Psychometric properties of an observation instrument to assess ADHD symptoms in the classroom using a continuous sampling approach

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Abstract

Objective: This study investigates the psychometric properties of the Dutch version of the Ghent University Classroom Coding Inventory (GUCCI-NL) by comparing children with (subthreshold) ADHD to typically developing peers. The advantage of the GUCCI is that it measures the proportion of time ADHD behavior was displayed and length of such intervals in a continuous manner that allows for more detailed assessment of behavior, such as on-task span, compared to traditional time sampling methods.

Method: We coded the scales Attention Problems, Motor and Verbal Hyperactivity, and Oppositional Behavior in a sample of 57 children with (subthreshold) ADHD and 34 controls (aged 6–12). Construct validity (i.e., group differences, convergent and divergent validity), predictive validity (including ROC curves), and inter-observer reliability were investigated. Outcome measures were percentage of time and interval span.

Results: The GUCCI-NL discriminated between the ADHD and control group for all scales (small to very large effects), with largest effects on percentage of time. Convergent validity against questionnaire and interview scores was confirmed for Verbal Hyperactivity and Oppositional Behavior, although divergent validity was weak. The Attention Problems scale was most sensitive to group membership ($AUC = .79$). Inter-observer reliability was sufficient ($r > .82$). Group differences on span length were found for Attention Problems but not for Hyperactivity, confirming the additional value of continuous coding.

Conclusion: The GUCCI-NL is a valid objective measure for ADHD symptoms in the classroom, which may be of added value in scientific practice, although for diagnostic purposes additional instruments should be used.

Keywords: ADHD, children, classroom observations, validity, psychometric properties, continuous sampling, on-task behavior

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common childhood mental disorders, characterized by age-inappropriate, impairing, and persistent levels of inattention and/or hyperactivity/impulsivity that are apparent in at least two settings (e.g., home, school) and interfere with development or functioning (American Psychiatric Association, 2013). In addition to the 5% of the children meeting full criteria for the disorder (Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014), an even larger group (11-18%) of children experience impairing symptoms without meeting full diagnostic criteria, a group designated as children with subthreshold ADHD (Kirova et al., 2019). Both groups experience largely similar problems related to behavioral, social and academic functioning (Daley & Birchwood, 2010; Kirova et al., 2019; Wilens et al., 2002). ADHD symptoms and the associated problems may exacerbate at school and negatively influence academic performance because of the specific demands placed on a child's attention and self-regulation (Abikoff et al., 2002; Junod, DuPaul, Jitendra, Volpe, & Cleary, 2006).

In scientific research on the treatment of ADHD, such as in randomized clinical trials where behavioral intervention effects are investigated, most studies have relied on assessments of ADHD symptoms by raters (e.g., teachers) that are directly involved in treatment delivery (Daley et al., 2014; Sonuga-Barke et al., 2013). ADHD symptoms in the classroom have typically been assessed using teacher ratings on DSM-based standardized behavior rating scales/questionnaires, as well as (although used in a lesser extent) the use of semi-structured clinical interviews. Both measures provide information on a child's behavior over extended time spans and in multiple situations, and the psychometric properties are reported to be adequate (American Academy of Pediatrics, 2011; Staff et al., 2020a; Tannock, Hum, Masellis, Humphries, & Schachar, 2002). However, both rating scales and interviews are vulnerable to teacher bias (Burns, Gomez, Walsh, & de Moura, 2003; Gomez, Burns, Walsh, & De Moura, 2003). For example, teachers may show symptom exaggeration (Abikoff, Courtney, Pelham, & Koplewicz, 1993), because of the large burden associated with symptoms of ADHD (Burns et al., 2003; Gomez et al., 2003; Poznanski, Hart, & Cramer, 2018).

Structured classroom observations are regarded as more objective measures of behavior than teacher informed measures, because they use standardized coding procedures measuring predefined behaviors within the natural setting in which these behaviors occur (Volpe, DiPerna, Hintze, & Shapiro, 2005). In addition, observations by independent observers have the advantage that coders are not affected by possible bias. Observations also provide possibilities to measure covert behavior, such as inattention, since this is difficult to observe for teachers (Poznanski et al., 2018). If easy to administer, observations may be used in clinical practice to objectively assess ADHD symptoms as well as student-teacher interactions.

Among the currently existing structured classroom observation measures, the Behavioral Observation of Students in Schools (BOSS; Shapiro, 2004), Classroom Observation Code (Abikoff & Gittelman, 1985), and

the Direct Observation Form (DOF; Achenbach, 1986) are the most commonly used instruments (Minder, Zuberer, Brandeis, & Drechsler, 2018; Staff et al., 2020b). Psychometric properties of these measures are generally acceptable regarding inter-observer reliability and predictive validity, although the latter is usually only examined for the total scales and not for subscales and related symptom domains. Agreement between observations of ADHD symptoms and teacher reports (i.e., construct validity) is small to moderate (Minder et al., 2018; Staff et al., 2020a). These instrument seem to be able to differentiate between children with ADHD and typically developing peers in the classroom (Kofler, Rapport, & Matt Alderson, 2008; Platzman et al., 1992).

A disadvantage of current observational instruments is that all of these measures use time sampling (event counting during a predefined interval or moment), while continuous sampling (event counting and duration recording without considering fixed intervals) has the advantage of assessing predefined behavior in a more detailed way (e.g., proportion of time behavior occurred, length of span). Therefore, currently we do not know whether group differences between children with and without ADHD in for example on-task behavior can be attributed to a shorter attention span of children with ADHD (i.e., more shifts) or fewer intervals that they are on-task, or both. So far, there is only one instrument using continuous sampling to assess ADHD in a classroom setting: the Ghent University Classroom Coding Inventory (GUCCI) (Imeraj et al., 2016; Imeraj et al., 2013). However, this measure has not been validated yet, which is the aim of the current study.

By using the GUCCI, one may be able to detect more subtle differences between children with and without ADHD by the use of continuous sampling. Two studies using the GUCCI assessed percentage of time and interval length of attention problems and showed differences in behavior depending on the type of measurement (i.e., larger differences between groups on percentage of time, compared to interval length) (Imeraj et al., 2016; Imeraj et al., 2013). We will extend this work, by also studying the magnitude (e.g., length of interval) of motor hyperactivity and verbal hyperactivity in a systematic way. Further we will add oppositional defiant behavior to the coding system, given that this behavior often co-occurs with ADHD behaviors (American Psychiatric Association, 2013). Moreover, most observation instruments to assess ADHD are purported to measure inattention (i.e., time off-task) and disruptive (i.e., visually detective aspects of motor activity or noisiness) in an ordinal way. However, ADHD covers a range of behaviors differing in severity. For example motor hyperactivity, which is defined within the DSM as fidgeting or squirming in seat but also as often leaving seat or running about (American Psychiatric Association, 2013). To gain insight into such more subtle behavioral differences between children or as a result of an intervention, we have introduced in the GUCCI-NL a more fine-grained analyses of ADHD symptoms, by differentiating between severity levels of behaviors. Taken together, the GUCCI-NL may provide us with more insight into differences in (subtle) patterns

of classroom problem behaviors between children with ADHD and typically developing peers regarding inattentive, hyperactive and oppositional behavior.

The aim of the current study was to examine the psychometric properties of the GUCCI (Imeraj et al., 2016; Imeraj et al., 2013), which was expanded by measuring different levels of motor hyperactivity, and by examining oppositional behavior and adjusted to the Dutch school setting (GUCCI-NL). To examine construct validity, we aimed to confirm group differences on these behaviors between a group of children with (subthreshold) ADHD and a group of typically developing peers. In addition, construct validity was assessed by determining the convergent and divergent validity of the GUCCI-NL by comparing observation to scores on a teacher rating scale and clinical teacher interview. Further, we examined the inter-observer reliability, and studied the predictive validity of the GUCCI-NL for group membership.

Methods

Participants

This study included 57 children with (subthreshold) ADHD (referred to as ADHD group) and 34 typically developing children (referred to as controls). Both groups attended regular primary education and were in the age range 6 – 12 years (grade 1-6). In total, 58 teachers from 41 schools throughout the Netherlands participated in the study, with a maximum of two children (one ADHD, one control) per teacher. Eighty-five percent of the controls were classmates of children assigned to the ADHD group.

Children in the ADHD group were included if they (see Staff et al., 2020b): (a) obtained a score > 90th percentile on the teacher rated Inattention and/or Hyperactivity/Impulsivity scale of the Disruptive Behavior Disorders Rating Scale (DBDRS) (Oosterlaan, Scheres, Antrop, Roeyers, & Sergeant, 2008); (b) showed at least three symptoms (item score ≥ 2) on the Inattention and/or Hyperactivity/Impulsivity scale of the semi-structured DSM-IV-TR Teacher Telephone Interview (TTI) (Tannock et al., 2002); and (c) obtained a score > 5 (indicating impairment, range 0 - 10) on at least one domain of the teacher rated Impairment Rating Scale (IRS) (Fabiano et al., 2006). Teachers rated school impairment on the IRS assessing five areas of functioning: peer, teacher, classroom, academic, and self-esteem. For four children inclusion took place before summer holiday and teachers were thus not able to rate impairment in the first week of school. For these children impairment was based on the fact that the teacher was seeking help to cope with the child's behavior, which was substantiated by TTI scores. In order to avoid overlap between the ADHD and control groups (see below), we added an additional inclusion criterion for this study and excluded children within the ADHD group who scored < 80th percentile on the Hyperactivity scale of the teacher rated Strengths and Difficulties Questionnaire (SDQ) (Diepenmaat, Van Eijdsden, Janssens, Loomans, & Stone, 2014; Goodman, 1997).

The typically developing children were classmates of the children assigned to the ADHD group, and were recruited through the teachers that could nominate a classmate of the same age. Control children were required not to attend special education classes and to obtain a score < 80th percentile on the Hyperactivity scale of the teacher rated SDQ. Teacher ratings on the Hyperactivity scale of the SDQ are highly correlated to teacher ratings on the Inattention and Hyperactivity/Impulsivity scales of the DBDRS ($r = .83$, $r = .79$, respectively) (Oosterlaan et al., 2008).

To assess ADHD and ODD symptom severity at home, parent ratings on the Strengths and Weaknesses of ADHD-symptoms and Normal behavior scale (SWAN; Swanson et al., 2012) and ODD-scale of the DBDRS were used.

Children were excluded if they: (a) had an estimated full scale IQ lower than 70 as assessed with a short form of the Wechsler Intelligence Scale for Children-third edition (WISC-III) (Wechsler, Kort, & Compaan, 2005) including the subtests Block Design and Vocabulary (Sattler, 2008), (b) were taking psychotropic medication during the last month, or (c) had a diagnosis of autism spectrum disorder or conduct disorder according to the DSM-IV-TR or DSM-5 as reported by parents on a demographic questionnaire.

Materials

Classroom observations

Coding system The GUCCI is an observation instrument developed to assess observable ADHD behavior in the classroom, based on DSM descriptions of ADHD symptoms. Accordingly, the instrument consists of three scales: Attention Problems (i.e., visual attention to task), Motor Hyperactivity (i.e., motor movements) and Verbal Hyperactivity (i.e., talking, making noises). Each scale comprises of multiple levels of behavior (i.e., behavioral categories) to be coded. Behavioral levels within each scale were mutually exclusive (e.g., Verbal Hyperactivity consisting of the levels no verbal hyperactivity, verbal hyperactivity) (Imeraj et al., 2016; Imeraj et al., 2013). All behaviors were continuously coded.

We used an Dutch adjusted version of the GUCCI (Imeraj et al., 2016; Imeraj et al., 2013): the GUCCI-NL. The original GUCCI included two levels at each scale (the behavior was absent or present), and assessed for each scale the proportion of time each level of the behavior occurred. For the Attention Problems scale the mean duration (i.e., interval length) of on-task intervals was also assessed. We made the following adjustments for the GUCCI-NL (see Table 1 for descriptions of all scales and levels within each scale): 1) More fine-grained measurement of Motor Hyperactivity now comprising of three instead of two levels of motor hyperactivity (no motor hyperactivity, minor motor hyperactivity, and gross motor hyperactivity), in order to differentiate between severity levels of hyperactivity (American Psychiatric Association, 2013); 2) Including an Oppositional Behavior scale, given the high comorbidity rates between ADHD and ODD symptoms for which frequency of occurrence was used as outcome measure; 3) Calculating time off-task by dividing the total time off-task by the

total time interval in which the child was expected to be involved in class activities (sum of the time of on- and off-task), rather than the total time coded as used in the original GUCCI. When no involvement in class activities was expected, the interval was coded as “no-task”; 4) Calculating both the proportion of time behavior occurred and the mean duration of the scales Attention Problems, Motor and Verbal Hyperactivity (see Table 1).

Observations were coded according to a manual providing in depth instructions on how to code behavior and examples. The manual is available from the authors. The Observer XT Software (Noldus Information Technology, version 13; Zimmerman, Bolhuis, Willemsen, Meyer, & Noldus, 2009) was used to analyze video material, allowing for electronic data entry, coding behaviors and calculating outcomes. The continuous nature of the coding in the Observer XT software allows for analyzing the percentage of time behavior occurred within the observation and the length of individual intervals of behaviors (i.e., off-task span).

Coding procedure In every classroom, participating children included in the ADHD group and control group were simultaneously observed for approximately 90 minutes using two video cameras. We conducted observations in the morning, with the exception of four children (2 ADHD, 2 control) for practical reasons. Observations were conducted when children attended lessons in their own classroom led by their primary teacher, preferably in the morning. We tried as much as possible to code approximately 60 minutes per child that contained actual lessons (e.g., the observation started when children were arriving at the beginning of the day, coding started when the teacher started the first lesson) ($M = 1:02\text{hr}$, $SD = 0:06\text{hr}$).

Inter-observer reliability agreement Fourteen graduate psychology students (i.e., observers) were intensively trained by the first author (AS) to code the specific behaviors and to work with Observer XT software. To increase accuracy of coding and inter-observer reliability, observers coded a maximum of two scales. For the total group of 91 children, four observers coded Attention Problems, five other observers coded Motor Hyperactivity, and another five observers coded Verbal Hyperactivity and Oppositional Behavior. A random sample (twenty-four percent) of the observations were coded twice to calculate inter-observer agreement between the observers (totaling into 479 hours of coding). Reliability estimates were obtained throughout the whole coding period. It was randomly determined which videos were checked and coders were randomly assigned to a second observer to code observations twice. Videos were recoded if reliability decreased. Inter-observer agreement was calculated within Observer XT as the percentage of time two observers agreed on the behavior per scale across all observations that were coded twice (Zimmerman et al., 2009). Given that we examined the exact percentage of time behaviors occurred rather than a more global index of the occurrence measured by the frequency of (the intervals in which) behavior occurred, we used the overlap in percentage of time coders scored the same level of a behavior from a particular scale as inter-rater reliability, rather than the frequency two observers coded a behavioral category (i.e., kappa). Observers were masked to the group status (ADHD or control) of the child. The observers were individually trained by the first author (AS) in

at least two sessions of two hours. During this training they were introduced to the behavioral categories and coding system; thereafter observers practiced coding of the observations and discussed their coding with the first author. Per observer, extra training sessions were held until inter-observer agreement with the trainer reached $\geq .80$.

Validity measures

ADHD and ODD symptoms assessed by a semi-structured clinical interview

The TTI is a semi-structured clinical teacher interview based on the DSM-IV-TR criteria (Tannock et al., 2002). The clinician rates the presence and severity of symptoms based on teacher descriptions of the child's behavior in various situations. The ADHD items are divided into two scales (Inattention and Hyperactivity/Impulsivity) of nine items each and the ODD scale consists of eight items, both rated on a 4-point Likert scale (range 0 – 3). Scores of 2 or greater for an individual symptom are regarded as clinically significant. Inter-rater reliability (Hum, 2004), and sensitivity and specificity are high (Parker & Corkum, 2016).

ADHD and ODD symptoms assessed by rating scales

ADHD. Symptoms of Inattention and Hyperactivity/Impulsivity were assessed using SWAN rating scale (Swanson et al., 2012). This DSM-based rating scale contains two scales measuring Inattention (nine items) and Hyperactivity/Impulsivity (nine items). Teachers rated a child's behavior on a 7-point Likert scale ($-3 = \text{far below average}$, $+3 = \text{far above average}$). All scores were reversed for consistency with other measures used in this study. Scores may range between -27 and 27 for both scales, with higher scores now indicating more ADHD symptoms. Excellent reliability estimates have been obtained for the SWAN ($\alpha = .95$), and convergent and discriminant validity are sufficient (Swanson et al., 2012). High internal consistency was also found in this sample: $\alpha = .98$.

ODD. Symptoms of Oppositional Defiant Disorder (ODD) (American Psychiatric Association, 2013) were measured with the teacher-rated ODD-scale of the DBDRS (Oosterlaan et al., 2008). This scale consists of eight DSM-based items rated on a 4-point Likert scale. Scores can range between 0 and 24, with higher scores indicating more symptoms. The internal consistency is high ($\alpha = .95$), and convergent validity is strong (Oosterlaan et al., 2008). Internal consistency was high in this sample: $\alpha = .94$.

-- Insert Table 1 about here --

Procedure

The local medical ethical committee waived the need for medical ethical approval (University Medical Center Groningen, 2016/198). The study was conducted in accordance with the Declaration of Helsinki (2013). Teachers were recruited through school principals, school collaboration networks, and outpatient mental health clinics. Participating teachers enlisted one or two children displaying ADHD symptoms in their classroom for which they needed behavioral support (data collection for this study was part of a larger intervention study

reported elsewhere: Staff et al. (2020b), and Dutch trial register: <https://www.trialregister.nl/trial/6616>).

Teachers and parents provided their consent for study participation. Clinical interviews with teachers were assessed by the first author (AS). Teacher and parent questionnaires were administered via a secured website, in the same week classroom observations took place. Classroom observations were conducted during one school day between April 2017 and April 2019. Observers were introduced as interns who visited different classes for their study. Teachers explained the children that the interns were observing how children are working during a lesson. Cameras were positioned in a corner at front of the classroom to prevent target children being aware they were the object of observation (parents were agreed with this procedure). The WISC-III short form was also administered by the observer for both the ADHD and control child, in a quiet room at the school at the same day the classroom observation took place.

Statistical analysis

Statistical analyses were performed using Stata, version 16. Differences in demographic characteristics, IQ, and ADHD and ODD related symptoms between the ADHD and control group were assessed using independent samples *t*-tests and chi-square test. Effect sizes were expressed as Cohen's *d*, with .20, .50 and .80 referring to the thresholds for small, medium and large effects, respectively, or Cramer's *V* with .07-.21 referring to small, .21-.35 to medium, and >.35 to large effects (Cohen, 2013).

Inter-observer reliability

To examine inter-observer reliability of the GUCCI-NL, agreement between observers of the same behaviors (i.e., scale) expressed in terms of percentage of observed time observers agreed upon, was calculated in the coding software.

Construct validity: Group comparisons

To test for construct validity of the GUCCI-NL, differences in child behaviors on the classroom observations were compared between the ADHD and control group. Because children in both groups were classmates, multivariate mixed model analyses were conducted. Four hierarchical levels were distinguished: observations (level 1), nested within children (level 2), nested in classrooms (level 3), and nested in schools (level 4).

Random intercepts at classroom and school level were included only if they significantly improved model fit as determined by Likelihood Ratio Test. We inserted group as between-subject factor (*ADHD* = 0, *control* = 1) and the five scales of the observational coding system (see Table 1) as outcomes. For Motor Hyperactivity, two analyses were conducted. First, to compare groups on the amount of motor hyperactivity shown, we compared no motor hyperactivity to an aggregated measure of minor and gross motor hyperactivity (i.e., percentage of time and interval length). Second, we assessed group differences on levels of motor hyperactivity by comparing groups on minor versus gross motor hyperactivity (i.e., percentage of time and interval length). Outliers (>3 SD) were winsorized (Tabachnick, Fidell, & Ullman, 2007). Because metrics of scores differed per scale (e.g.,

percentage versus length of interval), all outcomes were transformed into *z*-scores. The regression coefficient for group therefore represents the difference between groups as expressed in SD units, and is equal to Cohen's *d* measure of effect.

Construct validity: Convergent and divergent validity

To examine convergent and divergent validity of the GUCCI-NL, correlations between the observational scores of the GUCCI-NL and the questionnaire based teacher ratings (SWAN for ADHD, DBDRS for ODD) or semi-structured clinical teacher interview scores (TTI: ADHD and ODD) were assessed. Convergent validity was assessed by calculating correlations between corresponding scales of the GUCCI-NL and rating scale or clinical interview (e.g., for inattention the correlation between the Attention Problems scale of the GUCCI-NL and Inattention scale of the SWAN was calculated). For divergent validity of the different ADHD scales of the GUCCI-NL, correlations were calculated with the rating scale or clinical interview assessing the non-corresponding symptom domain (e.g., calculating the correlation between the Attention Problems scale of the GUCCI-NL and the Hyperactivity/Impulsivity scale of the SWAN). For oppositional scale of the GUCCI-NL, correlations were calculated with the ODD scale of the DBDRS and TTI (convergent validity) and with the ADHD scale of the SWAN and TTI (divergent validity). Correlational analyses were conducted in both groups separately, since group differences may have inflated strengths of associations. When significant effects were observed, differences between convergent and divergent validity coefficients were tested using Fisher's *r* to *z* transformations (Borenstein, Hedges, Higgins, & Rothstein, 2011).

Predictive validity

To examine predictive validity of the GUCCI-NL for group membership (ADHD versus control), receiver operating characteristics (ROC) curves were calculated. Accuracy was expressed in terms of area under the curve (AUC), with $\leq .50$, $.51 - .70$, $.71 - .90$, and $.91 - 1.00$ referring to non-informative, less accurate, moderately accurate, and perfect, respectively (Greiner, Pfeiffer, & Smith, 2000; Swets, 1988). In addition, the Youden index (*J*) is calculated for overall diagnostic accuracy. *J* is defined as the maximum of [sensitivity + specificity – 1], and provides the optimal cut-off values with the maximum difference between sensitivity and specificity (Schisterman, Perkins, Liu, & Bondell, 2005). The index can range between 0 and 1, with 1 indicating that the diagnostic test accurately predicted diagnostic group membership (i.e., no false positive or false negatives) and 0 indicating no predictive value.

Results

Table 2 displays the characteristics of the sample. Group comparisons revealed no differences in age and IQ between the ADHD and control group. As expected based on the higher rate of ADHD in boys, there were more boys in the ADHD group compared to the control group. Therefore, all analyses were re-run using groups

matched on age and sex (see Supplemental Material S1, Table A). Supporting the validity of our inclusion procedures, children in the ADHD group showed higher teacher and parent ratings of ADHD and ODD symptoms as compared to controls as assessed with the SWAN and DBDRS ODD-scale ($d = .99 - 4.59$, see Table 2). A total of 14 of 57 children (25%) in the ADHD group had a clinical diagnosis of ADHD as indicated by parents on the demographic questionnaire, and none of the children had a clinical diagnosis of ODD according to parental report. Based on the TTI scores, 26 children in the ADHD group (46%) showed clinical levels of ADHD symptoms and 2 children (4%) showed clinical levels of ODD symptoms.

-- Insert Table 2 about here --

Reliability

Inter-observer agreement was calculated for 24% of the observations on all four behavioral scales. Inter-observer agreement was on average 82.86% ($SD = 8.18$) for Attention Problems, 90.39% ($SD = 6.83$) for Motor Hyperactivity, 92.99% ($SD = 5.31$) for Verbal Hyperactivity, and 99.80% ($SD = .01$) for Oppositional Behavior.

Construct validity: Group comparisons

Multivariate multilevel results indicated that the ADHD group showed higher scores on the scales Attention Problems, Motor Hyperactivity, Verbal Hyperactivity (trend significant; effects only significant for % of time), and Oppositional Behavior compared to the control group (see Table 3), with small to (very) large effects. Univariate multilevel results showed that children in the ADHD group showed longer intervals of off-task behavior and shorter intervals of no motor hyperactivity compared to controls (medium to large effects). Further, children in the ADHD group showed more minor motor hyperactivity compared to controls (medium effect for percentage of time), but there were no group differences in levels of gross motor hyperactivity. Also verbal hyperactivity effects were only significant for the percentage of time: children in the ADHD group showed more verbally disruptive behavior than children in the control group (medium effect).

Sensitivity analyses in the groups matched on age and sex ($n = 27$ per group, with 17 boys and 10 girls per group) revealed approximately similar results. Effect sizes were identical to the results of the full sample (see Supplemental Material S1, Table A).

-- Insert Table 3 about here --

Construct validity: Convergent and divergent validity

Given that the largest group differences were found for percentage of time (compared to interval length, see Table 3), we have used this outcome for further validation analyses. Since groups did not differ in levels of gross motor hyperactivity, minor and gross motor hyperactivity were aggregated for further validity assessments

(i.e., some level of motor hyperactivity). Most behaviors on observational outcomes were skewed, except off-task behavior in the ADHD group. Given that distributions were visually inspected and outliers were winsorized, it was deemed appropriate to use Spearman correlations. Table 4 shows correlations of observed classroom behavior and teacher measures (i.e., rating scales and interview) of ADHD and ODD in the ADHD and control group.

For the ADHD group, convergent validity was confirmed for the GUCCI-NL Verbal Hyperactivity scale and for the Oppositional Behavior scale as validated against the teacher rated ODD-scale of the DBDRS (but not to the TTI ODD scale), although for Verbal Hyperactivity effects slightly failed to reach conventional levels of statistical significance ($p = .052$). Verbal Hyperactivity was not significantly related to the Inattention scale of the SWAN and TTI, providing support for divergent validity of this scale (although the differences in association of the Verbal Hyperactivity scale with SWAN and TTI Inattention and with SWAN and TTI Hyperactivity/Impulsivity were not statistically significant; $z = .95, p = .342$ and $z = 1.25, p = .211$ respectively). For the Oppositional Behavior scale, the correlations with the SWAN ADHD total scale was trend significant ($p = .061$), arguing against divergent validity (confirmed by a lack of statistical difference in association of the Oppositional Behavior scale with DBDRS and TTI ODD and with SWAN and TTI total ADHD; $z = .26, p = .795$ and $z = .24, p = .810$ respectively). Regarding the GUCCI- NL Attention Problems and Motor Hyperactivity scales, neither convergent nor divergent validity was confirmed in the ADHD group. For Motor Hyperactivity, there was a significant correlation with the Inattention scale of the TTI, but not with the Hyperactivity/Impulsivity scale of the TTI.

For the control group, none of the associations between the observational scales Attention Problems, Motor Hyperactivity and Verbal Hyperactivity and teacher ratings were significant. Convergent and divergent validity could thus not be confirmed for the control group. Since none of the children in the control group showed oppositional behavior during the observations, correlations were not calculated for this scale within this group.

-- Insert Table 4 about here --

Predictive validity

To examine to what extent the GUCCI-NL could accurately identify children as belonging to the ADHD or control group, ROC curves were calculated. Given that the largest group differences were found for percentage of time (compared to interval length) for Attention Problems, Motor (i.e., aggregated measure of minor and gross motor hyperactivity) and Verbal Hyperactivity, we have used these outcomes for the ROC analysis. Results showed that the GUCCI-NL coding system was moderately accurate in predicting group membership (ADHD or control) based on coding of Attention Problems. For Motor Hyperactivity, Verbal Hyperactivity and

Oppositional Behavior the ROC curve is showing a less accurate fit, see Figure 1. Table 5 provides an overview of the *AUC*, *J*, and optimal cut-off values for sensitivity and specificity.

-- Insert Figure 1 about here --

-- Insert Table 5 about here --

Discussion

To gain more insight into subtle patterns in ADHD behavior, such as lapses of attention and varying levels of hyperactivity, structured classroom coding inventories for ADHD related behaviors using continuous sampling are needed. Although there is one recently developed continuous coding measure, the GUCCI (Imeraj et al., 2016; Imeraj et al., 2013), this measure has not been validated yet. This study investigated the psychometric properties of the Dutch adjusted version of the GUCCI observation instrument (GUCCI-NL). We were able to achieve sufficient inter-observer reliability levels for all scales ($r > .82$). The instrument was able to discriminate between children with (subthreshold) ADHD and typically developing peers with small to (very) large effects, confirming construct validity for all scales, in particular on the percentage of time children displayed these behaviors. Convergent validity was confirmed for the scales Verbal Hyperactivity and Oppositional Behavior in the ADHD group, but divergent validity of the GUCCI in terms of discrimination between ADHD subscales was weak. There were indications for the convergent validity of the Attention Problems scale in the control group. The Attention Problems scale was most sensitive to group membership with moderately accurate discriminative properties ($AUC = .79$) supporting its predictive validity, whereas the other scales showed less accurate discriminative abilities ($AUC < .70$).

By using continuous sampling, we were able to investigate differences between the ADHD and control group regarding both percentage of time behavior occurred and the average length of such intervals. Our results showed that children with (subthreshold) ADHD were approximately 71% of the time on-task, compared to 86% for controls, which is similar to group differences obtained with other observational instruments (Kofler et al., 2008; Lauth, Heubeck, & Mackowiak, 2006). Regarding hyperactivity, both groups showed more motor hyperactivity than verbal hyperactivity, and children in the ADHD group showed the behaviors more frequently in the classroom (35% and 9% of the observed time, respectively) than typically developing peers (25% and 5%, respectively). Further, our results show added value of continuous sampling: For hyperactivity, children with (subthreshold) ADHD show more hyperactivity than controls when looking at percentage of time (i.e., minor motor movements and verbal hyperactivity), but the length of the intervals did not differ between groups, suggesting a larger number of shifts between hyperactive and non-hyperactive behavior. Whereas hyperactive behavior can be intrusive and may have a negative impact on functional outcomes such as academic performance, incidental motor behavior may also have a functional role for children with (subthreshold) ADHD

to counteract their inattention (Rapport et al., 2009a; Sarver, Rapport, Kofler, Raiker, & Friedman, 2015). Our findings indicate that children with (subthreshold) ADHD show (short) moments of movements leading to frequent shifts between hyperactive and non-hyperactive behavior. Whether these bursts of hyperactivity actually lead to more or less on-task behavior, needs to be confirmed in experimental studies (e.g., see Antrop, Buysse, Roeyers, & Van Oost, 2005). For off-task behavior, both the percentage of time and length of interval were larger for children in the ADHD group compared to controls. More specifically, time on-task was on average eight seconds shorter in children with (subthreshold) ADHD than controls, likely reflecting their difficulties staying focused. Clearly our results show differences in the amount of time children show off-task behavior, motor and verbal hyperactivity, as well as the length of their off-task intervals are suited to discriminate between children with (subthreshold) ADHD and their peers.

Besides investigating percentage of time behavior occurred and interval length, we differentiated between severity levels of motor hyperactivity (i.e., minor and gross motor hyperactivity). Results showed that groups differed only on percentage of time they displayed minor motor hyperactivity but not on gross motor hyperactivity. One may argue that teachers may not tolerate gross motor movements, and thus that children in the ADHD group have successfully adjusted their behavior in response to these rules. Another explanation may be that our sample consisted of predominantly children with subthreshold levels of ADHD, wherefore ADHD behaviors (and differences with typically developing peers) may be less pronounced than in a fully clinical sample.

Despite group differences on most of the GUCCI-NL scales, only the Attention Problems scale of the GUCCI-NL is sensitive and specific enough to accurately differentiate between children in the ADHD and control group, whereas the observational scales for Motor and Verbal Hyperactivity and Oppositional Behavior are less suitable as shown by the ROC-curves. Also in earlier studies, off-task behavior was most accurate in discriminating between children with (subthreshold) ADHD and controls (Abikoff, Gittelman-Klein, & Klein, 1977; Abikoff, Gittelman, & Klein, 1980). Possibly, classroom rules regarding hyperactive and disruptive behaviors (e.g., remaining seated and working quietly during individual assignments) may have compromised these behaviors, while off-task behavior may be more difficult or less of a target for teachers to regulate. For oppositional behavior, the lack of discriminative power may also be explained by the limited variance (see Table 3) that may be explained by our sample comprised of predominantly of children with subthreshold levels of ADHD with few symptoms of ODD. Nevertheless, our study shows that children with (subthreshold) ADHD predominantly deviate from peers on observed attention problems, which is not observed in a similar manner when this is assessed using rating scales or interview. Since attention problems are difficult to observe for teachers (Poznanski et al., 2018), this finding is important for investigating (treatment effects on) ADHD symptoms in the classroom.

Correlations between the GUCCI-NL scales and both teacher ratings and clinical interview scores assessing the same constructs were (very) small to moderate: convergent validity could only be confirmed for the observational scales Verbal Hyperactivity and Oppositional Behavior. There was some evidence for divergent validity for the Verbal Hyperactivity scale. The validity findings for the Verbal Hyperactivity scale of the GUCCI-NL when compared to teacher rating scales are in line with other classroom observation systems included in a recent meta-analysis (Staff et al., 2020a). For Oppositional Behavior, convergent validity was established when validated against a teacher rating scale but not against a clinical interview. This is likely to be explained by the higher distribution of scores on the ODD scale of the rating scale. Nevertheless, both convergent and divergent validity of the GUCCI-NL were weak for the Attention Problems and Motor Hyperactivity scales, whilst these scales reflect core ADHD symptoms. These findings suggest that observed Attention Problems and Motor Hyperactivity measure different aspects of behavior in comparison to rating scales or interviews. However, weak divergent validity of the observational scales has been found for many observational instruments (see Staff et al., 2020a) and is partly explained by the high correlation between symptom domains of ADHD (Willcutt et al., 2012), that cannot be judged fully in isolation (see for a detailed discussion: Staff et al., 2020a). In addition, we compared observed motor and verbal hyperactivity but not impulsivity to combined hyperactivity/impulsivity scales of a teacher rating scale and clinical interview. Although impulsivity is partially taking into account when scoring motor and verbal hyperactivity (e.g., blurring out an answer, standing up without permission), this may have contributed to the lower correlations between the measures.

Based on the current findings, the GUCCI-NL appeared to be a masked measure that allows assessment of classroom ADHD symptoms as it is able to reliably discriminate between children with (subthreshold) ADHD and controls, especially for the Attention Problems scale. The fine-grained nature of continuous coding provides possibilities to assess subtle aspects of behaviors such as time on-task (e.g., lapses of attention, shifts in behavior), and enables us to use such an instrument for scientific purposes, for example, to assess treatment effects by independent raters in clinical trials. In addition to frequency of occurrence, length of time intervals (and indirectly the frequency of shifts in behavior) can be observed in detail and may add to future research into the functional role of behavior (e.g., incidental motor movements to increase attention) (Rapport, Kofler, Alderson, Timko Jr, & DuPaul, 2009b; Sarver et al., 2015). The diagnostic utility of the current observation instrument in the ability to discriminate between the two symptom domains of ADHD appears limited. Our findings suggest that different instruments (observations versus rating scales/interviews) may be used for different purposes (i.e., (more) objective assessment of treatment effects versus diagnostic purposes). Given that teacher rating scales and clinical interviews assess behavior over a longer period of time (i.e., the past six months), these may provide information regarding patterns in behavior and its antecedents, which is important

for diagnostic purposes. However, observations may be of added value in clinical practice for specific purposes such as the child's ability to stay focused during lessons or when parents and teachers disagree on the child's functioning.

Despite the strengths of the current study, there are limitations to note. First, classroom observations were conducted on one day based on the assumption that differences between children with and without ADHD in observed classroom behavior do not depend on time of day (Antrop, Roeyers, & De Baecke, 2005). However, a recent meta-analysis showed that correlations between classroom observations and teacher ratings are higher when observations are conducted on multiple days (Staff et al., 2020a). Second, impulsive behavior was not included in the coding scheme. In line with earlier work on other coding schemes (Volpe et al., 2005), impulsivity is difficult to observe since it often depends on existing (classroom) rules such as raising hand before answering a question. We can therefore not conclude on differences in observed impulsivity in children with and without ADHD symptoms with the GUCCI-NL.

It can be concluded that the GUCCI-NL is well able to discriminate between children with (subthreshold) ADHD and typically developing peers, with the strongest discriminative abilities for the Attention Problems scale and strong convergent validity for the Verbal Hyperactivity and Oppositional Behavior scales. This scale may be of scientific value when objective evaluation of classroom behavior and/or treatment effects is needed.

Supplemental Material

S1. Table A. Group comparisons on observational scales in groups matched on sex and age

References

- Abikoff, H., & Gittelman, R. (1985). Classroom observation code-a modification of the Stony-Brook code. *Psychopharmacology Bulletin*, 21(4), 901-909.
- Abikoff, H. B., Courtney, M., Pelham, W. E., & Koplewicz, H. S. (1993). Teachers' ratings of disruptive behaviors: The influence of halo effects. *Journal of Abnormal Child Psychology*, 21(5), 519-533.
- Abikoff, H. B., Gittelman-Klein, R., & Klein, D. F. (1977). Validation of a classroom observation code for hyperactive children. *Journal of consulting and clinical psychology*, 45(5), 772.
- Abikoff, H. B., Gittelman, R., & Klein, D. F. (1980). Classroom observation code for hyperactive children: A replication of validity. *Journal of consulting and clinical psychology*, 48(5), 555.
- Abikoff, H. B., Jensen, P. S., Arnold, L. E., Hoza, B., Hechtman, L., Pollack, S., . . . Hinshaw, S. (2002). Observed classroom behavior of children with ADHD: Relationship to gender and comorbidity. *Journal of Abnormal Child Psychology*, 30(4), 349-359.
- Achenbach, T. (1986). The Direct Observation Form of the Child Behavior Checklist (rev. ed.). Burlington: University of Vermont. *Research Center for Children, Youth, & Families*.
- American Academy of Pediatrics. (2011). ADHD: clinical practice guideline for the diagnosis, evaluation, and treatment of attention-deficit/hyperactivity disorder in children and adolescents. *Pediatrics*, 128(5), 1007.
- American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). Washington, DC.
- Antrop, I., Buysse, A., Roeyers, H., & Van Oost, P. (2005). Activity in children with ADHD during waiting situations in the classroom: A pilot study. *British Journal of Educational Psychology*, 75(1), 51-69.
- Antrop, I., Roeyers, H., & De Baecke, L. (2005). Effects of time of day on classroom behaviour in children with ADHD. *School Psychology International*, 26(1), 29-43.
- Association, W. M. (2013). WMA Declaration of Helsinki-Ethical principles for medical research involving human subjects. In: Fortaleza, Brazil.
- Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2011). *Introduction to meta-analysis*: John Wiley & Sons.
- Burns, G. L., Gomez, R., Walsh, J. A., & de Moura, M. A. (2003). Understanding source effects in ADHD rating scales: Reply to DuPaul (2003).
- Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*: Routledge.
- Daley, D., & Birchwood, J. (2010). ADHD and academic performance: why does ADHD impact on academic performance and what can be done to support ADHD children in the classroom? *Child: care, health and development*, 36(4), 455-464. doi:10.1111/j.1365-2214.2009.01046.x

- Daley, D., Van der Oord, S., Ferrin, M., Danckaerts, M., Doepfner, M., Cortese, S., . . . Group, E. A. G. (2014). Behavioral interventions in attention-deficit/hyperactivity disorder: a meta-analysis of randomized controlled trials across multiple outcome domains. *Journal of the American Academy of Child & Adolescent Psychiatry*, 53(8), 835-847. e835. doi:10.1016/j.jaac.2014.05.013
- Diepenmaat, A., Van Eijnsden, M., Janssens, J., Loomans, E., & Stone, L. (2014). Verantwoording SDQ Leerkrachtenvragenlijst. Voor gebruik binnen het onderwijs en in de zorg. GGD Amsterdam.
- Fabiano, G. A., Pelham, J., William E, Waschbusch, D. A., Gnagy, E. M., Lahey, B. B., Chronis, A. M., . . . Burrows-MacLean, L. (2006). A practical measure of impairment: Psychometric properties of the impairment rating scale in samples of children with attention deficit hyperactivity disorder and two school-based samples. *Journal of Clinical Child and Adolescent Psychology*, 35(3), 369-385.
- Gomez, R., Burns, G. L., Walsh, J. A., & De Moura, M. A. (2003). Multitrait-multisource confirmatory factor analytic approach to the construct validity of ADHD rating scales. *Psychological Assessment*, 15(1), 3.
- Goodman, R. (1997). The Strengths and Difficulties Questionnaire: A research note. *Journal of Child Psychology and Psychiatry*, 38(5), 581-586.
- Greiner, M., Pfeiffer, D., & Smith, R. (2000). Principles and practical application of the receiver-operating characteristic analysis for diagnostic tests. *Preventive veterinary medicine*, 45(1-2), 23-41.
- Hum, M. (2004). *Psychometric properties of a teacher semi-structured interview for childhood externalizing disorders*: University of Toronto.
- Imeraj, L., Antrop, I., Roeyers, H., Deboutte, D., Deschepper, E., Bal, S., & Sonuga-Barke, E. (2016). The impact of idle time in the classroom: Differential effects on children with ADHD. *Journal of attention disorders*, 20(1), 71-81.
- Imeraj, L., Antrop, I., Sonuga-Barke, E., Deboutte, D., Deschepper, E., Bal, S., & Roeyers, H. (2013). The impact of instructional context on classroom on-task behavior: A matched comparison of children with ADHD and non-ADHD classmates. *Journal of school psychology*, 51(4), 487-498.
- Junod, R. E. V., DuPaul, G. J., Jitendra, A. K., Volpe, R. J., & Cleary, K. S. (2006). Classroom observations of students with and without ADHD: Differences across types of engagement. *Journal of school psychology*, 44(2), 87-104.
- Kirova, A.-M., Kelberman, C., Storch, B., DiSalvo, M., Woodworth, K. Y., Faraone, S. V., & Biederman, J. (2019). Are subsyndromal manifestations of attention deficit hyperactivity disorder morbid in children? A systematic qualitative review of the literature with meta-analysis. *Psychiatry research*, 274, 75-90.
- Kofler, M. J., Rapport, M. D., & Matt Alderson, R. (2008). Quantifying ADHD classroom inattentiveness, its moderators, and variability: a meta-analytic review. *Journal of Child Psychology and Psychiatry*, 49(1), 59-69.

- Lauth, G. W., Heubeck, B., & Mackowiak, K. (2006). Observation of children with attention-deficit hyperactivity (ADHD) problems in three natural classroom contexts. *British Journal of Educational Psychology*, 76(2), 385-404.
- Minder, F., Zuberer, A., Brandeis, D., & Drechsler, R. (2018). A review of the clinical utility of systematic behavioral observations in Attention Deficit Hyperactivity Disorder (ADHD). *Child Psychiatry & Human Development*, 49(4), 572-606.
- Oosterlaan, J., Scheres, A., Antrop, I., Roeyers, H., & Sergeant, J. (2008). *Vragenlijst voor Gedragsproblemen bij Kinderen van 6 tot en met 16 jaar: Handleiding [Questionnaire on behavioral problems in children aged 6-16]*. Amsterdam: Hartcourt Publishers.
- Parker, A., & Corkum, P. (2016). ADHD diagnosis: as simple as administering a questionnaire or a complex diagnostic process? *Journal of attention disorders*, 20(6), 478-486.
- Platzman, K. A., Stoy, M. R., Brown, R. T., Coles, C. D., Smith, I. E., & Falek, A. (1992). Review of observational methods in attention deficit hyperactivity disorder (ADHD): Implications for diagnosis. *School Psychology Quarterly*, 7(3), 155.
- Polanczyk, G. V., Willcutt, E. G., Salum, G. A., Kieling, C., & Rohde, L. A. (2014). ADHD prevalence estimates across three decades: an updated systematic review and meta-regression analysis. *International journal of epidemiology*, 43(2), 434-442.
- Poznanski, B., Hart, K. C., & Cramer, E. (2018). Are teachers ready? Preservice teacher knowledge of classroom management and ADHD. *School Mental Health*, 10(3), 301-313.
- Rapport, M. D., Bolden, J., Kofler, M. J., Sarver, D. E., Raiker, J. S., & Alderson, R. M. (2009a). Hyperactivity in boys with attention-deficit/hyperactivity disorder (ADHD): a ubiquitous core symptom or manifestation of working memory deficits? *Journal of Abnormal Child Psychology*, 37(4), 521-534.
- Rapport, M. D., Kofler, M. J., Alderson, R. M., Timko Jr, T. M., & DuPaul, G. J. (2009b). Variability of attention processes in ADHD: Observations from the classroom. *Journal of attention disorders*, 12(6), 563-573.
- Sarver, D. E., Rapport, M. D., Kofler, M. J., Raiker, J. S., & Friedman, L. M. (2015). Hyperactivity in attention-deficit/hyperactivity disorder (ADHD): Impairing deficit or compensatory behavior? *Journal of Abnormal Child Psychology*, 43(7), 1219-1232.
- Sattler, J. M. (2008). *Resource guide to accompany assessment of children: Cognitive foundations*. La Mesa, CA: JM Sattler.
- Schisterman, E. F., Perkins, N. J., Liu, A., & Bondell, H. (2005). Optimal cut-point and its corresponding Youden Index to discriminate individuals using pooled blood samples. *Epidemiology*, 73-81.

- Shapiro, E. (2004). Direct observation: manual for the Behavioral Observation of Students in Schools (BOSS).
Bloomington, MN: Pearson.
- Sonuga-Barke, E. J., Brandeis, D., Cortese, S., Daley, D., Ferrin, M., Holtmann, M., . . . Döpfner, M. (2013).
Nonpharmacological interventions for ADHD: systematic review and meta-analyses of randomized
controlled trials of dietary and psychological treatments. *American journal of psychiatry*, 170(3), 275-
289.
- Staff, A. I., Oosterlaan, J., van der Oord, S., Hoekstra, P. J., Vertessen, K., de Vries, R., . . . Luman, M. (2020a).
The Validity of Teacher Rating Scales for the Assessment of ADHD Symptoms in the Classroom: A
Systematic Review and Meta-Analysis. *Journal of attention disorders*, 0(0).
doi:10.1177/1087054720916839
- Staff, A. I., Van Den Hoofdakker, B. J., Van der Oord, S., Hornstra, R., Hoekstra, P. J., Twisk, J. W. R., . . .
Luman, M. (2020b). Effectiveness of specific techniques in behavioral teacher training for childhood
ADHD: A randomized controlled microtrial. *Journal of Clinical Child & Adolescent Psychology*.
doi:10.1080/15374416.2020.1846542
- Swanson, J. M., Schuck, S., Porter, M. M., Carlson, C., Hartman, C. A., Sergeant, J. A., . . . Lakes, K. (2012).
Categorical and dimensional definitions and evaluations of symptoms of ADHD: history of the SNAP
and the SWAN rating scales. *The International Journal of Educational and Psychological Assessment*,
10(1), 51-70.
- Swets, J. A. (1988). Measuring the accuracy of diagnostic systems. *Science*, 240(4857), 1285-1293.
- Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics* (Vol. 5): Pearson Boston,
MA.
- Tannock, R., Hum, M., Masellis, M., Humphries, T., & Schachar, R. (2002). *Teacher telephone interview for
children's academic performance, attention, behavior and learning: DSM-IV Version (TTI-IV)*.
Toronto: The Hospital for Sick Children.
- Volpe, R. J., DiPerna, J. C., Hintze, J. M., & Shapiro, E. S. (2005). Observing students in classroom settings: A
review of seven coding schemes. *School Psychology Review*, 34(4), 454-474.
- Wechsler, D., Kort, W., & Compaan, E. (2005). WISC-III NL. *Wechsler Intelligence Scale for Children. Derde
editie NL. Handleiding en Verantwoording. London/Amsterdam: The Psychological
Corporation/Nederlands Dienstencentrum NIP.*
- Wilens, T. E., Biederman, J., Brown, S., Tanguay, S., Monuteaux, M. C., Blake, C., & Spencer, T. J. (2002).
Psychiatric comorbidity and functioning in clinically referred preschool children and school-age youths
with ADHD. *Journal of the American Academy of Child & Adolescent Psychiatry*, 41(3), 262-268.

- Willcutt, E. G., Nigg, J. T., Pennington, B. F., Solanto, M. V., Rohde, L. A., Tannock, R., . . . Lahey, B. B. (2012). Validity of DSM-IV attention deficit/hyperactivity disorder symptom dimensions and subtypes. *Journal of Abnormal Psychology, 121*(4), 991.
- Zimmerman, P. H., Bolhuis, J. E., Willemsen, A., Meyer, E. S., & Noldus, L. P. (2009). The Observer XT: A tool for the integration and synchronization of multimodal signals. *Behavior research methods, 41*(3), 731-735.

Table 1. Operational definitions of observed behaviors

Scale	Levels of behavior (coding category)	Description	Metric
Attention Problems	On-task	The child is involved in activities that are expected by the teacher (e.g., paying visual attention to task or to the teacher), and is following teacher's instructions and requests.	
	Off-task	The child is involved in activities that are not expected by the teacher (e.g., not working on assignments, daydreaming).	% of time; mean interval length
Motor Hyperactivity	No motor hyperactivity	The child remains seated. Small, but not disturbing, movements of arms, hands, feet or legs are observed.	% of time; mean interval length
	Minor motor hyperactivity	The child is not sitting still on the chair (e.g., overturns or swings the chair, squirms in chair). The child shows small movements that are annoying or disturbing peers (e.g., tapping with a pen, pricking neighbor with a finger).	% of time; mean interval length
	Gross motor hyperactivity	The child is not sitting on the chair (e.g., standing up without permission, sitting on their knees) or is walking or running through the classroom.	% of time; mean interval length
Verbal Hyperactivity	No verbal hyperactivity	The child is quiet, or the child talks in reaction to the teacher's request.	
	Verbal hyperactivity	The child is talking or making vocal sounds (e.g., whispering to self, humming), or talks to a peer regardless of whether this is allowed by the teacher (e.g., working in small groups).	% of time; mean interval length
Oppositional Behavior	No oppositional behavior	The child does not show any oppositional behavior, anger, aggression or antisocial behavior against others.	
	Oppositional behavior	The child shows oppositional behavior against another child or the teacher (e.g., refuses something). The child shows angry behavior (e.g., shows tantrum).	Frequency

Table 2. Sample characteristics

	ADHD (<i>n</i> = 57)	Control (<i>n</i> = 34)	Group comparisons
Age at assessment in years	8.52 (1.31)	8.76 (1.54)	$t(89) = -.78, p = .438, d = .17$
Sex, <i>n</i> (%) boys	46 (80.7)	17 (50.0)	$\chi^2(1) = 9.42, p = .002, V = .32$
IQ	99.86 (11.68)	105.20 (15.21)	$t(85) = -1.82, p = .072, d = .41$
TTI symptom severity			
Inattention	4.54 (1.71)		
Hyperactivity/Impulsivity	3.98 (2.10)		
ODD	.91 (1.24)		
IRS impairment			
Number of domains	3.19 (.96)		
Teacher ratings			
SWAN			
Inattention	15.00 (4.71)	-11.71 (7.34)	$t(49.43) = 21.15, p < .001, d = 4.59$
Hyperactivity/Impulsivity	14.33 (6.09)	-12.29 (7.95)	$t(56.12) = 16.82, p < .001, d = 3.89$
DBDRS symptom severity			
ODD	7.23 (5.45)	.50 (.93)	$t(61.34) = 9.10, p < .001, d = 1.54$
Parent ratings ^a			
SWAN			
Inattention	6.98 (7.65)	-9.55 (8.43)	$t(84) = 9.37, p < .001, d = 2.08$
Hyperactivity/Impulsivity	8.98 (7.09)	-11.64 (8.82)	$t(57.22) = 11.34, p < .001, d = 2.65$
DBDRS			

ODD	5.89 (4.12)	2.45 (1.92)	$t(83.51) = 5.33, p < .001, d = .99$
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Note. *M* and *SD* are depicted unless otherwise stated.

ADHD = Attention-Deficit/Hyperactivity Disorder; DBDRS = Disruptive Behavior Disorders Rating Scale; IRS = Impairment Rating Scale; ODD = oppositional defiant disorder; SDQ = Strengths and Difficulties Questionnaire; SWAN = Strengths and Weaknesses of ADHD and Normal Behavior; TTI = Teacher Telephone Interview.

^aTwo parents (<5%) did not complete the questionnaires (one in the ADHD group, one in the control group)

Table 3. Group differences on observation scales.

		ADHD (<i>n</i> = 57)	Control (<i>n</i> = 34)	Multivariate effect ^a	Univariate effect ^a
Off-task ^b	% of time	28.64 (14.64)	13.99 (10.91)	$B = -.83, SE = .15, p < .001$	$B = -.94, SE = .17, p < .001$
	Interval length	24.58 (11.37)	16.24 (8.83)		$B = -.72, SE = .17, p < .001$
No motor hyperactivity ^b	% of time	64.70 (18.94)	74.80 (20.45)	$B = .62, SE = .14, p < .001^e$	$B = .52, SE = .18, p = .004$
	Interval length	97.67 (71.08)	276.54 (393.71)		$B = .71, SE = .18, p < .001$
Minor motor hyperactivity ^c	% of time	11.95 (7.90)	7.25 (8.64)	$B = -.22, SE = .14, p = .133^f$	$B = -.56, SE = .21, p = .009$
	Interval length	19.73 (14.90)	19.50 (22.96)		$B = -.04, SE = .21, p = .954$
Gross motor hyperactivity ^c	% of time	23.36 (17.08)	17.95 (16.80)	$B = -.31, SE = .18, p = .092$	$B = -.32, SE = .21, p = .137$
	Interval length	70.68 (55.66)	71.80 (85.28)		$B = .02, SE = .21, p = .938$
Verbal hyperactivity ^c	% of time	8.80 (6.85)	5.11 (5.30)	$B = -.31, SE = .18, p = .092$	$B = -.57, SE = .21, p = .008$
	Interval length	5.14 (3.39)	4.98 (3.40)		$B = -.04, SE = .21, p = .823$
Oppositional behavior ^d	<i>k</i>	.84 (2.09)	.00 (.00)		$B = -.37, SE = .18, p = .036$

Note. *M* and *SD* are depicted. Interval length is the mean duration of an interval in seconds.

^a Effect size (Cohen's *d*) is equal to *B*.

^b Levels child and teacher were included in the model.

^c Level child was included in the model.

^d Level school was included in the model

^e Multivariate ANOVA including no motor hyperactivity versus an aggregated measure of minor and gross motor hyperactivity

^f Multivariate ANOVA including minor motor hyperactivity versus gross motor hyperactivity

Table 4. Convergent and divergent validity of the GUCCI-NL scales for classroom observations for the ADHD (*n* = 57) and control group (*n* = 34)

GUCCI-NL scale	Convergent validity measure	Correlation coefficient (ρ)	Divergent validity measure	Correlation coefficient (ρ)
<i>ADHD group</i>				
Attention Problems %	SWAN IN	.005	SWAN H/I	.113
	TTI IN	.004	TTI H/I	.190
Motor Hyperactivity %	SWAN H/I	.006	SWAN IN	-.032
	TTI H/I	.191	TTI IN	.279*
Verbal Hyperactivity %	SWAN H/I	.259 ^a	SWAN IN	.082
	TTI H/I	.281*	TTI IN	.049
Oppositional Behavior <i>k</i>	DBDRS ODD	.296*	SWAN ADHD	.250 ^a
	TTI ODD	.227 ^a	TTI ADHD	.183
<i>Control group</i>				
Attention Problems %	SWAN IN	.176	SWAN H/I	.293

Motor Hyperactivity %	SWAN H/I	.244	SWAN IN	.101
Verbal Hyperactivity %	SWAN H/I	.093	SWAN IN	.019
Oppositional Behavior <i>k</i>	DBDRS ODD	n.a.	SWAN ADHD	n.a.

Note. DBDRS = Disruptive Behavior Disorders Rating Scale; H/I = Hyperactivity/Impulsivity scale; IN = Inattention scale; n.a. = not applicable; ODD = Oppositional Defiant Disorder; SWAN = Strengths and Weaknesses of ADHD and Normal Behavior; TTI = Teacher Telephone Interview.

* $p < .05$

^a $p < .10$

Table 5. Predictive validity statistics for the GUCCI-NL scales based on ROC-curves.

	<i>AUC</i>	<i>J</i>	Sensitivity (%)	Specificity (%)
Attention Problems	.79	.51	71	81
Motor Hyperactivity	.66	.38	59	79
Verbal Hyperactivity	.68	.33	68	65
Oppositional Behavior	.61	.23	100	23

Note. *AUC* = Area Under the Curve; *J* = Youden index.

Figure 1. Sensitivity and specificity of the GUCCI-NL scales, as expressed in ROC-curves. $N = 91$.

Supplemental Material

Table A. Group comparisons on observational scales in groups matched on sex and age

		ADHD (<i>n</i> = 27)	Control (<i>n</i> = 27)	Multivariate effect ^a	Univariate effect ^a
Off-task ^b	% of time	29.90 (14.41)	14.69 (11.59)	<i>B</i> = -.91, <i>SE</i> = .18, <i>p</i> < .001	<i>B</i> = -1.04, <i>SE</i> = .21, <i>p</i> < .001
	Interval length	25.42 (11.11)	17.15 (9.41)		<i>B</i> = -.77, <i>SE</i> = .21, <i>p</i> < .001
No motor hyperactivity ^b	% of time	65.55 (17.15)	76.94 (17.70)	<i>B</i> = .70, <i>SE</i> = .20, <i>p</i> < .001 ^g	<i>B</i> = .64, <i>SE</i> = .25, <i>p</i> = .011
	Interval length	94.96 (61.30)	273.13 (419.00)		<i>B</i> = .75, <i>SE</i> = .25, <i>p</i> = .003
Minor motor hyperactivity ^c	% of time	12.13 (7.20)	5.71 (6.89)	<i>B</i> = -.37, <i>SE</i> = .15, <i>p</i> = .014 ^h	<i>B</i> = -.76, <i>SE</i> = .25, <i>p</i> = .002
	Interval length	20.19 (16.43)	15.25 (14.50)		<i>B</i> = -.27, <i>SE</i> = .25, <i>p</i> = .278
Gross motor hyperactivity ^c	% of time	22.32 (16.33)	17.35 (15.28)		<i>B</i> = -.29, <i>SE</i> = .25, <i>p</i> = .245
	Interval length	77.28 (54.12)	67.58 (89.81)		<i>B</i> = -.14, <i>SE</i> = .25, <i>p</i> = .567
Verbal hyperactivity ^c	% of time	9.53 (7.66)	5.41 (5.81)	<i>B</i> = -.33, <i>SE</i> = .24, <i>p</i> = .171	<i>B</i> = -.63, <i>SE</i> = .28, <i>p</i> = .025
	Interval length	5.05 (3.44)	4.96 (3.71)		<i>B</i> = -.03, <i>SE</i> = .28, <i>p</i> = .928
Oppositional behavior ^d	<i>k</i>	.93 (2.45)	.00 (.00)		<i>B</i> = -.34, <i>SE</i> = .18, <i>p</i> = .050

Note. *M* and *SD* are depicted. Interval length is the mean duration of an interval in seconds.

^a Effect size (Cohen's *d*) is equal to *B*.

^b Levels child and teacher were included in the model.

^c Level child was included in the model.

^d Level school was included in the model

^e Multivariate ANOVA including no motor hyperactivity versus an aggregated measure of minor and gross motor hyperactivity

^f Multivariate ANOVA including minor motor hyperactivity versus gross motor hyperactivity