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Screening With an ADHD-Specific Rating Scale in Preschoolers: A Cross-Cultural Comparison of the Early Childhood Inventory-4

Kristin Romvig Overgaard and Beate Oerbeck
Oslo University Hospital, Oslo, Norway

Svein Friis
Oslo University Hospital, Oslo, Norway, and University of Oslo

Guido Biele
Norwegian Institute of Public Health, Oslo, Norway

Are Hugo Pripp
Oslo University Hospital, Oslo, Norway

Heidi Aase
Norwegian Institute of Public Health, Oslo, Norway

Pål Zeiner
Oslo University Hospital, Oslo, Norway

The Early Childhood Inventory-4 (ECI-4) Hyperactivity-Impulsivity (HI) and Inattention (IA) subscales are screeners for attention-deficit/hyperactivity disorder (ADHD). There have been few studies of the screening properties of these subscales, particularly outside the United States. We investigated the classification accuracy of the parent and teacher versions of the HI and IA subscales and the cross-cultural validity of the cutoff values based on norms from a United States sample. The present study was part of the Norwegian Mother and Child Cohort Study. Parents and teachers rated boys (n = 332) and girls (n = 319) with the ECI-4 (mean Age 3.5 years). Interviewers who were blind to the ratings used the Preschool Age Psychiatric Assessment Interview to assign ADHD diagnoses. The ECI-4 HI and IA subscales showed acceptable accuracy in identifying ADHD in boys and girls (areas under the curve ranged from .67 to .85). In a multivariate regression analysis, the parent and teacher HI subscale scores significantly contributed to ADHD identification, but not the IA subscale scores. To achieve the necessary sensitivity to detect children with ADHD, lower cutoff levels than those specified by the United States ECI-4 norms were needed. For screening purposes, the parent and teacher ECI-4 showed acceptable accuracy in identifying preschoolers at risk for ADHD, and it may be sufficient to use the HI subscale scores. The suggested cutoff values provided by the United States ECI-4 norms had limited cross-cultural validity.

Public Significance Statement
The present study found that parent and teacher ADHD-specific rating scales may be used to screen preschoolers for ADHD, but lower cutoff levels than suggested by United States norms were needed to detect children at risk for ADHD. In screening of preschoolers, priority may be given to the ratings of symptoms of hyperactivity-impulsivity.

Keywords: attention-deficit/hyperactivity disorder, Early Childhood Inventory, ECI-4, children, sensitivity

Supplemental materials: http://dx.doi.org/10.1037/pas0000722.supp

Kristin Romvig Overgaard and Beate Oerbeck, Division of Mental Health and Addiction, Oslo University Hospital, Oslo, Norway; Svein Friis, Division of Mental Health and Addiction, Oslo University Hospital, and Institute of Clinical Medicine, University of Oslo; Guido Biele, Norwegian Institute of Public Health, Oslo, Norway; Are Hugo Pripp, Oslo Centre of Biostatistics and Epidemiology, Oslo University Hospital; Heidi Aase, Norwegian Institute of Public Health; Pål Zeiner, Division of Mental Health and Addiction, Oslo University Hospital.

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Correspondence concerning this article should be addressed to Kristin Romvig Overgaard, Division of Mental Health and Addiction, Oslo University Hospital, P.O. Box 4959 Nydalen, N-0424 Oslo, Norway. E-mail: kristin.romvig.overgaard@ous-hf.no

Attention-deficit/hyperactivity disorder (ADHD) is characterized by age-inappropriate and impairing hyperactivity, impulsivity, and inattention (Thapar & Cooper, 2016), and it is diagnosed two to nine times more frequently in boys than in girls (Rucklidge, 2010). ADHD is associated with increased risk of multiple mental health and social difficulties, as well as premature mortality (Chorozoglou et al., 2015; Thapar & Cooper, 2016). Most studies of ADHD have been on school-age children. However, during the last decade prospective studies have found that more than 70% of preschoolers with high levels of ADHD symptoms continue to have these symptoms in school age (Harvey, Youngwirth, Thakar, & Errazuriz, 2009; Law, Sideridis, Prock, & Sheridan, 2014; Riddle et al., 2013). Preschool ADHD symptoms are risk factors for poor outcomes, and early behavioral intervention is recommended (Daley et al., 2018). To provide early intervention, studies are needed that may improve identification of preschoolers at risk for ADHD. Although it is important to identify preschoolers at risk, it is equally important to avoid undue concern for age-appropriate behavior. Thus, accurate screening is essential.

The Early Child Inventory-4 (ECI-4) was developed for preschoolers, and it includes ADHD-specific rating scales, one subscale for hyperactivity-impulsivity (HI) and one for inattention (IA; Sprafkin, Volpe, Gadow, Nolan, & Kelly, 2002). These subscales correspond to the diagnostic criteria for ADHD in the American Psychiatric Association (APA)'s *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM–IV*; American Psychiatric Association, 1994; Gadow & Sprafkin, 2000). The ECI-4 can be used to screen for ADHD, as the manual provides norms to distinguish age-inappropriate from age-appropriate behavior (Gadow & Sprafkin, 1997). The developers have reported adequate psychometric properties for the ECI-4 in both community and clinical preschool samples (Gadow & Sprafkin, 2000; Gadow, Sprafkin, & Nolan, 2001; Sprafkin, Volpe, et al., 2002), as well as good convergent/divergent validity compared with other relevant rating scales (Sprafkin, Volpe, et al., 2002). In their clinical study, Sprafkin, Volpe, and colleagues compared the extent to which children met the ECI-4 ADHD cutoff score (according to the *DSM–IV* criteria: ≥6 HI and/or ≥6 IA symptoms) with ADHD chart diagnoses. They found that the parent ECI-4 ADHD cutoff score had a sensitivity of 66% and a specificity of 57%, whereas the teacher ADHD cutoff score had a sensitivity of 68% and a specificity of 69%. These numbers are close to the minimum value of 70% for sensitivity recommended in guidelines for screening instruments (Sheldrick & Garfinkel, 2017). Furthermore, the authors found that when they included either parent or teacher scores that were above cutoff levels, sensitivity improved to 90%, but specificity dropped to 41% (Sprafkin, Volpe, et al., 2002).

Boys tend to have higher mean ADHD scores on the ECI-4 than do girls, and parents and teachers rate boys and girls differently, which has led to separate norm tables and suggested cutoff scores for boys and girls (Gadow & Sprafkin, 1997; Sprafkin, Volpe, et al., 2002). One recent study using ECI-4 parent ratings reported a significantly higher prevalence of the predominantly hyperactive/impulsive presentation of ADHD in boys than in girls, with no significant difference in the prevalence of the predominantly inattentive presentation (Canals, Morales-Hidalgo, Jané, & Domènech, 2018). A meta-analysis concluded that increased efforts to improve the identification of ADHD in girls are needed (Tung et al., 2016). To this end, the ECI-4 IA subscale might be particularly useful in detecting girls with ADHD, as it has been suggested that inattentive symptoms are more prominent in girls (Rucklidge, 2010).

Knowing the psychometric properties of the ECI-4 HI and IA subscales is also important, because they have been used to estimate ADHD prevalence rates (Canals et al., 2018; Gadow et al., 2001), and associations between ADHD and a variety of child disorders (Catal et al., 2016; DeVincent, Gadow, Strong, Schwartz, & Cuva, 2008; Topal et al., 2016). Therefore, we conducted a systematic literature search in MEDLINE, Embase, PsycINFO, and HaPI (search terms: "Early childhood inventory" OR "Early child inventory" OR "ECI-4", with no limits for applied language or publication date). The resulting abstracts were limited to studies reporting data on ADHD and/or psychometric properties. This search indicated that the psychometrics of the ECI-4 ADHD subscales have scarcely been studied by anyone other than the developers. One Spanish pilot study ($n = 34$) found a significant correlation ($\rho = .65$) between teacher Conners Rating Scales-Revised (CRS-R) scores and teacher (but not parent) ECI-4 ratings (Poblano & Romero, 2006). However, this study failed to demonstrate satisfactory sensitivity and specificity for the ECI-4 when ADHD diagnoses were obtained through parent interviews. A clinical study of Romanian children with various diagnoses (3–7 years of age, $n = 52$), reported good sensitivity (.85) for ADHD with the teacher ECI-4 ratings, but the parent ECI-4 ratings had poor sensitivity (.57; Bălaj, Albu, Porumb, & Miclea, 2011). However, this study was limited by the use of chart diagnoses and the small sample size. Another study used the ECI-4 to validate a semistructured diagnostic interview with parents and found significantly higher ECI-4 ADHD severity scores when at least one diagnostic symptom for ADHD was present according to the interview (Birmaher et al., 2009).

In sum, there is need for a study that may improve identification of preschoolers at risk for ADHD through screening. Specifically, there are few studies regarding the classification accuracy of the parent and teacher ECI-4 HI and IA subscales in boys and girls, and few researchers have examined the validity of these subscales for ADHD that has been classified using a diagnostic interview in at-risk preschool samples, as recommended by the developers (Sprafkin, Volpe, et al., 2002). Furthermore, the cross-cultural validity of the United States cutoff scores for ECI-4 needs to be investigated.

The main aim of the present study was to evaluate the accuracy of the parent and teacher ECI-4 HI and IA subscales in detecting ADHD, as identified through a parent diagnostic interview. Thus, we investigated the classification accuracy and the group-level statistics (sensitivity, specificity, and the positive and negative predictive values) of the two subscales. Specifically, we analyzed whether the parent and teacher ECI-4 HI and IA subscales performed differently for boys and girls, and how the ECI-4 gender-specific United States norms compared with the cutoff scores in our sample.

Method

Participants

The Norwegian Mother and Child Cohort Study (MoBa) is an ongoing prospective population-based cohort study of Norwegian-speaking women that is conducted by the Norwegian Institute of

Public Health (41% participation rate; Magnus et al., 2016). The mean household income of study participants was $52,000 USD, similar to the population mean (Overgaard, Oerbeck, Aase, et al., 2018). The current paper is from a clinical substudy of ADHD oversampling of children at risk for ADHD, using data from the MoBa questionnaire that was sent to mothers at child Age 3 years (Overgaard et al., 2014). The questionnaire included 11 items about ADHD, including six items from the Child Behavior Checklist/1.5–5 (Achenbach & Rescorla, 2000) and five items from the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; *DSM–IV–TR*; APA, 2000) criteria for ADHD. Children with scores ≥90th percentile on these 11 items (n = 2,798) were invited to participate, along with randomly selected children (n = 654). Before recruitment to the present substudy, a total of 149 children with high scores on autistic symptoms were sampled to another MoBa substudy of autism and could therefore not be invited to the present study. In total, about 35% agreed to participate in the present substudy, and from 2007 to 2011, 1,195 children (mean Age: 3.5 years; age range: 3.1–3.8 years) took part in a 1-day clinical assessment including diagnostic interviews with parents (with few exceptions, mothers). Four weeks prior to the assessments, parents received the parent and teacher ECI-4 by mail (about 95% of the 3.5-year-old children in Norway during this period attended preschool). The parents gave the teacher versions to the preschool teachers, who then mailed their responses directly to the study administrator. Both the parents and the teachers completed the questionnaires before the day of the clinical assessment. The ECI-4 was distributed to the last 54% of those who agreed to participate (n = 651; 319 girls, 332 boys), who constituted the sample for the present study. Of this sample, 93% (n = 604) of the children scored ≥90th percentile on the 11 questionnaire items described above, and 7% (n = 47) were randomly selected from the MoBa.

The mean parental education level during pregnancy was 15.0 years (range 9–18 years). Parents of children who fulfilled symptom criteria for ADHD (see below) had significantly lower mean education years than the rest of the sample (14.4 vs. 15.1 years, $p < .001$).

A total of 43% (n = 280) of the participants fulfilled symptom criteria for oppositional defiant disorder (ODD; see below). Significantly more children who fulfilled criteria for ADHD, also fulfilled criteria for ODD, compared with children who did not fulfill ADHD criteria (65% vs. 38%, $p < .001$).

Measures

The children's gender and birth date information were obtained from the Medical Birth Registry of Norway.

Length of parental education was obtained from the first MoBa assessment (about Week 17 of pregnancy) and reported in mean number of years.

Preschool Age Psychiatric Assessment (PAPA) interview. Diagnostic assessments of the children were based on the PAPA interviews with parents (Egger & Angold, 2004).

The PAPA interview was developed for use with parents of 2- to 5-year-old children. In a study of test–retest reliability of this multidisorder interview, estimates were very similar to those obtained for interviews for older children and adults. The test-retest intraclass correlations (ICCs) for ADHD classification according to the PAPA was .80 (Egger et al., 2006). In a study using the PAPA interview at Ages 3 and 6, there was significantly homotypic continuity of ADHD during this period (odds ratio [*OR*] = 17.96; Bufferd, Dougherty, Carlson, Rose, & Klein, 2012).

In the present study, only ADHD symptoms lasting ≥3 months were counted as present. Trained graduate psychology students who were blind to parent and teacher screen ratings conducted the interviews (under supervision). All interviews were video recorded. As part of their training, the students were instructed in the use of the PAPA to make psychiatric diagnoses. They also rated video-recorded interviews done by experienced interviewers. All students did at least five interviews that were extensively supervised by a child psychiatrist or psychologist. Throughout the study, child psychiatrists and psychologists were available for discussions, and always supervised the scoring of the interview. As an interrater reliability check, we had a separate rater who was blind to the parent and teacher screen ratings rescore audiotapes of 79 randomly selected assessment interviews. The average ICCs were .97 for HI symptoms and .99 for IA symptoms.

Based on the PAPA interview data, ADHD was defined by the presence of symptom criteria for the predominantly hyperactive/impulsive, predominantly inattentive or combined presentation of ADHD (as defined by the *DSM–IV–TR*) that were reported by parents to be pervasive across at least two settings. Twenty percent of the children (n = 130/651) fulfilled ADHD criteria: 76% hyperactive/impulsive (n = 99; 41 girls), 8% inattentive (n = 10; 8 girls), and 16% combined presentation (n = 21; 7 girls). The proportion of ADHD in our sample was 22% for boys and 18% for girls, which, as expected, is much higher than the 1.9–3.3% prevalence rates previously reported in two preschool community studies that used the PAPA interview (Egger & Angold, 2006; Wichstrøm et al., 2012). Note however, that ADHD defined by PAPA is not equivalent to clinical ADHD diagnoses that would require a broader assessment, including multiple sources of information and informants.

ODD was defined by the presence of ≥4 *DSM–IV* ODD symptoms according to information from the PAPA interview.

Screening measures. The ECI-4 contains 108 items that correspond to the symptom lists of the child psychiatric disorders in the *DSM–IV* (Gadow & Sprafkin, 2000). The inventory was translated into Norwegian and back-translated into English by professional translators, and the translation was approved by the ECI-4 developers. We used only the HI and IA subscales, each with nine items (Gadow & Sprafkin, 2000). Individual items are rated on a 4-point Likert scale (0 = *never*, 1 = *sometimes*, 2 = *often*, 3 = *very often*), and the item scores are summed for HI and IA symptom severity scores (Gadow & Sprafkin, 1997). The ECI-4 developers provide tables to convert subscale scores to t scores, with different norms for parent and teacher ratings for boys and girls (based on a norm sample of 531 United States 3–5-year-old children). T scores from 60–69 indicate moderate severity and t scores that are ≥70 indicate high severity (Gadow & Sprafkin, 1997).

In our sample, Cronbach alphas were .84 and .81 for the parent HI and IA subscales, respectively, and .91 and .90 for the two teacher subscales. Pearson correlations between the HI and IA subscale scores were high for parents (.70; $p < .001$) and teachers (.78; $p < .001$). The parent and teacher subscale scores were moderately correlated (.33 and .34 for HI and IA ratings, respec-

tively; $p < .001$). We did not know the gender of the ECI-4 informants but assumed that mostly mothers rated the questionnaires in our substudy (as in MoBa), and because Statistics Norway report that about 90% of preschool teachers in Norway are female (www.ssb.no) we have reason to believe that female preschool teachers predominated.

Ethics

Informed written consent was obtained from participants upon recruitment to the MoBa and the ADHD substudy, and both studies obtained permission from the Norwegian Data Inspectorate. The study was approved by the Regional Committee for Medical Research Ethics.

Statistical Analyses

Statistical analyses were performed using IBM SPSS, Version 23 and the R-package pROC in R 3.2.2 (R Development Core Team, 2008). Internal consistencies were analyzed using Cronbach's alpha, correlations with the Pearson's correlation coefficient, and differences between means of continuous variables by *t* tests. Receiver operating characteristic (ROC) analyses estimated area under the curve (AUC) to quantify the accuracy of the parent and teacher ECI-4 subscales. The ROC curve graphically represents the probability of true positive results of ADHD as a function of the probability of false positive results. As a guideline for evaluating AUC values, we used <0.70 = poor, 0.70–0.79 = fair, 0.80–0.89 = good, and 0.90–1.00 = excellent (Swets, 1988).

To investigate which parent and teacher subscale scores contributed to ADHD classification, we did univariate and multivariate logistic regression analyses. In the univariate analyses, we regressed gender and each parent and teacher HI and IA subscale score on ADHD classified according to the PAPA. Predictors that contributed significantly were then included in the multivariate logistic regression models. In the final multivariate models, we only included predictors which made significant contributions ($p \leq .05$).

We estimated sensitivity (the probability that a measure correctly classifies a case as positive) and specificity (the probability that a measure correctly identifies noncases as negative) for cutoffs at each step of the scale for boys and girls. Children who scored at or above a given cutoff score were categorized as screen positive, whereas children who scored below were screen negative. We calculated the PPV (the probability of a true case, given a positive test), NPV (the probability of a true noncase, given a negative test), the positive likelihood ratios (LRs; the probability of a child who has the disorder testing positive divided by the probability of a child who does not have the disorder testing positive), and negative LRs (LRs; the probability of a child who has the disorder testing negative divided by the probability of a child who does not have the disorder testing negative). LRs between 0 and 1 argue against the presence of the disorder; the closer they are to 0, the less likely the disorder. LRs greater than 1 argue for the presence of the disorder, whereas LRs that are equal to 1 lack diagnostic value (McGee, 2002). LRs above 10 and below .1 are considered to provide strong evidence to rule in or rule out diagnoses, respectively (Deeks & Altman, 2004). LRs are derived from sensitivity and specificity and are independent of the proportion of the disorder in the sample. Therefore, they are more likely to generalize outside the sample compared with PPV/NPV (Youngstrom, 2014). We checked whether co-occurring ODD altered the proportion of boys and girls with ADHD who were correctly classified. Statistical tests to compare ROC curves were conducted with the R-package pROC. For paired samples (parents vs. teachers for girls and boys, respectively), statistical comparisons (*D*-statistics) were done using bootstrap tests for two correlated ROC curves. For unpaired samples (parents vs. teachers), we used DeLong's test for two ROC curves.

Results

Boys and girls who were classified with ADHD had significantly higher mean HI and IA scores than those who did not (Table 1). For both boys and girls, the parent and teacher HI and IA scores discriminated true positive and true negative cases significantly better than chance ($p < .001$), but only the parent HI scores for boys performed well (AUC $\geq$ .80; for AUC values, see Table 1; for ROC curves see the online supplemental materials; Figures 1S and 2S). For boys, the parent HI scores significantly outperformed teacher HI scores (AUCs of .85 and .70, respectively; $D = 3.88$, $p < .001$), while there was no significant difference in AUC values between informants for the HI scores for girls (statistics not shown). There was no significant difference in classification accuracy between the parent HI scores for

Table 1
T-Test Comparisons and Area Under the Curves (AUCs) for the Parent (p) and Teacher (t) ECI-4 HI and IA Subscales for Boys and Girls With and Without ADHD

ECI-4 subscales by gender	ADHD, *M* (*SD*)	No ADHD, *M* (*SD*)	*t*-test	*p* value	AUC [95% CI]
Boys (*n* = ADHD/no ADHD)					
p-ECI HI (71/253)	13.76 (4.46)	7.89 (3.85)	10.08	<.001	.85 [.80, .89]
p-ECI IA (73/251)	10.45 (4.41)	7.17 (3.30)	5.90	<.001	.73 [.66, .80]
t-ECI HI (68/246)	10.07 (6.60)	5.73 (4.92)	5.06	<.001	.70 [.63, .78]
t-ECI IA (70/236)	9.49 (6.25)	5.70 (4.13)	4.77	<.001	.69 [.61, .76]
Girls (*n* = ADHD/no ADHD)					
p-ECI HI (56/259)	12.18 (5.58)	7.35 (3.73)	6.18	<.001	.76 [.69, .83]
p-ECI IA (56/255)	9.93 (4.45)	6.15 (2.87)	6.08	<.001	.76 [.69, .83]
t-ECI HI (48/247)	7.23 (5.98)	3.78 (3.94)	3.84	<.001	.69 [.60, .77]
t-ECI IA (48/245)	6.90 (5.32)	4.07 (3.74)	3.52	<.001	.67 [.58, .76]

Note. ADHD = attention-deficit/hyperactivity disorder; CI = confidence interval; ECI-4 = The Early Childhood Inventory-4; HI = Hyperactivity-Impulsivity subscale; IA = Inattention subscale.

Table 2
Univariate and Multivariate Logistic Regression Analyses Predicting ADHD Diagnosis

	Univariate					Multivariate				
Predictors	*B*	*SE*	*OR*	95% CI	*p*	*B*	*SE*	*OR*	95% CI	*p*
Gender	.30	.20	.74	[.50, 1.09]	.13					
Parent ECI-4 HI	.27	.03	1.31	[1.24, .1.39]	<.001	.26	.03	1.29	[1.22, 1.37]	<.001
Parent ECI-4 IA	.26	.03	1.29	[1.22, 1.37]	<.001					
Teacher ECI-4 HI	.14	.02	1.15	[1.10, 1.19]	<.001	.10	.02	1.10	[1.06, 1.15]	<.001
Teacher ECI-4 IA	.15	.02	1.15	[1.11, 1.21]	<.001					

Note. Only predictors that contributed significantly were included in the final multivariate regression model. ADHD = attention-deficit/hyperactivity disorder; ECI-4 = The Early Childhood Inventory-4; HI = Hyperactivity-Impulsivity subscale; IA = Inattention subscale; *OR* = odds ratio; CI = confidence interval.

boys and girls (AUCs of .85 and .76, respectively; $D = 1.15$, $p = .25$), nor was there any significant gender difference in AUCs for the teacher HI scores (statistics not shown). For the IA subscale scores, the same comparisons were made as for the HI subscale scores, with no significant differences (statistics not shown).

In the univariate logistic regression analyses, both subscales that the parents and teachers rated contributed significantly to ADHD, while gender did not. In the final multivariate model, only the parent and teacher HI scores contributed significantly to ADHD classification (Table 2). For each step on the scale, the parent and teacher HI scores increased the odds of ADHD identification by 1.29 (95% CI [1.22, 1.37], $p < .001$), and 1.10 (95% CI [1.06, 1.15], $p < .001$), respectively. Because only the HI subscales made a significant contribution to ADHD identification, the group-level statistics are presented for this subscale only.

Sensitivity, specificity, positive and negative predictive values (PPV and NPV, respectively) and positive and negative likelihood ratios (+LR, −LR) for the parent and teacher ECI-4 HI scores for cutoffs at each step of the scale for boys and girls are shown in Tables 3 and 4.

The parent HI subscale accurately ruled out children classified without ADHD when the parents assigned low scores (−LR < .1 at scores ≤7 for boys and ≤4 for girls). When the parents assigned high HI scores (≥19 for boys and ≥16 for girls), the HI subscale had high probabilities of correctly identifying children who fulfilled ADHD criteria according to the PAPA (+LR = 12.47 and 8.48 for boys and girls, respectively), but low sensitivity (10% for boys, 20% for girls). When creating parent HI cutoff levels for a sensitivity of ≥70%, scores 10 for boys and 8 for girls were found, with corresponding specificities of 78% and 66%.

Table 3
Boys: Sensitivity (Se), Specificity (Sp), Positive and Negative Predictive Values (PPV, NPV), and Positive and Negative Likelihood Ratios (+LR, −LR) for the ECI-4 Hyperactivity-Impulsivity (HI) Subscale for ADHD Diagnosis

	Parents						Teachers					
ECI-4 HI cutoff	Se (%)	Sp (%)	PPV	NPV	+LR	−LR	Se (%)	Sp (%)	PPV	NPV	+LR	−LR
1	100	02	.22	1.00	1.02	.00	93	23	.25	.92	1.21	.32
2	100	04	.23	1.00	1.05	.00	85	30	.25	.88	1.23	.48
3	100	09	.24	1.00	1.10	.00	78	39	.26	.86	1.,28	.57
4	100	19	.26	1.00	1.24	.00	76	46	.28	.88	1.43	.51
5	99	28	.28	.99	1.38	.05	72	54	.30	.88	1.58	.51
6	99	40	.32	.99	1.64	.04	71	64	.35	.89	1.97	.46
7	97	52	.36	.99	2.03	.05	65	68	.36	.88	2.04	.52
8	93	64	.42	.97	2.56	.11	54	78	.40	.86	2.43	.59
9	77	72	.44	.92	2.76	.31	47	81	.41	.85	2.52	.65
10	72	78	.48	.91	3.30	.36	44	84	.43	.84	2.78	.66
11	63	82	.49	.89	3.49	.45	40	87	.45	.84	2.96	.70
12	56	87	.54	.88	4.19	.50	35	89	.47	.83	3.22	.73
13	*49*	*91*	*.61*	*.87*	*5.67*	*.56*	31	91	.50	.83	3.62	.76
14	*42*	*94*	*.65*	*.85*	*6.68*	*.62*	24	95	.55	.82	4.45	.81
15	*35*	*96*	*.74*	*.84*	*9.90*	*.67*	*15*	*95*	*.45*	*.80*	*3.01*	*.90*
16	*25*	*97*	*.69*	*.82*	*8.02*	*.77*	*15*	*96*	*.50*	*.80*	*3.62*	*.89*
17	*18*	*98*	*.68*	*.81*	*7.72*	*.84*	*13*	*98*	*.60*	*.80*	*5.43*	*.89*
18	*14*	*99*	*.77*	*.80*	*11.88*	*.87*	*10*	*98*	*.58*	*.80*	*5.06*	*.92*
19	**10**	**99**	**.78**	**.80**	**12.47**	**.91**	*10*	*99*	*.70*	*.80*	*8.44*	*.91*
20	**08**	**100**	**.86**	**.79**	**21.38**	**.92**	*07*	*99*	*.71*	*.79*	*9.04*	*.93*
21	**07**	**100**	**.83**	**.79**	**17.82**	**.93**	*06*	*100*	*.80*	*.79*	*14.47*	*.95*
22	**04**	**100**	**1.00**	**.79**		**.96**	*06*	*100*	*.80*	*.79*	*14.47*	*.95*
23							**04**	**100**	**.75**	**.79**	**10.85**	**.96**

Note. The proportion of boys who fulfilled attention-deficit/hyperactivity disorder (ADHD) criteria in the sample was 22%. Moderate severity and high severity (according to the ECI-4 T-score norms) are indicated in italics and bold, respectively. ECI-4 = The Early Childhood Inventory-4.

Table 4
Girls: Sensitivity (Se), Specificity (Sp), Positive and Negative Predictive Values (PPV, NPV), and Positive and Negative Likelihood Ratios (+LR, −LR) for the ECI-4 Hyperactivity-Impulsivity (HI) Subscale for ADHD Diagnosis

	Parents						Teachers					
ECI-4 HI cutoff	Se (%)	Sp (%)	PPV	NPV	+LR	−LR	Se (%)	Sp (%)	PPV	NPV	+LR	−LR
1	100	03	.18	1.00	1.03	.00	81	36	.20	.91	1.28	.51
2	100	08	.19	1.00	1.08	.00	77	46	.22	.91	1.42	.50
3	100	14	.20	1.00	1.17	.00	71	55	.23	.91	1.56	.53
4	100	24	.22	1.00	1.31	.00	65	66	.27	.91	1.92	.53
5	93	35	.24	.96	1.42	.21	54	74	.29	.89	2.06	.62
6	84	43	.24	.93	1.48	.37	50	80	.32	.89	2.47	.63
7	80	54	.27	.93	1.75	.36	44	84	.34	.88	2.70	.67
8	71	66	.31	.91	2.08	.44	31	89	.35	.87	2.76	.78
9	57	73	.32	.89	2.14	.58	27	91	.38	.87	3.19	.80
10	54	80	.37	.89	2.67	.58	25	94	.44	.87	4.12	.80
11	*46*	*88*	*.46*	*.88*	*3.88*	*.61*	*21*	*96*	*.48*	*.86*	*4.68*	*.83*
12	*39*	*93*	*.54*	*.88*	*5.36*	*.66*	*19*	*97*	*.53*	*.86*	*5.79*	*.84*
13	*38*	*95*	*.62*	*.88*	*7.47*	*.66*	*13*	*98*	*.55*	*.85*	*6.18*	*.89*
14	*29*	*96*	*.62*	*.86*	*7.40*	*.74*	*13*	*98*	*.55*	*.85*	*6.18*	*.89*
15	*25*	*97*	*.67*	*.86*	*9.25*	*.77*	*08*	*98*	*.44*	*.85*	*4.12*	*.94*
16	**20**	**98**	**.65**	**.85**	**8.48**	**.82**	*04*	*99*	*.50*	*.84*	*5.15*	*.97*
17	**18**	**98**	**.71**	**.85**	**11.56**	**.83**	**04**	**100**	**.67**	**.84**	**10.29**	**.96**
18	**16**	**99**	**.82**	**.85**	**20.81**	**.85**	**04**	**100**	**.67**	**.84**	**10.29**	**.96**
19	**09**	**100**	**.83**	**.83**	**23.13**	**.91**	**04**	**100**	**.67**	**.84**	**10.29**	**.96**

Note. The proportion of girls who fulfilled attention-deficit/hyperactivity disorder (ADHD) criteria in the sample was 18%. Moderate severity and high severity (according to the ECI-4 *t* score norms) are indicated in italics and bold, respectively. ECI-4 = The Early Childhood Inventory-4.

For the teacher HI subscale, low scores discriminated less well than did parent ratings for both boys and girls with no clear scores to rule out children classified without ADHD (−LR ≥ .32 for boys and ≥.51 for girls; Tables 3 and 4). High scores (≥23 for boys and ≥17 for girls) gave high probabilities of correctly identifying a child who fulfilled ADHD criteria according to the PAPA (+LR = 10.85 and 10.29 for boys and girls, respectively), but low sensitivity (4% for both boys and girls). When creating teacher HI cutoff levels for a sensitivity of ≥70%, scores of 6 for boys and 3 for girls were found, with corresponding specificities of 64% and 55%.

Using a high HI score from either the parent or the teacher as the criterion increased sensitivity to 20% for boys and 33% for girls without losing specificity. At lower cutoff scores on the ECI-4, combining parent and teacher scores did not improve detection.

Figures S3 and S4 (in the online supplemental materials) show the proportion of boys and girls with ADHD and co-occurring ODD who were correctly identified by the different parent and teacher ECI-4 scores, compared with those with ADHD without ODD. Overall, co-occurring ODD increased the proportion of children correctly identified for the high parent ECI-4 HI scores in boys, the middle and high parent HI scores in girls, as well as the middle and high teacher ECI-4 HI scores in both boys and girls.

Discussion

In our at-risk preschool sample, the parent and teacher ECI-4 showed acceptable accuracy in detecting boys and girls who fulfilled ADHD criteria according to a parent diagnostic interview. The parent HI subscale discriminated well for boys (AUC = .85) and outperformed the teacher HI subscale. The parent and teacher HI subscale scores contributed significantly to the ADHD classification in the multivariate regression model, whereas the IA subscale scores did not. Based on the United States norms provided by the developers of the ECI-4, the few children who received high severity scores from parents or teachers had a high probability of being classified with ADHD. However, using the suggested cutoffs for high severity would lead to many false negatives. We found the parent low cutoff scores particularly useful to rule out ADHD. The parent and teacher cutoff scores that gave the recommended sensitivity ≥70% were considerably lower than the United States high severity cutoff scores. Using a high HI score from either the children's parents or the teachers increased sensitivity for boys and girls without loss of specificity, but sensitivity was still low (20% for boys and 33% for girls). At the lower cutoff levels, combining parent and teacher ratings did not improve detection.

Our finding of acceptable accuracy in detecting children classified with ADHD with the parent and teacher ECI-4 is consistent with studies that have demonstrated good convergent/divergent validity for the ECI-4 compared with other relevant rating scales (Sprafkin, Volpe, et al., 2002). However, this finding is contrary to one study that reported significant correlations only between the teacher ECI-4 and the CRS-R scores (Poblano & Romero, 2006). That same study failed to demonstrate strong sensitivity and specificity for the ECI-4 when ADHD diagnoses were obtained from a parent interview, but it was limited by a small sample size (n = 34; Poblano & Romero, 2006). Another small study (n = 52 with a variety of diagnoses) found good sensitivity (.85) for chart ADHD diagnosis with the ECI-4 teacher version and poor sensitivity (.57) for parents (Bălaj et al., 2011).

Consistent with an earlier study by the developers, we found modest correlations (.33–.34) between the parent and teacher subscales (Sprafkin, Gadow, Salisbury, Schneider, & Loney, 2002). However, we found that both the parent and teacher HI subscale

scores contributed significantly to identifying children classified with ADHD in a multivariate regression model, and using high symptom severity scores from either the children's parents or teachers improved detection. These results support earlier findings that the clinical utility of the ECI-4 may be enhanced by including both parent and teacher reports (Sprafkin, Gadow, et al., 2002; Sprafkin, Volpe, et al., 2002). However, we only found a slight increase in sensitivity for children with high HI scores from either parents or teachers, while at lower cutoff scores, combining parent and teacher scores did not improve detection. Thus, the improvement through combining scores was so small that it is uncertain whether they are clinically relevant. The IA subscale did not contribute significantly in the multivariate regression analysis. This was not surprising, as the HI and IA scores from the same informant were highly correlated, and it suggests that the HI subscale may be sufficient to detect ADHD, at least in preschoolers.

Overall, our results support using a multithreshold approach to maximize the clinical utility of screening, in line with other studies on screening properties of ordinal scales (Overgaard, Oerbeck, Friis, et al., 2018; Sheldrick et al., 2015). Based on the findings in the present study, clinicians may assume that low parent ECI-4 HI subscale scores suggest that ADHD can be ruled out with confidence in both girls and boys ($-LR < .1$), while the low teacher scores were not clear. The highest parent and teacher ECI-4 HI scores substantially increased the probability of children being classified with ADHD ($+LRs$ of about 10), although many children classified with ADHD will be missed. Creating lower cut-off scores to achieve the minimum sensitivity value of 70% recommended in guidelines for screening instruments (Sheldrick & Garfinkel, 2017), would give undue concern for many children with false positive tests, as would all the other intermediate scores. However, in support of lowering the cutoff scores, the developers of the ECI-4 have pointed out that for screening instruments such as the ECI-4, it is important to minimize false negatives. As there is low risk of harmful consequences of follow-up evaluations of false positives, sensitivity is the most important consideration (Sprafkin, Volpe, et al., 2002). Depending on available resources, follow-up evaluation could range from doing another screening after some time, to referral or broader clinical assessments.

Furthermore, clinicians need to be aware that the proportion of ADHD among the children they screen, as well as the setting, will affect the probability of finding true positive children. The present study was not from a clinical setting, where the challenge of using screening measures would be to discriminate children with ADHD from children with other diagnoses. Yet, the sampling procedure gave a four-to-ten-times higher proportion of ADHD than expected in a community sample. In a community study where the proportion of children with ADHD diagnosis was 1.8%, we recently investigated the predictive validity of another ADHD rating scale. In that study, we found an unsatisfactory probability of correctly identifying a child with ADHD (PPV = .02) at the cutoff score that gave sensitivity ≥70%, leading us to question the feasibility of screening the general child population for ADHD (Overgaard, Madsen, Oerbeck, Friis, & Obel, 2018). Our present "high-risk" sample may resemble the base rate in a primary health care unit after concerned parents have asked whether their preschool child might have ADHD. This scenario, with an increased base rate due to parental concern, may be a more feasible scenario for screening.

As pointed out above, the sensitivity, specificity, and PPV and NPV for different cutoff levels in our sample suggest that, to achieve the necessary sensitivity to detect more than a few children classified with ADHD, lower cutoff levels than those specified by the United States ECI-4 norms are needed. This finding may be consistent with a study reporting cross-cultural differences in the parent-rated Child Behavior Checklist, wherein some Nordic countries had substantially lower total mean scores compared with the estimated mean of most included countries (Rescorla et al., 2011). In addition, a study of the Strengths and Difficulties Questionnaire (SDQ) concluded that lower Norwegian questionnaire scores for externalizing problems appeared to reflect real and substantial differences between Norway and Great Britain (Heiervang, Goodman, & Goodman, 2008).

In accordance with earlier studies and ECI-4 norms, we see from Tables 3 and 4 that boys in our study received higher parent and teacher scores than girls (Gadow & Sprafkin, 1997; Sprafkin, Volpe, et al., 2002). Furthermore, parent HI scores significantly outperformed teacher HI scores only for boys. We did not find significant gender differences in classification accuracy between the parent or teacher HI scores. This is contrary to a recent study of the SDQ, where preschool teachers were significantly more accurate in detecting girls than boys with ADHD (Overgaard, Oerbeck, Friis, et al., 2018).

Inattentive symptoms have been reported to be more prominent in girls (Rucklidge, 2010). Even if it is unclear to what extent this is the case among preschoolers, we assumed that the ECI-4 IA subscale might be particularly useful in detecting girls with ADHD. This was not confirmed in the present study, in line with a meta-analytic review reporting equal ratio between preschool boys and girls for the ADHD IA subtype (Willcutt, 2012). Low attentional demands during preschool age might make IA less noticeable and difficult to assess, and could explain why relatively few children (8%) were found to have the predominantly inattentive presentation of ADHD in our study, which is consistent with other preschool studies (Overgaard, Oerbeck, Friis, et al., 2018; Posner et al., 2007; Wichstrøm et al., 2012).

Studies have reported high rates of co-occurring ODD symptoms in preschoolers with ADHD (Harvey, Breaux, & Lugo-Candelas, 2016; Lahey et al., 2016), and we found that co-occurring ODD increased the proportion of boys and girls correctly identified with ADHD (Figures S3 and S4 in the online supplemental materials). These findings are in line with a recent study of 9-year-olds, where externalizing behavior problems (both hyperactivity/impulsivity and conduct problems) increased the risk for ADHD diagnoses (Mowlem et al., 2018). That same study concluded that girls with ADHD may be more easily missed in the ADHD diagnostic process unless they have prominent externalizing problems, which our Figures S3 and S4 in the online supplemental materials illustrate.

Strengths and Limitations

The strengths of our study included the population-based cohort design and the use of a standardized diagnostic interview. The study also had several limitations. First, there were selection biases due to attrition in the MoBa (Magnus et al., 2016) and the ADHD

substudy (Overgaard et al., 2014). One study of ADHD in MoBa, reported a lower proportion of ADHD, less psychosocial adversity, and better child global functioning in the cohort compared with the general child population, but differences were small and assumed to affect generalizability to a limited degree (Oerbeck et al., 2017). Second, our diagnostic outcome was based on parent report and might have contributed to the stronger screening accuracy of the parent HI subscale scores compared with teacher ratings for boys. However, by using the PAPA the parents would have to report the symptoms to be pervasive across at least two settings (e.g., at home, in preschool) for them to be assessed as present. As noted in the Method section, the classification of ADHD according to the PAPA is not equivalent to clinical ADHD diagnoses that would require a broader assessment, including multiple sources of information and informants. However, using a parent diagnostic interview, where the interviewer asks questions until she/he can decide whether the symptoms are present, is a different process from collecting information with a rating scale, and is still considered to be the diagnostic gold standard.

Third, the present study is cross-sectional, and does not address the predictive validity of ADHD classification according to the PAPA. However, another study using the PAPA interview at Ages 3 and 6, found significant homotypic continuity of ADHD during this period ($OR = 17.96$; Bufferd et al., 2012), supporting that the PAPA is a good tool to identify preschoolers at risk for ADHD. As pointed out by Law et al. (2014), early community samples reported about 50% stability of children Aged <7 years after $\geq$2-year period by using checklists to ascertain ADHD diagnosis. More recent clinical/high-risk samples including some form of standardized diagnostic assessments have demonstrated higher stability ($>70\%$; Harvey et al., 2009; Law et al., 2014; Riddle et al., 2013). Studies of the course for preschoolers diagnosed with ADHD, have thus far been few compared with studies of schoolchildren. Based on the available evidence, the new edition of the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; APA, 2013) acknowledged that many parents first observe hyperactivity in their preschool child, but also underlined that hyperactive symptoms are difficult to distinguish from highly variable normative behaviors before the age of 4 years. By evaluating the screening properties of preschool ADHD-specific rating scales corresponding to the *DSM–IV* diagnostic criteria, the present study has potential to improve early identification of children at risk for ADHD.

Fourth, we do not have details about the gender of the ECI-4 informants, recently suggested to be important, as boys were nearly twice as likely to be identified as at risk for ADHD when rated by females versus males using the ADHD Rating Scale-5 (Anastopoulos et al., 2018). We assume that mostly mothers rated the questionnaires in our substudy (as in MoBa), and as previously indicated, Statistics Norway reports that about 90% of preschool teachers in Norway are female. This may have influenced results but unfortunately, we are not able to examine these effects. Finally, our at-risk sample had a higher proportion of children with ADHD than does the general population. This increased the probability of finding true cases, given a positive screen result. However, this should not affect estimates of sensitivity, specificity, and LRs, which may generalize to other samples.

Conclusions

The ADHD-specific rating scales of the ECI-4 had acceptable accuracy in identifying boys and girls who fulfilled ADHD criteria according to a parent diagnostic interview in our at-risk sample, and the HI subscale seemed sufficient to screen preschoolers. Overall, we found few significant gender differences, but the parent HI scores significantly outperformed teacher HI scores only for boys. The United States cutoff values provided by the ECI-4 developers appeared to have limited cross-cultural validity. Still, our findings suggest that the ECI-4 may be useful for screening purposes in Norwegian samples as well as in other similar countries. To maximize the clinical utility of screening with the ECI-4 our results support using a multithreshold approach, meaning that ADHD can be ruled out with confidence at low parent HI subscale scores, while high scores indicate that ADHD is likely. Best balance between sensitivity and specificity was reached at lower cutoff scores than the United States norms, but as lowering the cutoffs increased the number of false positives, we recommend additional assessment at these scores. Using high HI scores from either the parent or the teacher as the criterion increased sensitivity somewhat, compared with using one informant, but overall there was little added value of combining parent and teacher scores to improve detection in preschoolers. Future longitudinal studies are needed to determine which proportion of preschool children screening positive at different ECI-4 cutoff levels go on to develop ADHD over time.

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