specific behavior must be initiated. These functions are also involved when generating hypotheses, planning actions, judging a situation, making a decision, or updating and monitoring information (e.g., Lezak, 1982; Miyake et al., 2000). Thus, the EF framework refers to higher order interrelated cognitive processes.

Many authors consider executive functions to involve separate cognitive processes (e.g., Miyake et al., 2000). Two or three specific executive functions are usually identified, of which inhibition and working memory are the most common ones; some studies have also identified a third factor referred to as cognitive flexibility or shifting (e.g., Huizinga, Dolan, & van der Molen, 2006; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; St. Clair-Thompson & Gathercole, 2006). Specific executive dysfunctions have been linked to developmental disorders such as ADHD (e.g., Pennington & Ozonoff, 1996; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) and acquired disorders such as traumatic brain injury (for a review, see Levin & Hanten, 2005). It is therefore important for neuropsychologists to use precise and specific process-related measures to detect deficits in the principal executive functions. In addition, clinicians need to better understand the nature and frequency of dysexecutive behaviors associated with specific developmental and/or acquired disorders in day-to-day life. However, to date, only a few behavioral measures have been specifically developed for children to assess these complex processes in their day-to-day functioning. Furthermore, as emphasized by Huizinga and Smidts (2011), the use of these questionnaires has primarily been limited to English-speaking countries. Until now, there have been only two exceptions: the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Espy, & Isquith, 2003) and the Childhood Executive Functioning

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Inventory (CHEXI; Thorell & Nyberg, 2008) for which recent validation studies using versions in several different languages have been conducted (e.g., the Dutch adaptation of the BRIEF, Huizinga & Smidts, 2011; the French adaptation of the CHEXI, Catale, Lejeune, Merbah, & Meulemans, in press). The use of these questionnaires makes an important contribution to the applied research field examining EF, as it has been demonstrated that laboratory measures and questionnaires tap into at least partly different aspects of EF (e.g., Bodnar, Pralune, Cutting, Denckla, & Mahone, 2007; Catale et al., in press).

In this study, we are particularly interested in a promising new inventory: the CHEXI (Thorell & Nyberg, 2008). The CHEXI is a 26-item inventory of executive functions for children; it is available for download free of charge on the Internet in several different languages, including English, Spanish, French, Swedish, Chinese, and Farsi (see www.chexi.se). It was developed with the aim of focusing specifically on different types of executive control rather than on more general statements or items directly related to the symptom criteria for ADHD. It includes items specifically related to executive behavior and is divided into four a priori subscales: Working Memory, Planning, Inhibition, and Regulation. However, using exploratory factor analysis (EFA) in a sample of Swedish children aged 5 to 6 years old, Thorell and Nyberg (2008) showed that the CHEXI can be characterized by two factors: Inhibition and Working Memory. This two-factor model was replicated with the French adaptation of the CHEXI in a sample of young French-speaking children in Belgium (Catale et al., in press), confirming the cross-cultural robustness of the structure of this inventory.

In addition, both the original version (Thorell & Nyberg, 2008) and the adapted French version (Catale et al., in press) have shown good test–retest reliability and internal consistency, which confirm the psychometric strengths of this inventory. Finally, it has also been demonstrated that the CHEXI can be used to discriminate between young Swedish children fulfilling the diagnostic criteria for ADHD and normally developing children (Thorell, Eninger, Brocki, & Bohlin, 2010). To conclude, these previous studies confirm that the CHEXI can be successfully used as a screening instrument for dysexecutive behaviors in young children.

Aim of the Present Study

This article presents two studies. In Study I, we aimed to analyze the psychometric characteristics of the CHEXI when used with older children (8 to 11 years old instead of preschoolers and kindergarten children as in previous studies) and to determine through confirmatory factor analysis (CFA) whether the two-factor solution (Working Memory and Inhibition) found in previous studies in young children can also be applied to children aged 8 to 11 years old.

In Study II, we aimed to assess the cross-cultural clinical validity of the CHEXI by examining to what extent this questionnaire can discriminate between children with ADHD and normally developing children in one Belgian and one Swedish sample of children aged 8 to 11 years old.

Study I

Participants and Procedure

Participants. A total of 242 parents of normally developing 8- to 11-year-old children (120 boys) filled out the CHEXI (*M* age and standard deviation [*SD*] in months = 119.64 ± 14.80). All children were French-speaking Belgian and were recruited in the province of Liège, Belgium. Similarly to the study of the French adaptation of the CHEXI (Catale et al., in press), exclusion criteria for participation in the study were a history of traumatic brain injury or neurological, developmental, learning, or psychiatric disorders. Twenty parents were solicited to complete the CHEXI a second time within a 3-month interval to determinate the test–retest reliability.

Questionnaire. The CHEXI, originally developed by Thorell and Nyberg (2008), consists of 26 items, divided into four a priori subscales: Working Memory, Planning, Inhibition, and Regulation. As the two last items of the questionnaire were excluded due to overly low sampling adequacy in the original study (Thorell & Nyberg, 2008), these two items were also excluded from the present study. We used the French- and Swedish-language versions of the questionnaire. The Swedish version was used in the original study by Thorell and Nyberg, and the French adaptation has also been used in previous studies (Catale et al., in press). As mentioned above, the questionnaire is available for download in several different languages.

Statistical Analyses. We performed a CFA using LISREL 8.80 (Jöreskog & Sörbom, 2006) to examine the CHEXI's factor structure in the sample of 8- to 11-year-old children. We tested the two-factor model found by Thorell and Nyberg (2008), including a Working Memory factor and an Inhibition factor (see Table 1).

To evaluate the fit of this two-factor model, the following goodness-of-fit indices were used: (a) the chi-square value, (b) the root mean square error of approximation (RMSEA; Browne & Cudeck, 1989), (c) the comparative fit index (CFI; Bentler, 1990), and (d) the standardized root mean square residual (SRMR). Generally, the fitness index is calculated from the value for the chi-square divided by the degrees of freedom. A value for χ^2/df below 2 usually suggests a good model fit, and below 3 an acceptable model fit (Bollen, 1989). The RMSEA indicates a "good" approximation if it is less than .05. An RMSEA between .05 and .08 reflects a "reasonable" approximation, and an RMSEA greater than .08

Table 1. Confirmatory Factor Analysis: Factor Loading.

Items/a priori scale	WM	INH
1. Has difficulty remembering lengthy instructions/WM	.64	—
2. Seldom seems to be able to motivate himself of herself to do something that he or she does not want to do/REG	—	.78
3. Has difficulty remembering what he or she is doing in the middle of an activity/WM	.43	—
4. Has difficulty following through on less appealing tasks unless he or she is promised some type of reward for doing so/REG	—	.73
5. Has a tendency to do things without first thinking about what could happen/INH	—	.74
6. When asked to do several things, he or she only remembers the first or last/WM	.70	—
7. Has difficulty coming up with a different way of solving a problem when he or she gets stuck/WM	.60	—
8. When something needs to be done, he or she is often distracted by something more appealing/REG	—	.76
9. Easily forgets what he or she is asked to fetch/WM	.63	—
10. Gets overly excited when something special is going to happen (e.g., going on a field trip, going to a party)/INH	—	.68
11. Has clear difficulties doing things that he or she finds boring/REG	—	.84
12. Has difficulty planning for an activity (e.g., remembering to bring everything necessary for a field trip or things needed for school)/PLAN	.69	—
13. Has difficulty holding back his or her activity despite being told to do so/INH	—	.68
14. Has difficulty carrying out activities that require several steps (e.g., for younger children, getting completely dressed without reminders; for older children, doing all homework independently)/PLAN	.61	—
15. To be able to concentrate, he or she must find the task appealing/REG	—	.89
16. Has difficulty refraining from smiling or laughing in situations where it is inappropriate/INH	—	.35
17. Has difficulty telling a story about something that has happened so that others may easily understand/PLAN	.54	—
18. Has difficulty stopping an activity immediately upon being told to do so. For example, he or she needs to jump a couple of extra times or play on the computer a little bit longer after being asked to stop/INH	—	.60
19. Has difficulty understanding verbal instructions unless he or she is also shown how to do something/WM	.58	—
20. Has difficulty with tasks or activities that involve several steps/PLAN	.60	—
21. Has difficulty thinking ahead or learning from experience/WM	.52	—
22. Acts in a wilder way compared with other children in a group (e.g., at a birthday party or during a group activity)/INH	—	.38
23. Has difficulty doing things that require mental effort, such as counting backward/WM	.44	—
24. Has difficulty keeping things in mind while he or she is doing something else/WM	.68	—
25. Thinks out loud, even when performing relatively simple tasks/WM	NI	NI
26. Has difficulties understanding the concept of time compared with same-aged peers/WM	NI	NI

Note: WM = working memory; INH = inhibition; REG = regulation; PLAN = planning; NI = not included.

indicates a "poor" approximation. A CFI greater than .95 indicates an adequate model fit. Finally, values of the SRMR are expected to stay below .10 (Kline, 2005).

Results

CFAs. In line with Thorell and Nyberg (2008) and Catale et al. (in press), a two-factor model was constructed in which the items of the CHEXI were hypothesized to reflect two factors: Inhibition and Working Memory (for CFA item loading, see Table 1). The chi-square of the model was significant, $\chi^2(251) = 520,336$, $p < .001$. The χ^2/df ratio is 2.07, which indicates an acceptable fit. For the other fit indices, we obtained an RMSEA of .07, a CFI of .97, and an SRMR of .06. Consequently, the combination of these indices indicated an adequate fit for the two-factor model tested.

Reliability. The internal consistency (Cronbach's α) was .85 for the Inhibition subscale and .89 for the Working Memory subscale. In addition, the results showed high test–retest reliability for both subscales: r =.74, $p < .001$ for the Working Memory subscale, and r = .87, $p < .001$

for the Inhibition subscale (*M* score and *SD* for the whole sample for the Working Memory subscale = 24.54 ± 8.05, and *M* score and *SD* for the whole sample for the Inhibition subscale = 26.88 ± 8.1).

Study II

Participants and Procedure

Participants

Sample 1: Belgian French-speaking children. The Belgian sample included 25 children (aged 8 to 11 years old) diagnosed with ADHD according to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; American Psychiatric Association [APA], 1994) criteria and a control group of 25 children who were matched to the clinical sample with regard to age and gender. The clinical sample was recruited from an ambulatory assessment for a neuropsychological investigation in the Psychological and Speech Therapy Consultation Center of the University of Liège (Belgium). Only 8- to 11-year-old children with inattention and/or agitation/impulsive behaviors in day-to-day life were included in this study. An extensive anamnesis was then conducted by a training neuropsychologist to exclude children with any neurological (e.g., traumatic brain injury) or psychopathological disorder. Furthermore, each child's ADHD diagnosis was confirmed by the parents using a French adaptation of the ADHD Rating Scale IV (DuPaul, Power, Anastopoulos, & Reid, 1998), which includes the 18-symptom criteria for ADHD presented in the *DSM-IV* (APA, 1994). Among the 25 children (18 boys, *M* age in months = 120.60, *SD* = 16.62), 13 met the criteria for the ADHD combined type (ADHD-C), 11 met the criteria for the ADHD inattentive type (ADHD-I), and 1 for the ADHD hyperactive type (ADHD-H) following the *DSM-IV*. The control group consisted of 25 children recruited from the normally developing children in Study I (18 boys, *M* age in months = 118.72, *SD* = 14.48).

Sample 2: Swedish children. The Swedish sample included 62 children diagnosed with ADHD according to the *DSM-IV* criteria (APA, 1994). These children were recruited from the Stockholm ADHD center, a government-funded institution that supports families of children with ADHD. Similarly to the Belgian sample, the ADHD diagnosis was confirmed by the parents using the ADHD Rating Scale IV (DuPaul et al., 1998). In the clinical sample (38 boys, *M* age in months = 117.71, *SD* = 12.79), 46 met the criteria for ADHD-C, 15 met the criteria for ADHD-I, and 1 met the criteria for ADHD-H according to the *DSM-IV* (APA, 1994). The control group was recruited from randomly selected schools in the Stockholm area and consisted of 62 children (*M* age in months = 117.32, *SD* = 13.25) who were matched for age and gender with the children of the clinical group.

Questionnaire. The CHEXI described in Study I was administered to the parents of the children in the Belgian and Swedish samples.

Results

A two-way ANOVA with Group (ADHD vs. control) and Country (Sweden vs. Belgium) as independent variables was computed on both subscales (see Table 2). For both CHEXI subscales, there was a significant Group effect with the ADHD children having significantly lower scores than the children in the control group. There was also a marginally significant effect of Country for inhibition but not for working memory. Finally, there was a significant interaction effect of Group and Country with regard to inhibition. Post hoc analyses revealed that, for this subscale, the scores for the clinical group did not differ significantly between the two countries ($p > .05$), whereas control Belgian children had more inhibitory problems compared with control Swedish children ($p < .05$).

Logistic regression analyses were then conducted to determine the subscales' sensitivity and specificity in assigning the children into the correct group (ADHD vs. controls). The results showed that, using the parental ratings, the CHEXI Inhibition and Working Memory subscales contributed significantly to discriminating the ADHD children from the control group (chi-square ranged between 40.62 and 57.17, *p*s < .001, for the Belgian sample, and from 146.94 to 149.97 for the Swedish sample, *p*s < .001). The sensitivity (range = .90-.94) and the specificity (range = .84-.96) were high for both the Inhibition and Working Memory subscales in the two samples (see Table 3). Considering the normality of the distribution of all variables (using the Kolmogorov–Smirnov test, $p > .05$) and the homogeneity of variance (using the Levene test, $p > .05$), cutoff scores for each subscale in each country were also calculated (see Table 3).

Discussion

The principal aim of this study was to determine whether the two-factor model (Inhibition and Working Memory) of the CHEXI that had previously been found in young children would be replicated in older children (8 to 11 years). In addition, this study investigated the CHEXI's ability to discriminate between 8- to 11-year-old Belgian and Swedish children with ADHD and normally developing children matched to the ADHD samples for age and gender.

First, the results of the CFA showed that, as in previous studies with young children, the two-factor solution of the CHEXI (Inhibition and Working Memory) can be considered as an appropriate model in 8- to 11-year-old children. In other words, as previously confirmed in younger children, the CHEXI specifically measured inhibition- and

Table 2. Means and *SD*s for the Two CHEXI Subscales for the ADHD Groups and the Control Groups: Results of a Two-Way ANOVA.

	ADHD group		Control group		Group	Country	Interaction
	Belgian *M* (*SD*)	Swedish *M* (*SD*)	Belgian *M* (*SD*)	Swedish *M* (*SD*)	*F*	*F*	*F*
Working Memory	46.44 (8.89)	45.79 (8.14)	23.60 (6.12)	22.05 (7.17)	329.61*	0.74	0.12
Inhibition	42.00 (6.61)	43.13 (7.37)	26.20 (7.24)	20.66 (7.41)	247.43*	3.28	7.51*

Note: *SD* = standard deviation; CHEXI = Childhood Executive Function Inventory.
*$p < .01$.

Table 3. Sensitivity, Specificity, and Overall Classification Rate.

Subscales	Specificity	Sensitivity	Classification rates	Cutoff score
Belgian clinical sample (*n* = 25/25)				
Factor 1: Working Memory	96	92	94	35
Factor 2: Inhibition	84	92	88	34
Swedish clinical sample (*n* = 62/62)				
Factor 1: Working Memory	90	90	90	34
Factor 2: Inhibition	90	94	92	32

working-memory-related behaviors when used with older children. Furthermore, the results showed that the CHEXI has good test–retest reliability and good internal consistency, which confirm its good psychometric properties. Thus, combined with the results of previous studies, our results demonstrate the cross-cultural robustness of the two-factor structure of the CHEXI, and replicate the psychometric strengths of this inventory when used in children from 5 to 11 years old.

The results of the present study also provide evidence that inhibition and working memory should be considered as two of the core executive processes, which is in line with previous studies using laboratory measures (Lehto et al., 2003; St. Clair-Thompson & Gathercole, 2006). Consequently, the CHEXI constitutes a good cross-cultural tool to assess dysexecutive behaviors related to inhibition and working memory in early and middle childhood.

A second objective of this study was to investigate the cross-cultural clinical validity of the CHEXI in discriminating between 8- to 11-year-old Belgian and Swedish children with ADHD and matched control children. Mainly, the results showed significant differences between children with ADHD and controls for both Inhibition and Working Memory subscales in both cultural samples. As in the study by Thorell et al. (2010) with young children, results of the logistic regression analysis showed both high sensitivity and specificity. Thus, the CHEXI could be a valuable clinical tool for the identification of ADHD in children from preschool age up until 11 years old. Furthermore, as emphasized by Thorell et al. (2010), these results are particularly interesting considering that the CHEXI includes items that specifically target the EF constructs of inhibition and working memory rather than items that are similar, or even identical, to the diagnostic criteria for ADHD (as observed, for example, in the BRIEF). These results are in line with numerous studies suggesting that EF deficits such as inhibition and working memory should be considered of primary importance for the diagnosis of ADHD (Barkley, 1997; Pennington & Ozonoff, 1996).

When looking at the two CHEXI subscales separately, Thorell et al. (2010) found a higher ADHD versus control classification rate for the Inhibition subscale in young children. This finding corroborated Barkley's (1997) ADHD model, suggesting that inhibition is the primary core deficit in ADHD, especially in young children. However, in the present study, the classification rate was similar for the two subscales in both countries. This could suggest that, in ADHD, the discriminant validity of the different CHEXI subscales varies with the age of the child, with the Inhibition subscale being most strongly related to ADHD in younger children, whereas in older children, there are equally strong relations with more advanced cognitive functions such as working memory (cf. Barkley, 1997). Future studies should ideally combine the CHEXI and laboratory measures of both simple and complex executive functions in children ranging in age from preschool to adolescence to examine this issue further.

From a cross-cultural point of view, it has been demonstrated that laboratory measures of EF (e.g., Sabbagh, Xu, Carlson, Moses, & Lee, 2006), measures of other neuropsychological functions (e.g., Rosselli & Ardila, 2003), and psychopathology rating scales (e.g., Shojaei, Wazana, Pitrou, & Kovess, 2009) can be influenced by cultural differences. These cultural differences include several aspects, such as way of life, way of thinking and beliefs, behaviors, feeling, knowledge, and so on. In our study, we showed that the Belgian sample was rated as having more inhibitory deficits than the Swedish sample, although this difference was only found in the control group. One previous study had examined whether cultural differences could be observed with the CHEXI and found that Chinese children were generally rated as having more executive deficits than Swedish, Spanish, and Iranian children (Thorell, Veleiro, Siu, & Mohammadi, in press). The authors concluded that this was most likely an effect of cultural biases; indeed, two previous studies have demonstrated that, when asked to rate the same children from videotapes, Chinese teachers rated the children as displaying higher levels of disruptive behaviors than American teachers did (Mann et al., 1992; Mueller et al., 1995). Until now, these cultural biases have not received much attention in pediatric and neuropediatric clinical units because of the lack of adapted cultural norms (norms that come largely from English-speaking countries are used). The data from the present study and that of Thorell et al. (in press) demonstrate that culturally adapted norms are required to better identify children with psychopathological disorders and dysexecutive behaviors.

Despite some cultural differences in the mean values on the CHEXI, the results showed that, for the total classification rates, the ADHD and control groups are similar in the two cultural samples (ranging from 88 to 94). This confirms that dysexecutive behaviors are relatively robust in children with ADHD across cultures. Consequently, the CHEXI could be used as an easy and fast cross-cultural screening inventory in clinical practice, such as general pediatric, neuropediatric, and neuropsychological units, to detect children at risk of being diagnosed later with ADHD. Previous research (Thorell et al., in press) also suggested that ratings on the CHEXI are related to both mathematics and language skills, which suggests that this inventory may also be used as a screening measure for early learning difficulties. Finally, it is possible that this inventory could be used in clinical and experimental follow-up designs when the effects of cognitive and/or medical treatments need to be evaluated.

To conclude, the CHEXI can be considered a user-friendly inventory that can be used as a screening measure for ADHD in children from preschool until middle childhood. Future studies will have to examine its usefulness in samples of adolescents, and explore the construct and clinical validity of the other language versions of the CHEXI (e.g., the Chinese adaptation). Of course, it would also be interesting to examine whether the CHEXI can discriminate between children with ADHD and children with other neurological or psychopathological disorders (e.g., traumatic brain injury, conduct disorder, autism, etc.).

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr. Thorell has served as a consultant for Shire, and she is on the advisory board for Prima. Drs. Catale and Meulemans have no potential conflicts of interest to report.

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