Developmental Neuropsychology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t775653638

The Childhood Executive Functioning Inventory (CHEXI): A New Rating Instrument for Parents and Teachers

Lisa B. Thorell [ab]; Lilianne Nyberg [c]
[a] Department of Psychology, Stockholm University, Stockholm, Sweden [b] Stockholm Brain Institute, Karolinska Institutet, Stockholm, Sweden [c] Department of Psychology, Uppsala University, Uppsala, Sweden

Online Publication Date: 01 July 2008

To cite this Article Thorell, Lisa B. and Nyberg, Lilianne(2008)'The Childhood Executive Functioning Inventory (CHEXI): A New Rating Instrument for Parents and Teachers',Developmental Neuropsychology,33:4,536 — 552
To link to this Article: DOI: 10.1080/87565640802101516
URL: http://dx.doi.org/10.1080/87565640802101516

DEVELOPMENTAL NEUROPSYCHOLOGY, *33*(4), 536–552

ISSN: 8756-5641 print / 1532-6942 online
DOI: 10.1080/87565640802101516

Psychology Press
Taylor & Francis Group

The Childhood Executive Functioning Inventory (CHEXI): A New Rating Instrument for Parents and Teachers

Lisa B. Thorell
Department of Psychology
Stockholm University, Stockholm, Sweden
Stockholm Brain Institute, Karolinska Institutet
Stockholm, Sweden

Lilianne Nyberg
Department of Psychology
Uppsala University, Uppsala, Sweden

Poor executive functioning has been shown to be of central importance in disruptive behavior disorders such as attention deficit hyperactivity disorder (ADHD), and a large number of laboratory measures of executive functioning have been developed. There are, however, few available questionnaires tapping executive functioning and those that exist also include items focused directly on the symptom criteria for ADHD, which makes it difficult to draw conclusions regarding executive functioning per se. In the present study, a new rating instrument, the Childhood Executive Functioning Inventory (CHEXI) was therefore introduced. This instrument was shown to have good test-retest reliability. Using factor analysis, two factors tapping working memory and inhibition emerged using parent ratings and these two factors were replicated using teacher ratings. Modest, yet mostly significant, relations to laboratory measures of working memory and inhibition were found. Ratings on the CHEXI were also found to be significantly related to ADHD symptoms as well as early academic achievement. Interestingly, ratings on the CHEXI and laboratory measures of working memory and inhibition were shown to explain independent variance in ADHD symptoms and academic achievement, which point to the importance of using a multi-assessment strategy when studying executive functioning.

Correspondence should be addressed to Lisa B. Thorell, Department of Psychology, Stockholm University, 10691 Stockholm, Sweden. E-mail: lisa.thorell@psychology.su.se

Executive functions (EFs) can be defined as higher order cognitive abilities such as working memory, inhibitory control, and planning (e.g., Welsh, 2002), and much human behavior requires satisfactory EFs in order to run smoothly (e.g., Barkley, 1997, Pennington & Ozonoff, 1996). In addition, EFs have been argued to play a primary role in the development of childhood psychiatric disorders such as attention deficit hyperactivity disorder (ADHD; Barkley, 1997). During the last decade, an increasing number of studies have presented various laboratory measures of executive functioning for use even with preschoolers or children in the early school years (e.g., Carlson, 2005; Hughes & Ensor, 2005). However, with regard to questionnaires, most established instruments have included items measuring EFs such as inhibitory control and working memory as well as items that directly measure ADHD symptoms. As the behaviors associated with ADHD (i.e., hyperactivity, impulsivity, and inattention) are relatively common even in normally developing children, distinguishing between age-appropriate behavior and early symptoms of behavior problems has proven to be difficult, at least in the preschool years (cf. Campbell, 2002).

EFs, which have been presented as potential endophenotypes for ADHD (e.g., Doyle et al., 2005), may have greater discriminatory power than the behaviors directly associated with ADHD. The aim of the present study was therefore to develop a new EF rating scale for parents and teachers, the Childhood Executive Functioning Inventory (CHEXI), with the aim of focusing chiefly on executive functioning. This questionnaire is not intended as a replacement for laboratory EF measures in that rating instruments naturally capture more global behavior and therefore provide less process-specific information compared to laboratory tests. In addition, rater bias is an issue that always needs to be taken into consideration when using questionnaires (cf. Denckla, 2002). On the other hand, rating instruments have the advantage of capturing behavior over an extended period of time, and as they are easy to administer, they can be most valuable as a screening instrument for identifying children at risk for developing psychiatric disorders.

Of the few previous studies that have measured EFs through questionnaires, the Behavior Rating Inventory of Executive Function (BRIEF, Gioia, Andrews Epsy, & Isquith, 2003) is probably the most well-known instrument. The BRIEF is an 86-item questionnaire, which includes five different subscales tapping inhibition, shifting, emotional control, working memory, and planning/organization. It has proven to be a measure with good test-retest reliability (Gioia, Isquith, Guy, & Kenworthy, 2000), and it has been shown to be able to differentiate between comparison controls on the one hand and children with various developmental disorders such as ADHD, reading disorder, autism spectrum disorders, and traumatic brain injury on the other hand (Gioia & Isquith, 2004; Gioia, Isquith, Kenworthy, & Baron, 2002; Mahone, et al., 2002).

Another instrument of executive functioning is the Children's Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001), which is an instru-

ment that is perhaps less well-known to developmental neuropsychologists, but very well-known within the field of temperament. This instrument captures a large variety of childhood problem behaviors such as shyness, anger/frustration, and fear. However, it also focuses on similar areas as the BRIEF in that it includes subscales measuring inhibitory control, attentional focusing, and impulsivity. A third instrument of executive functioning worth mentioning is the Five-to-fifteen (FTF) questionnaire, which is a Scandinavian instrument with an emphasis on everyday behaviors and psychiatric symptoms that should be readily observable for parents as well as clinicians. The extensive 181-item FTF questionnaire covers several domains, that is, Motor Skills, Executive Functions, Perception, Memory, Language, and Learning. Thus, it includes a broad range of behaviors known to be indicative of various learning disorders as well as developmental delays. The FTF has been validated (Bohlin & Janols, 2004) and shown to relate to scales with common content from the well-established Child Behavior Checklist (CBCL).

Why, then, develop a new instrument for measuring executive functioning when there already are a number of instruments available? The main reason for doing so is that all of the aforementioned instruments include items measuring EFs, in addition to items reflecting the diagnostic symptoms of ADHD. In, for example, the BRIEF, the following items are included: "is impulsive," "has trouble concentrating on games, puzzles, or play activities," "has a short attention span," and "gets easily side-tracked during activities." These items are essentially identical to the diagnostic criteria for ADHD as presented in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed. [*DSM-IV*]; American Psychological Association [APA], 1994). Rothbart's CBQ and the FTF are instruments that include similar items as those mentioned earlier, as well as items that tap problem behaviors more generally. Thus, there is a semantic overlap between rating measures of EF and ADHD symptoms, which means that correlations between these measures and ADHD symptoms are built into the operationalizations.

The inclusion of items reflecting diagnostic criteria does not necessarily need to be a limitation of these questionnaires. However, if one is interested in measuring how executive functioning is related to other constructs, such as different behavior problems, a questionnaire that focuses on executive functioning more specifically is necessary. Measures such as the BRIEF, which includes both ADHD symptoms and EFs, might for example be used to improve early identification of children at risk of developing ADHD later in life. However, if for example a significant relation between preschool ratings on the BRIEF and later ADHD symptoms were to be found, this would not necessarily mean that early executive functioning is a good predictor of ADHD symptoms. The reason why it would be premature to draw such a conclusion is that when using aforementioned EF inventories, the predictor (i.e., the EF questionnaires) is almost identical to the outcome variable (i.e., ratings of ADHD symptoms). Thus, the relation to later ADHD symptoms might be best interpreted as a reflection of the stability in ADHD symptoms.

Questionnaires such as the BRIEF should neither be used in an attempt to differentiate various clinical groups based on their executive functioning profile. If using the BRIEF, one might, for example, conclude that children with ADHD, but not children with other disorders, have deficient working memory. However, as the working memory scale also taps sustained attention (e.g., "has a short attention span" is one of the items of the BRIEF working memory subscale), children with ADHD most likely receive high scores on this scale as inattention is included in the diagnostic criteria for the disorder and not because they have poor working memory. In the BRIEF manual (Gioia et al., 2003), it is concluded that the ability to sustain attention and performance is integral to working memory and this is the reason that items measuring attention are included in the working memory subscale. However, regardless of how the relation between working memory and attention is best described, items that measure sustained attention should not be used as a measure of working memory, at least not if the questionnaire is used for identifying specific executive deficits in children with developmental disorders.

Due to the fact that the aforementioned rating measures of executive functioning are very broad, and include specific EFs as well as ADHD symptoms, the ambition of this study was to construct an easily administered questionnaire, including items geared at executive functioning more specifically, reflecting core functions such as working memory, inhibition, and self-regulation. The present study examines the reliability and validity of this new rating instrument, the Childhood Executive Functioning Inventory (CHEXI). First, ratings from both parents and teachers of children between the ages of 4–7 were collected and test-retest reliability was studied in a subsample. Second, factor analysis was used to examine the structure of the questionnaire. Third, the obtained subscales of the CHEXI were studied in relation to laboratory measures of inhibition and working memory. Finally, in order to study whether the CHEXI is related to everyday behavior, relations to ADHD symptoms and early academic achievement were examined.

METHOD

Participants and Procedure

The present study included children from two different community-based samples that were both part of larger studies investigating executive functioning in early childhood. The first, larger sample (sample A) included 130 Swedish kindergarten children (age $M = 76$ months, $SD = 5$, 77 boys/53 girls). Sample A was recruited by sending letters to all parents with children in kindergarten at eight randomly selected schools in a smaller town. Ninety-six percent of the parents agreed to fill out the parental questionnaire and to let their child participate in the cognitive testing at the preschool. Despite written, informed consent and 2 reminders, parent ques-

tionnaires were, however, not returned for 16 children. Teacher ratings were also collected at all preschools except one at which teachers did not agree to fill out questionnaires. At the remaining seven preschools, four teacher questionnaires were not returned despite two reminders. In total, all 130 children participated at the cognitive testing at the preschools, parental ratings were collected for 114 children (88% of the total sample), and teacher ratings were collected for 105 children (81% of the total sample).

In the second sample (sample B), only parent ratings on the CHEXI were collected. This sample consisted of 62 5-year-old children recruited from 9 different preschools in a smaller town. Parent ratings were collected as a follow-up to this study (no reminders were sent out) and included ratings for 32 children (12 boys/20 girls).

The present study included the 162 children (55% boys) from the 2 samples described earlier for which ratings had been collected from at least the parent or the teacher. Parent ratings were collected for 146 children, teacher ratings for 105 children, and cognitive testing for 130 children. In Sample A, the children for which only parent or teacher ratings were obtained did not differ from those without ratings with regard to any laboratory measures of inhibition or working memory, all *t*s < 1.07, *ns*. In Sample B, the children for whom CHEXI parent ratings were obtained did not differ significantly from those without these data with regard to measures of ADHD symptoms or other externalizing problem behaviors, all *t*s < 1.20, *ns*.

No demographic data, except for sex, was collected for the smaller Sample B. In the larger Sample A, most of the children (81%) were of Swedish origin, with both parents also being born in Sweden. About 12% of the mothers, 14% of the fathers, and 12% of the children were born outside Sweden. Measures of parental education showed that 23% of the parents only had the required 9-years of schooling, 56% had a high school degree and 21% had a university/college degree. These numbers correspond relatively well to the racial ethnicity and educational level of the Swedish population in general (Nordic Council of Ministers, 2007). According to parental ratings, none of the children were diagnosed with any psychiatric disorder and none of them were currently on any type of psychiatric medication (e.g., stimulants).

Measures

Childhood Executive Function Inventory. All items included in the CHEXI are presented in Table 1. The 26 items of the CHEXI can be divided into four a priori subscales: working memory (11 items), planning (4 items), inhibition (6 items), and regulation (5 items). The questions included in the CHEXI were created based on Barkley's (1997) hybrid model in which inhibition, working memory, and regulation are seen as constituting the major EF deficits in children with ADHD. With

TABLE 1
Factor Structure of the CHEXI for Parent and Teachers Ratings

		Parents		*Teachers*	
	A Priori Scale	*Working Memory*	*Inhibition*	*Working Memory*	*Inhibition*
19. Has difficulty understanding verbal instructions unless he/she is also shown *how* to do something	WM	**.81**	–.17	**.97**	–.17
3. Has difficulty remembering what he/she is doing, in the middle of an activity	WM	**.78**	–.13	**.77**	.20
20. Has difficulty with task or activities that involve several steps	PLAN	**.72**	.05	**.77**	.21
6. When asked to do several things, he/she only remembers the first or last	WM	**.68**	.09	**.85**	–.01
23. Has difficulty doing things that require mental effort, such as counting backwards	WM	**.68**	.00	**.62**	.19
1. Has difficulty remembering lengthy instructions	WM	**.65**	.13	**.91**	.00
9. Easily forgets what he/she is asked to fetch	WM	**.62**	.03	**.89**	–.13
24. Has difficulty keeping things in mind while he/she is doing something else	WM	**.60**	.11	**.72**	.15
21. Has difficulty thinking ahead or learning from experience	WM	**.55**	.22	**.58**	.37
7. Has difficulty coming up with a different way of solving a problem when he/she gets stuck	WM	**.53**	.21	**.54**	**.41**
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	**.53**	.21	**.74**	.14
17. Has difficulty telling a story about something that has happened so that others may easily understand	PLAN	**.49**	.00	**.77**	–.12
12. Has difficulty planning for an activity (e.g., remembering to bring everything necessary for a field trip or things needed for school)	PLAN	**.48**	.23	**.76**	.15
2. Seldom seems to be able to motivate him-/herself to do something that he/she doesn't want to do	REG	–.14	**.86**	–.02	**.88**

(continued)

TABLE 1 (*Continued*)

		Parents		*Teachers*	
	A Priori Scale	*Working Memory*	*Inhibition*	*Working Memory*	*Inhibition*
8. When something needs to be done, he/she is often distracted by something more appealing	REG	.00	**.78**	.19	**.72**
13. Has difficulty holding back his/her activity despite being told to do so	INHIB	.06	**.72**	.09	**.72**
4. Has difficulty following through on less appealing tasks unless he/she is promised some type of reward for doing so	REG	–.04	**.72**	–.02	**.79**
15. In order to be able to concentrate, he/she must find the task appealing	REG	.13	**.71**	.10	**.80**
18. Has difficulty stopping an activity immediately upon being told to do so. For example, he/she needs to jump a couple of extra times or play on the computer a little bit longer after being asked to stop	INHIB	.04	**.63**	.30	**.50**
11. Has clear difficulties doing things he/she finds boring	REG	.11	**.61**	–.09	**.91**
5. Has a tendency to do things without first thinking about what could happen	INHIB	.25	**.56**	.16	**.66**
10. Gets overly excited when something special is going to happen (e.g., going on a field trip, going to a party)	INHIB	–.06	**.56**	–.01	**.77**
22. Acts in a wilder way compared to other children in a group (e.g., at a birthday party or during a group activity)	INHIB	.14	**.46**	–.07	**.87**
16. Has difficulty refraining from smiling or laughing in situations where it is inappropriate	INHIB	.13	**.42**	–.00	**.69**
Thinks out loud, even when performing relatively simple tasks	*WM*	*Not included in the factor analysis as these two*			
Has difficulties understanding the concept of time compared to same-aged peers.	*WM*	*items showed too low sampling adequacy*			

Note. WM = working memory, PLAN = planning, REG = regulation, INHIB = inhibition. Bold-faced entries denotes factor loadings of .40 or higher.

regard to working memory, the items were also based on the theoretical formulation by, for example, Baddeley and Hitch (1974) who emphasized that working memory is comprised of multiple components, involved in the storage of verbal and spatial information, as well as the processing of such information. These dual components of storage and processing are required, for instance, when performing multiple tasks simultaneously, or in tasks that involve several steps. With regard to specific item constructions, a major aim was to provide rather specific examples of situations which demand different types of executive control rather than more general statements or items directly related to the symptom criteria for ADHD. Due to the strong connection between EF deficits and ADHD symptoms (e.g., Barkley, 1997), a complete separation of the two was not possible. This was especially so with regard to inhibition and symptoms of impulsivity. However, a major ambition when creating the CHEXI was to focus on items geared more specifically toward EFs, thus avoiding unnecessary semantic overlap between EF deficits and ADHD symptoms.

Laboratory Tasks of Executive Functioning. Inhibition was studied using a task based on the Go No-Go paradigm. The particular version used in this study has been developed by Berlin and Bohlin (2002) and it consists of pictures depicting a blue square, a blue triangle, a red square, and a red triangle that are presented on a computer screen. During the first part of the task, the children are instructed to press a key ("go") when a frequent stimulus (a blue figure) appeared on the screen, but to make no response ("no-go") when an infrequent stimulus (a red figure) appears. The same stimuli are used for the second part of the task, but the children are then instructed to press a key every time they see a square, and to inhibit their response every time they see a triangle, irrespective of color. Altogether the task includes 60 stimuli with a "go-rate" of 77%. The score derived from the task was number of commission errors (pressing the key when a "no-go" target was presented).

Working memory was assessed using a word span task, which has been used previously by, for example, Thorell and Wåhlstedt (2006). This task is based on the Digit Span subtest from Wechsler Intelligence Test for Children—3rd edition (WISC—III; Wechsler, 1991), although it is especially suitable for young children as words are used as stimuli instead of digits. The words are simple nouns that all children know well (e.g., cat, tree, rabbit, and clown) and the series of words is to be produced in a backwards order to that presented by the experimenter. Similarly to the Digit Span subtest in WISC—III, two trials are given at each span length, and the test is concluded when the participant failed to repeat at least one trial correctly at that span length. One point was awarded for each correct trial (i.e., producing all words in the correct order) and the sum of points was used as a measure of working memory.

ADHD Symptoms. ADHD symptoms were assessed by the children's preschool teachers using the ADHD Rating Scale—IV (DuPaul, Power, Anastopoulos, & Reid, 1998), which is a widely used, well-validated measure containing the 18 criteria for ADHD as presented in the *DSM-IV* (APA, 1994). Each item was rated on a 4-point scale ranging from 0 ("never or rarely") to 3 ("very often"). In line with the two ADHD symptom domains as presented in *DSM-IV* (APA, 1994), the sum of the first nine items were used as a measure of inattention and the sum of the last nine items as a measure of hyperactivity/impulsivity.

Early Academic Skills. Early academic skills were assessed in two sub-areas, mathematics and language skills, using selected tests from a test battery normally used in Sweden as a screening instrument for early learning difficulties. Mathematic skills were assessed using six different subtests: (1) counting to ten forwards and backwards, (2) knowledge of order ("which is the third, seventh and sixth?"), (3) identifying numbers, (4) knowledge of "half as many" and "twice as many," (5) knowledge of geometric shapes (triangle/square/circle/rectangle), and (6) writing numbers. Language skills were assessed using five subtests: (1) knowledge of which words that rhyme, (2) knowledge of how many syllables a word contains, (3) combining two words into one (e.g., fire + truck = firetruck), (4) identifying letters, and (5) writing letters. Test-retest reliability for these measures have been shown to range between $r = .77$ to .84 (Thorell, 2007).

RESULTS

To determine test-retest reliability, 30 randomly selected parents from Sample A were asked to complete the CHEXI questionnaire a second time with an average time of 3 weeks (range 2–4 weeks) between the first and the second assessment. All but 2 of the selected 30 parents responded and the test-retest reliability was found to be adequate ($r = .89$, $p < .001$) for the total CHEXI score. Test-retest reliability for the four different a priori subscales was .86 for the inhibition subscale, .84 for the regulation subscale, .75 for the working memory subscale, and .94 for the planning subscale. In addition, there were no significant group differences between the two measurement points for any of the CHEXI subscales, all *t*s < 1.41, *ns*.

Factor Structure of the CHEXI

The factor analysis was conducted using the SAS 8.12 statistical package. The sampling adequacy of the items intended to be included in the factor analysis was assessed using Kaiser's measure of sampling adequacy. All items except two ("thinks out loud, even when performing relatively simple tasks" and "has difficul-

ties understanding the concept of time compared to same-aged peers.") were retained, each showing a sampling adequacy greater than .80.

In order to examine the dimensionality of the CHEXI, we first conducted a factor analysis of parent ratings on the CHEXI, using an iteration procedure to estimate communalities. Both orthogonal and oblique solutions were considered, using two, three, and four factors (three factors emerged with an eigenvalue above 1.00). The three-factor solution did not appear to provide the best fit for our data in that several items loaded on more than one factor, which made interpretation of factors difficult. The same applied for a four-factor solution. A two-factor solution did, however, show two clear factors which were easily interpreted. In that the two factors were highly correlated, $r = .65$, an oblique rotation method was chosen. Factor loadings greater than .40 were considered to load on each respective factor. This two factor solution accounted for 41.2% of the variance in the CHEXI items. As presented in Table 1, the first factor was comprised of items from the two a priori subscales tapping working memory and planning. The first factor was interpreted as working memory (CHEXI-WM) in that planning is often considered a more advanced working memory function (e.g., Barkley, 1997). The second factor included the two subscales tapping inhibition and regulation of motivation. Together, these items can be interpreted as measuring both the cognitive and motivational aspect of inhibitory control and the second subscale was therefore namned inhibition (CHEXI-I).

To further analyze the factor structure of the CHEXI, we studied whether the obtained factor structure using parent ratings could be replicated using teacher ratings. As presented in Table 1, the results showed that the working memory factor and inhibition factor found using parent ratings were replicated using teacher ratings. For the teacher ratings, the two factors explained 67% of the variance and the two factors were shown to be highly correlated, $r = .69$. The correlation between teacher and parent ratings were significant for both the working memory factor ($r = .32$, $p < .01$) and the inhibition factor ($r = .38$, $p < .001$).

CHEXI in Relation to Laboratory Tasks of Executive Functioning

To study the construct validity of the CHEXI, relations to laboratory measures of inhibition and working memory were examined. As can be seen in Table 2, The CHEXI-WM factor was found to be significantly related to both laboratory measures using either teacher or parent ratings. Regarding the CHEXI-I factor, significant relations were found to the laboratory measures of inhibition using either parent or teacher ratings. Using teacher ratings, a significant relation was also found between the CHEXI-I and the laboratory measure of working memory.

TABLE 2
Correlations between the CHEXI and Laboratory Measures, ADHD Symptoms and Early Academic Skills (One-Tailed)

	Laboratory Measures		*ADHD Symptoms*[a,b]		*Early Academic Skills*[b]	
	Inhibition	*Working Memory*	*Hyperactivity/ Impulsivity*	*Inattention*	*Language Skills*	*Mathematics*
Parent ratings (*N* = 113)						
Working memory factor	.33***	.26**	**.36*** **	.13	**–.41*** **	**–.29*** **
Inhibition factor	.28**	.07	**.27*** **	**.26*** **	–.16*	–.11
Teacher ratings (*N* = 89/105)						
Working memory factor	.29**	.39***	**.33** **	**.21***	**–.46*** **	**–.42*** **
Inhibition factor	.35***	.19*	**.28** **	**.27** **	–.25**	–.24**

*$p < .05$, **$p < .01$, ***$p < .001$.

[a]Relations to ADHD symptoms represent correlations across raters

[b]Bold-faced entries denote relations that remained significant also when controlling for the effect of EF laboratory measures.

CHEXI in Relation to ADHD Symptoms and School Achievement

The suitability of the CHEXI to be used as a predictor of everyday behavior was examined by studying relations to ADHD symptoms and school achievement (i.e., mathematics and language skills). With regard to relations to ADHD symptoms, bivariate correlations were first of all computed across raters. Thus, the parent ratings on the CHEXI were correlated with teacher ratings of ADHD symptoms, and teacher ratings on the CHEXI were correlated with parent ratings of ADHD symptoms. This way, the strength of the correlations reflected a true relation between the constructs studied rather than a general view of the child as being problematic or not. As shown in Table 2, all correlations were significant except for the relation between teacher rated inattention and the working memory factor using parent ratings. In order to examine whether CHEXI ratings can explain additional variance in ADHD symptoms, beyond the influence of EF laboratory measures, all correlation analyses were re-run using the two EF laboratory measures as covariates. The results showed that all relations remained significant, *r*s ranging from .19 to .27, *p*s $< .05$.

With regard to early academic achievement, both factors on the CHEXI for parent as well as teacher ratings were significantly related to language skills and mathematics, except for the relation between the CHEXI-I factor using parent ratings and mathematics (see Table 2). All relations between the CHEXI-WM factor and early academic achievement remained significant after controlling for the effect of EF laboratory measures, *r*s ranging from .18 to .31, *p*s $< .05$. However, all relations between early academic achivement and the CHEXI-I factor was reduced to being non-significant when controlling for the effects of EF laboratory measures.

DISCUSSION

In the present study, the Childhood Executive Function Inventory (CHEXI), a new rating instrument of executive functioning for parents and teachers, was presented. This new instrument was developed because there is a need for an easily administered measure of executive functioning which focuses specifically on EFs, without including items that show a semantic overlap with the diagnostic criteria of ADHD. The results of the present study showed that the CHEXI has adequate test-retest reliability. Using factor analysis, two factors tapping working memory and inhibition emerged using parent ratings and these two factors were replicated using teacher ratings. The working memory factor on the CHEXI was modestly, although significantly, correlated with laboratory measures of working memory and inhibition, and the inhibition subscale was related to the laboratory measure of in-

hibition using either parent or teacher ratings and to the laboratory measure of working memory when using teacher ratings. With a couple exceptions, ratings on the CHEXI were also found to be significantly related to both ADHD symptoms and early academic achievement.

Factor Structure of the CHEXI

Regarding the factor structure of the CHEXI, separate factors could not be distinguished for all a priori subscales. However, the two large factors found correspond relatively well to previous factor analytic studies of EF laboratory measures that have found separate factors for working memory/planning and inhibitory control (e.g., Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Brocki & Bohlin, 2004; Levin et al., 1991; Welsh, Pennington, & Grossier, 1991). In addition, the role of working memory and inhibition as two of the most basic EF functions corresponds well with several theoretical models, such as those presented by Barkley (1997), Engle and Kane (2004), and Roberts and Pennington (1996). It should, however, be noted that several previous empirical studies (e.g., Brocki & Bohlin, 2004; Barkley et al., 2001) have also obtained a third factor that has most often included measures tapping reaction time or arousal. These constructs are, however, difficult to capture using questionnaires, and they were therefore not included in the CHEXI. With regard to Barkley's (1997) model, the third factor tapping self-regulation could not be differentiated from inhibition in the present study and neither could Barkley's fourth factor, which taps planning, be differentiated from items measuring working memory. A plausible explanation for these results may be the young age of our sample. According to Barkley's (1997) model, inhibition is the first EF to develop, followed by spatial and verbal working memory. Self-regulation and planning are more advanced EFs, which start to develop later and continue to develop throughout childhood. Thus, the factor structure of the CHEXI should be examined also in older samples to study whether it is possible to distinguish between more of the a priori scales in school-aged children and adolescents.

Another issue that needs to be examined more closely relates to the fact that the two-factor solution for the CHEXI obtained in the present study only accounted for 41% of the variance in parent ratings, but 67% of the variance in teacher ratings. This could be taken to mean that compared to teachers, parents have more difficulties in distinguishing between different problem domains. The reason for this is that unlike most parents, teachers have extensive experience with a large number of children and they therefore have an implicit normative data base against which to judge different types of problem behaviors. With regard to executive functioning, teachers also more often than parents observe children in situations that demand high executive control.

Relations to EF Laboratory Measures

The present study found relatively modest, but significant, correlations between the two CHEXI subscales and the laboratory measures of inhibition and working memory. It might appear surprising that the relations were not stronger. However, it should be noted that the two CHEXI subscales measure executive functioning much more broadly than the laboratory measures. The global nature of the CHEXI, as well as the fact that inhibition and WM are highly interrelated constructs, might explain why the CHEXI-WM subscale should not be expected to be specifically related to the WM laboratory measure and the CHEXI-I subscale specifically related to the inhibition laboratory measure. Compared to previous studies using the BRIEF, the obtained relations between ratings and laboratory measures are relatively high (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Mahone, et al., 2002; Vriezen & Pigott, 2002). Moreover, Mahone and colleagues (2002) found that correlations between parent ratings and self-reports on BRIEF were sometimes as low as .25. Thus, even when using an identical measure, but two different raters, correlations have been found to be low.

Anderson and colleagues (2002) presented several explanations that might account for these low correlations. According to one hypothesis, laboratory tests primarily capture the cognitive aspect of executive functioning, which is based in dorsolateral prefrontal cortex, whereas rating instruments such as the BRIEF, and at least to some extent probably also the CHEXI, capture more emotional and social aspects, which are linked to orbito-frontal areas. Another possible explanation is that the sampling frame for the two types of data is different. For questionnaires, the rater provides reports on the child's behavior in the "real world" and the view is based on observations during an extended period of time. Laboratory tests on the other hand, are administered in a much more predictable and structured environment during a short period of time, although such tests might have the advantage of being able to capture functions that are not readily observable. At any rate, questionnaire ratings and laboratory measures most likely capture different aspects of executive functioning, and these types of measurement should therefore been seen as complementary to one another rather than interchangeable.

Relations to ADHD Symptoms and Early Academic Skills

Regarding relations between executive functioning and ADHD symptoms, both CHEXI subscales were found to correlate significantly with symptoms of ADHD across raters, except for parent-rated CHEXI-WM and teacher-rated symptoms of inattention. These results are in line with previous studies of EF laboratory measures and theoretical models, which have identified poor executive functioning as a major deficit in ADHD (for reviews, see Barkley, 1997; Pennington & Ozonoff, 1996; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). In addition, the sig-

nificant relations between the CHEXI and ADHD symptoms demonstrates that this new instrument is ecologically valid in the way that it is related to children's everyday behavior. The lack of a significant relation between working memory and inattention for parent, but not teacher ratings, could be seen as a further reflection of the inconsistency with regard to the relation between working memory and ADHD symptoms in preschool children. At this early age, some previous studies have found relations between working memory and ADHD symptoms (Sonuga-Barke, Dalen, Daley, & Remington, 2002; Thorell & Wåhlstedt, 2006) whereas others have failed to show such a relation (e.g., Sonuga-Barke, Dalen, & Remington, 2003; Brocki, Nyberg, Thorell, & Bohlin, 2007).

Finally, it should be noted that the present study was also able to demonstrate significant relations between CHEXI ratings and early academic achievement. This provides further support for the ecological validity of the CHEXI. The most interesting finding is that ratings on the CHEXI-WM factor explained additional variance, beyond the influence of EF laboratory measures, in mathematics, language skills, and ADHD symptoms. Thus, the inclusion of both laboratory measures and the CHEXI might provide a more complete picture of the child's executive functioning, which could be important when identifying children at risk for ADHD and/or poor school performance.

Conclusions and Future Directions

Promising results have been presented herein on the development of a new rating instrument geared toward capturing EFs more specifically than has previously been the case. The CHEXI was shown to be a reliable rating measure and should be of value in future research investigating EFs. Although a major ambition with the CHEXI was to exclude items focusing on ADHD symptoms, it should be emphasized that the strong connection between this disorder and EF deficits (especially with regard to inhibition and impulsivity) makes it impossible to avoid all forms of overlap. The CHEXI related to ADHD symptoms as well as early language skills and mathematics. It should be noted that, as this study included children recruited from a population-based sample, only correlation analyses were conducted, and further research is needed in order to determine whether the CHEXI can be used to distinguish between children diagnosed with ADHD and normal controls. In addition, it would be of great importance for future studies to compare ratings on the CHEXI to those of other rating instruments such as the BRIEF. Furthermore, longitudinal studies are needed in order to examine if the CHEXI is related to neuropsychological disorders and daily functioning over time. Thus, more research on the CHEXI is needed, and in light of the fact that EF ratings correlate modestly with laboratory measures, the need of using a multi-assessment strategy when studying EFs should be highlighted.

ACKNOWLEDGMENT

This study was supported by a grant from The Vårdal Foundation to the first author.

REFERENCES

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Anderson, V. A., Anderson, P., Northam, E., Jacobs, R., & Mikiewicz, O. (2002). Relationships between cognitive and behavioral measures of executive function in children with brain disease. *Child Neuropsychology, 8*, 231–240.

Baddeley, A. D., & Hitch, G. (1974). Working memory. In G. H. Bower (ed.), *The psychology of learning and motivation: Volume 8, advances in research and theory* (pp. 47–89). New York: Academic Press.

Barkley, R. A. (1997). *ADHD and the nature of self-control.* New York: Guilford Press.

Barkley, R. A., Edwards, G., Laneri, M., & Fletcher, K. (2001). Executive functioning, temporal discounting, and sense of time in adolescents with attention deficit hyperactivity disorder (ADHD) and oppositional defiant disorder (ODD). *Journal of Abnormal Child Psychology, 29*, 541–556.

Berlin, L., & Bohlin, G. (2002). Response inhibition, hyperactivity and conduct problems among preschool children. *Journal of Clinical Child and Adolescent Psychology, 31*, 242–251.

Bohlin, G., & Janols, L.-O. (2004). Behavioural problems and psychiatric symptoms in 5–13 year-old Swedish children—A comparison of parent ratings on the FTF (Five to Fifteen) with the ratings on CBCL (Child Behavior Checklist). *European Journal of Child and Adolescent Psychiatry (Suppl. 3), 13,* 14–22.

Brocki, K. C., & Bohlin, G. (2004). Executive functions in children age 6–13: A dimensional and developmental study. *Developmental Neuropsychology*, *26*, 571–593.

Brocki, K. C., Nyberg, L., Thorell, L. B., & Bohlin, G. (2007). Early concurrent and longitudinal symptoms of ADHD and ODD: Relations to different types of inhibitory control and working memory. *Journal of Child Psychology and Psychiatry, 48,* 1033–1041.

Campbell, S. B. (2002). *Behavior problems in preschool children* (2nd ed.). New York: Guilford Press.

Carlson, S. M. (2005). Developmentally sensitive measures of executive functions in preschool children. *Developmental Neuropsychology*, *28*, 595–616.

Denckla, M. B. (2002). The behavior rating inventory of executive function: Commentary. *Child Neuropsychology, 8*, 304–306.

Doyle, A. E., Willcutt, E. G., Seidman, L. J., Biederman, J., Chouinard, A., Silva, J., et al. (2005). Attention-Deficit/Hyperactivity Disorder Endophenotypes, *Biological Psychiatry, 57*, 1324–1335.

DuPaul, G. J., Power, T. J., Anastopoulos, A. D., & Reid, R. (1998). *ADHD rating scale-IV. Checklists, norms, and clinical interpretation.* New York: Guilford Press.

Engle, R. W., & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In B. H. Ross (ed.), *The psychology of learning and motivation: Advances in research and theory,* volume 44 (pp. 145–199). New York: Elsevier Science.

Gioia, G. A., Andrews Epsy, K., & Isquith, P. K. (2003). *BRIEF-P. Behavior rating inventory of executive function—Preschool version. Professional manual.* Lutz, FL: Psychological Assessment Resources, Inc.

Goia, G. A., & Isquith, P. K. (2004). Ecological assessment of executive function in traumatic brain injury. *Developmental Neuropsychology*, *25*, 135–158.

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). Behavior rating inventory of executive function. *Child Neuropsychology, 3*, 235–238.

Gioia, G. A., Isquith, P. K., Kenworthy, L., & Baron, R. M. (2002). Profiles of everyday executive function in acquired and developmental disorders. *Child Neuropsychology, 8*, 121–137.

Hughes, C., & Ensor, R. (2005). Executive function and theory of mind in 2 year olds: A family affair? *Developmental Neurospcyhology, 28*, 645–668.

Levin, H. S., Culhane, K. A., Hartmann, J., Evankovich, K., Mattson, A. J., Harward, H., et al. (1991). Developmental changes in performance on tests of purported frontal lobe functioning. *Developmental Neuropsychology, 7*, 377–395.

Mahone, E. M., Cirino, P. T., Cutting, L. E., Cerrone, P. M., Hagelthorn, K. M., Hiemenz, J. R., et al. (2002). Validity of the behavior rating inventory of executive function in children with ADHD and/or Tourette syndrome. *Archives of Clinical Neuropsychology, 17*, 643–662.

Nordic Council of Ministers (2007). *Nordic statistical yearbook 2007*, volume 45. Skive, Denmark: Arco Grafisk A/S.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 37,* 51–87.

Roberts, R. J., & Pennington, B. F. (1996). An interactive framework for examining prefrontal cognitive processes. *Developmental Neuropsychology, 12*, 105–126.

Sonuga-Barke, E. J. S., Dalen, L., Daley, D., & Remington, B. (2002). Are planning, working memory, and inhibition associated with individual differences in preschool ADHD symptoms? *Developmental Neuropsychology, 21*, 255–272.

Sonuga-Barke, E. J. S., Dalen, L., & Remington, B. (2003). Do executive deficits and delay aversion make independent contributions to preschool attention-deficit/hyperactivity disorder symptoms? *Journal of the American Academy of Child and Adolescent Psychiatry, 42*, 1335–1342.

Thorell, L. B. (2007). Do delay aversion and executive function deficits make distinct contributions to the functional impact of ADHD symptoms?: A study of early academic skill deficits. *Journal of Child Psychology and Psychiatry, 48,* 1061–1070

Thorell & Wåhlstedt (2006). Executive functioning deficits in relation to symptoms of ADHD and/or ODD in preschool children. *Infant and Child Development, 15,* 503–518.

Vriezen, E. R., & Pigott, S. E. (2002). The relationship between parental report on the BRIEF and performance-based measures of executive function in children with moderate to severe traumatic brain injury. *Child Neuropsychology, 8*, 296–303.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children—3rd ed.* (Psykologiförlaget AB, Stockholm, Trans.) New York: The Psychological Corporation.

Welsh, M. C. (2002). Developmental and clinical variations in executive functions. In D. L. Molfese and V. J. Molfese (eds.), *Developmental variations in learning: Applications to social, executive function, language, and reading skills* (pp. 139–185). Mahawah, NJ: Erlbaum.

Welsh, M. C., Pennington, B. F., & Grossier, D. B. (1991) A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology, 7,* 131–149.

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,* 1336–1346.