Europe's Journal of Psychology, 7(3), pp. 443-457
www.ejop.org

In search for objective measures of hyperactivity, impulsivity and inattention in adult attention deficit hyperactivity disorder using the Quantified Behavior Test Plus

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Abstract
Clinical assessment tools for adult attention deficit hyperactivity disorder (ADHD) such as rating scales, interviews and behavior observations are often based on subjective judgments which enhance the risk of overlooking or misinterpreting symptoms. In search for objective measures of adult ADHD, the present study investigated levels of sensitivity and specificity for the Quantified Behavior Test Plus, QbTest-Plus, in adult patients (*N* = 19) awaiting clinical assessment for ADHD. QbTest-Plus report objective measures of ADHD core symptoms using an infrared motion tracking system and a continuous performance test. The measures were collected and evaluated previous to clinical assessment and compared regarding the diagnosis of ADHD. Sensitivity for detecting ADHD with QbTest-Plus was 83 % and specificity was 57 %. The results, possibly affected by confounding factors, suggest further examination of calibrated and objective measure for the QbTest-Plus with regard to ADHD in adults.

Keywords: attention deficit hyperactivity disorder, objective measures, clinical assessment, adults, the quantified behavior test plus.

Introduction

The neurobiological developmental disorder Attention Deficit Hyperactivity Disorder (ADHD) occurs in about 2.5 percent of the adult population (Simon, Czobor, Bálint, Meszaros, & Bitter, 2009) and includes core symptoms of hyperactivity, impulsivity and inattention as described in the Diagnostic and Statistical Manual of Mental Disorders IV, DSM-IV (American Psychiatric Association, 2000). Past occurrence, current severity and the levels of malfunctioning that the symptoms impose on the patients´ everyday life are critical aspects of the diagnostic assessment (American Psychiatric Association, 2000).

Assessment tools such as rating scales, clinical interviews and behavior observations are often based on subjective perception, second-hand information and the enhanced risk of overlooking or misinterpreting symptoms of adult ADHD which is reflected in unclear validity and weak inter-rater reliability (Gordon, Barkley, & Lovett, 2006). There are few scientifically verified methodologies developed specifically for adults with ADHD but instead, the examiner will decide as to which neuropsychological tests to perform and how to interpret the results from the perspective of ADHD in adulthood and its differential diagnoses. Except for cognitive tests, objective and experimental measures of behavior symptoms may be performed. However, the few tests available for this purpose (Gordon, et al., 2006) have not been standardized satisfactorily for adults. Initially, the same neuropsychological procedures performed in childhood was adopted for ADHD in adulthood but over the years, a better understanding of developmental aspects as reflected in ceiling effects and low predictive values of psychometric tests have been supporting age-dependent and performance-based testing of the disorder.

Also, diagnostic assessment of ADHD in adulthood is oftentimes complicated by comorbid psychiatric disorders, non-specific core diagnostic characteristics of ADHD and the prevalent diagnostic criterias that are developed with regard to symptom manifestations during childhood (Kaplan & Stevens, 2002). Studies of clinic-referred adults with ADHD report enhanced risks of developing lifelong comorbid psychopathology including for example mood, substance abuse, antisocial, conduct and eating disorders of which some are likely to be secondary to ADHD-failure and frustration, which altogether makes objective assessment a complex and critical part of the clinical evaluation of ADHD in adulthood (Barkley, Fischer, Smallish, & Fletcher, 2002; Davidson, 2008; McGough *et al.,* 2005; Murphy, Barkley, & Bush, 2002)

The continuous performance paradigm

Objective measures of ADHD-core symptoms have been conducted with primary reference to children with the disorder, and less so with regard to the symptom manifestation in adults. Using for example Continuous Performance Tests (CPT) of cognitive core symptoms, e.g., inattention and impulsivity, children (Grodzinsky & Barkley, 1999; Teicher, Ito, Glod, & Barber, 1996) and adults (Ossman & Mulligan, 2003; Weyandt, Mitzlaff, & Thomas, 2002) with ADHD tend to display higher rates of errors related to cognitive deficits, i.e., omission and commission errors, relative to clinical (Downey, Stetson, Pomerleau, & Giordani, 1997; Seidman, Biederman, Faraone, Weber, & Ouellette, 1997) and normative controls (Murphy, Barkley, & Bush, 2001; Nigg *et al.,* 2005). CPT measures also provide effective treatment monitoring of stimulants (Epstein *et al.,* 2006; Konrad, Gunther, Hanisch, & Herpertz-Dahlman, 2004) and other treatment strategies (Klingberg, Forssberg, & Westerberg, 2002). However, a ceiling effect for adult subjects with ADHD has been suggested and especially when symptoms are less severe (Koelega, 1993), and there is a general lack of specificity with regard to clinical controls and cognitive symptom domains of adult ADHD (Epstein, Johnson, Varia, & Conners, 2001).

Objective measures of hyperactivity

For the motor domain of the disorder, i.e., hyperactivity, portable electronic activity monitors so called actigraphs and motion tracking systems (MTS) have been applied for detection of ADHD symptomathology in natural and laboratory settings of children, adolescents and to some extent also adults (Brocki, Tillman, & Bohlin, 2010; Halperin, Matier, Bedi, Sharma, & Newcorn, 1992; Halperin, Newcorn, Matier, Sharma, McKay, & Schwartz, 1993; Porrino, Rapoport, Behar, Sceery, Ismond, & Bunney, 1983). Successful monitoring of stimulant treatment effects (Vogt & Williams, 2011; Tabori-Kraft, Sørensen, Dalsgaard, Kœrgaard, & Thomsen, 2007), and associations between striatal dopamine markers and motor hyperactivity in male adolescents with ADHD has been reported (Jucaite, Fernell, Halldin, Forssberg, & Farde, 2005). Motor-signs in children with ADHD include 25-30 % higher activity levels, less complex but more linear movement patterns and especially during academic and laboratory-based tasks of attention as compared to healthy controls (Losier, McGrath, & Klein, 1996; Teicher, *et al.,* 1996). Epidemiological findings of combined cognitive and motor symptoms in boys (Brocki *et al*., 2010) were positively correlated with age, suggesting that ADHD symptoms exists and varies along a continuum in the normal population. However, hyperactivity reflected in motor-activity is assumed to diminish with increased age (Brocki *et al*., 2010; Wilens, Biederman, & Spencer, 2002) but only three studies of objective measures of motor activity in adults with ADHD exist

(Boonstra, *et al*., 2007; Lis, Baer, Stein-en-Nosse, Gallhofer, Sammer, & Kirsch, 2010; Tuisku, *et al.*, 2003), and they indicate measurable signs of increased motor activity in adult ADHD as compared to healthy participants. Age-relevant symptoms of hyperactivity are stipulated as diagnostic criteria in DSM-IV (American Psychiatric Association, 2004) and many adult subjects report fidgeting their feats and fingers several times a day (Murphy & Barkley, 1996).

Combined measures of cognitive and motor domains in adult ADHD

Recently, both cognitive and behavior domains of adult ADHD were measured using the Quantified Behavior Test Plus, QbTest-Plus (Lis *et al.,* 2010). The test combines simultaneous objective measures of motor activity using infrared motion tracking systems and measures of attention and impulsivity using CPT measures. Core symptoms of ADHD were objectively measured in 20 adult subjects and separated from matched and healthy controls. Measures of hyperactivity were significant in the ADHD group using parameters such as distance, time active, area and micro-events. Hyperactivity offered higher separation than the cognitive parameters operationalized as omission and commission errors. The study suggests that hyperactivity was the core symptom that best separated ADHD from healthy controls and especially when measured in distance, i. e., the number of centimeters the subject has moved during the test. In the present study, we use these findings as a benchmark for assessment of the objective ADHD-measures, focusing on both motor and cognitive domains in attempts to optimize separation from ADHD and non-ADHD clinical subjects. We applied the combined measurement technique in a naturalistic sample of adult clinic-referred psychiatric patients in order to assess differential validity, i.e., sensitivity and specificity, for the Quantified Behavior Test Plus with regard to adult ADHD.

Aim of the study

The aim of the study is to investigate levels of sensitivity and specificity for the QbTest-Plus with regard to ADHD in nineteen clinic-referred adult patients awaiting clinical assessment of ADHD.

Quantities of hyperactivity, impulsivity and inattention are expected to be high in adults receiving a diagnosis of ADHD so that the core symptom triad will be sufficient for identifying a majority of the subjects with ADHD and separating them from a majority of the non-ADHD subjects.

Method

Participants

This study included 19 participants, 10 women and 9 men, who underwent clinical assessment for ADHD at the psychiatric clinic in the NU-health care. The participants mean age was 31.7 (*SD* = 9.3, *range* = 20 to 54). One person had not begun high school but a majority had completed (*n* = 6) or made parts of it (*n* = 9) and some (*n* = 3) had studied at post-graduate levels. Nine were singles, six either married or sharing household with a partner, three had a relationship and one person was divorced. A majority were unemployed, on sick-leave or carried sickness pension (*n* = 14) and the remaining part had full- or part-time work (*n* = 1), arranged daytime activities (*n* = 1), studied (*n* = 1), were on parents leave (*n* = 1) or retired (*n* = 1). The mean Body Mass Index was 26.2 (*SD* = 5.2, *range* = 18 to 35), and eleven persons regularly smoked tobacco while eight did not smoke at all.

Participants were out-patients whose mean age for initial psychiatric contact was 20.2 (*SD* = 10.9, *N* =12) and ten persons had undertaken psychiatric hospitalization one or more times starting at the mean age of 27.1 (*SD* = 9.9 *range* = 14 to 48). The mean of the latest Global Assessment of Functioning, GAF (Luborsky, 1962), which is a commonly used, qualitatively assessed and global measure of adult social, occupational, and psychological functioning ranging from 0 (severe dysfunction) to 100 (perfect function) regarding both the level of symptom severity, which was 49.9 (*SD* = 6.9, *range* = 40 to 60) and the level of adaptive functioning, which was 48.2 (*SD* = 8.8, *range* = 35 to 60) for participants of the present study, which indicate both serious symptoms and dysfunctions. Previous to clinical assessment of ADHD, all but two participants had at least one psychiatric diagnose and some (*n* = 8) had two. A total of seven participants had relapsing episodes of depression or dysthymia, five had various anxiety disorders or mixed states of anxiety and depression, three had a bipolar disorder, three had a substance abuse disorder, two had a personality disorders, one had an adaptive disorder and another participant had a diagnose of acute stress reaction at the time of the assessment.

None had undergone clinical assessments for ADHD in childhood and a majority (*n* = 14) had no family or relative with ADHD. Regarding medical treatment, 14 participants generally used it but during the day of the study, participants used none (*n* = 8), one (*n* = 4), two (*n* = 5) or three and more (*n* = 2) medical treatments. The following medical treatments were used by participants: antidepressants (*n* = 12), anxiolytics (*n* = 5), and neuroleptics (*n* = 3). The mean time from smoking or chewing tobacco at the first minute of the QbTest-Plus (see the instruments section) was 23.8

minutes (*N* = 11, *SD* = 14.7). Statistical analyses (Independent Samples *t*-test, 5 % level) did not reveal any significant differences between men and women with regard to age, BMI, education, age at first contact with psychiatry, GAF-symptom, GAF-function, or ASRS (see the instrument section).

Design

The current study evaluated levels of sensitivity and specificity for the QbTest-Plus with regard to ADHD using objective measures of ADHD core symptoms. The independent variable was the clinical assessment regarding the diagnosis of ADHD. The dependent variable was the results of the QbTest-Plus, which was collected and analyzed prior to the clinical assessment. Clinical assessments were made by trained clinicians in the NU-health care and typically included observations, childhood anamnesis, self-report symptom scales, information from relatives, psychological or occupational-therapeutic tests and sometimes additional batteries of well-chosen psychological tests performed by specialists in neuropsychiatry. The psychiatric center asserted the DSM-IV (American Psychiatric Association, 2000) for diagnostic considerations. DSM-IV includes three subtypes of ADHD that was categorized into one dichotomous variable of No (not ADHD) or Yes (ADHD is established) and compared with the outcome of QbTest-plus; "Probably not ADHD", "Possibly ADHD, further assessment is needed" or "Probably ADHD".

Instruments

QbTest-plus. This instrument (Knagenhjelm & Ulberstad, 2010) combines a Continuous Performance Test (CPT) installed as a software program on a PC with measures of attention and impulsivity and an activity test with measures of motor-activity during 20 minutes. While performing the CPT-test on the computer, movements of the participant are recorded using an infrared camera following a reflective marker attached to a head-band. The CPT-test involves rapid presentations of figures with various shapes (square or circle) and colors (red or blue) and the participant are instructed to press a handheld button when a stimuli subsequently repeats itself (a target) and not to press the button when the stimulus varies relative to the previous one (a non-target). The stimuli are presented at a pace of one per two seconds, each one visible for 200 milliseconds, and the total number of stimuli is 600, presented with a 25 % target probability.

QbTest-Plus aims to provide objective information regarding core-symptoms of ADHD; hyperactivity on basis of motor-activity measured with the camera, and inattention and impulsivity on basis of the CPT-test. In this study, hyperactivity has

been operationalized with the parameter called "distance", i.e., the length of the path describing the movement of the headband reflector during the test. Inattention is operationalized on basis of omission errors (no response is registered and the stimulus was a target) and impulsivity with commission errors (a response is registered and the stimulus was a non-target). Cut-off levels (Q-score 1.3) of core-items are based on 149 male and 118 female (*N* = 267) healthy controls from thirteen to fifty-five years of age and is set at the 90th percentile of the distribution (Knagenhjelm *et al.,* 2010). For means and standard deviations of the present study see Table 1.

Table 1: The results of hyperactivity, impulsivity and inattention using QbTest-Plus

QbTest-Plus Core Item	*M*	*SD*	*Min*	*Max*
Hyperactivity	5.86	4.47	2.00	16.80
Impulsivity	3.30	8.29	0.00	37.10
Inattention	14.04	13.81	0.00	54.00

The results of hyperactivity, impulsivity and inattention using QbTest-Plus. Means (M), Standard Deviations (SD), Minimum (Min), and Maximum (Max) scores of the QbTest-Plus core items; hyperactivity (distance), impulsivity (commission errors), and inattention (omission errors).

Procedure

Nurses informed patients awaiting clinical assessment about the purpose and procedure of the study and the interested patients were registered for participation. When arriving at the psychiatric centre, the participant was met by a researcher and the written informed consent obtained. Instructions for the QbTest-Plus were given both verbally and by means of the standardized video presenting procedures of the test (Knagenhjelm, *et al,* 2010). Participants performed a one minute pre-test to ensure instructions had been understood correctly. After QbTest-plus was performed, the participant answered questions about demographics and current medication. The psychiatric record and the status of the assessment were unknown throughout the process of experimental testing and assessment. Results would not intervene with clinical assessment. Methods and results of the clinical assessments, the GAF, medical treatment, psychiatric anamnesis and clinical diagnosis were collected. The study procedures were examined and approved by the Regional Ethical Review Board of Uppsala, Sweden (2008/110/2).

Analysis of data

Objective core items from QbTest; hyperactivity measured in distance, impulsivity measured with commission errors and inattention measured with omission errors, were divided into either "No" or "Yes" relative to the predetermined cut-off level indicating moderately atypical behavior (Q-score > 1.3) (Knagenhjelm *et al.,* 2010). Core items were combined into a total judgment of either "Probably not ADHD" (all three No), "Possibly ADHD, further assessment is needed" (one or two Yes) or "Probably ADHD" (all three Yes) which were compared with the independent variable of "No" or "Yes" regarding the clinical diagnosis of ADHD.

Results

Sensitivity for detecting ADHD was 83 % and specificity was 57 %. Comparisons between clinical assessments and the QbTest-Plus indicated 74 % accuracy including ten true positive and four true negative cases, as well as three false positive and two false negative cases. The positive predictive value was 77 % and the negative predictive value was 66 %.

Discussion

The present study investigated levels of sensitivity and specificity for QbTest-Plus regarding ADHD in 19 adult patients awaiting clinical assessment for ADHD. Sensitivity for detecting ADHD was 83 % and the specificity was 57 % when compared to the clinical assessment. As expected, objective measures of the core symptom triad were sufficient for identifying a majority of the subjects with ADHD. As expected, the core symptoms were also sufficient for extracting a majority of the subjects without ADHD. However, the level of specificity was just a little better than chance and the present study therefore tentatively suggest that the test is unsuitable for disconfirming a diagnosis of ADHD. The test performance may be triggered by other reasons than ADHD. All participants qualified for an ADHD-assessment but had substantial psychiatric disorders with ADHD-core symptoms per se, which may influence levels of sensitivity in clinical samples. One asset of the objective behavioural measures is that core symptoms are recorded and presented regardless of the hypothetical reasons. But in order to interpret and apply the measures during diagnostic assessment for example; clinicians will be able to consider other clinical data and use QbTest-Plus according to the complementary intents of the test.

Psychiatric comorbidity is common for adults undertaking clinical screens and assessment for ADHD (Kaplan, et al., 2002). A majority of the clinically recruited participants of the current study had comorbid psychiatric disorders which hypothetically influences the levels of sensitivity and specificity. The QbTest-Plus are not intended to disentangle multifaceted comorbidity but rather to measure and quantify adult ADHD as one of other integrated facets of a clinical procedure. Having a blind design of the current study did not allow preparations based on the clinical records. Prospective studies would preferably have as much of diagnostically pure groups as possible in order to investigate levels of sensitivity and specificity with regard to ADHD in adult participants.

Using rather small samples, Epstein et al (2001) compared adult participants with ADHD (N = 25), participants with anxiety symptomatology (N = 15), and healthy participants (N = 30) by means of Conners´ CPT (Conners, 1992; Conners, 1995). Significantly higher rates of commission errors were found for the ADHD versus both other groups but non-significant rates of commission errors for participants with anxiety versus the healthy participants. Other studies of continuous performance tests and adult ADHD have found similar results for commission errors (Cohen and Shapiro, 2007), omission errors (Johnson, Epstein, Waid, Latham, Voronin, & Anton, 2001), and response speed (Himelstein & Halperin, 2000; Johnson, *et al*., 2001), but the samples were rather small. Seidman and colleagues (1998) reported differences between healthy controls, adults with ADHD and adults with schizophrenia by means of omission and commission errors. Adults with ADHD made fewer errors than clinical controls but more errors than normative controls. For most part, CPT studies of adults with ADHD are limited by the fact that small sample sizes and assorted CPT paradigms are applied for testing which limits the statistical power to detect effect sizes. In general, results from previous CPT studies suggest that measures of ADHD core symptoms may hold significant discriminative value when comparing groups with ADHD and healthy controls but that psychiatric comorbidity may seriously limit the discriminative power. Discriminative power of combined CPT and MTS measures was investigated by Lis and collegues (2010) who reported most discriminative power for objective measures of motor activity for participants with ADHD and healthy controls.

Today there are no golden standards available for assessing test-statistics of the QbTest-Plus. In order to assess data from participants, the current study utilized cut-off scores based on the 90th percentile of the normative dataset (see the instruments section) and previous studies of predictive measures of ADHD core symptoms in children and adults (Brocki *et al*., 2010; Lis *et al*., 2010). Other alternatives for identifying cut-off scores, such as roc-curve analysis were not helpful. A calibrated

and composite measure based on continuous scores for the whole ADHD core symptom spectra would perhaps facilitate the objective of QbTest-Plus with regard to adult patients.

Limitations

The present study had some limitations. The participants had comorbid psychiatric disorders with joint symptoms vis-à-vis ADHD. Among others this included bipolar, anxiety, mood and personality disorders. Twelve participants used one or more psychotropic medications and the current study did not make apparent whether the sample was representative for clinic-referred adults suspected to have ADHD in general. The results may therefore be regarded tentatively. Hopefully, future studies will be able to investigate psychometric properties of the test thoroughly.

Conclusions

The present study reported 83 % sensitivity and 57 % specificity for the QbTest-Plus with regard to adult ADHD. The results, possibly affected by confounding factors, may be regarded tentatively and suggest further examination of calibrated and objective measures from the test. Future research may investigate behavioral measures with regard to adult clinical and healthy controls, as well as compare the results with other assessment tools of ADHD in adulthood. The current study was one of the first to investigate objective behavioral measures of the core symptom triad in adult ADHD, and a majority of participants with ADHD was possible to identify. The study is limited but encourages further research on behavioral measures of hyperactivity, impulsivity and inattention in adult ADHD.

References

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders.* DSM-IV-TR. Washington, DC: Author (Swedish translation, Danderyd: Pilgrim Press, 2002).

Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2002). The persistence of attention-deficit/hyperactivity disorder into young adulthood as a function of reporting source and definition of the disorder. *Journal of Abnormal Psychology, 111,* 279-289.

Boonstra, A. M., Kooij, J. J., Oosterlaan, J., Sergeant, J. A., Buitelaar, J. K., & Van Someren, E. J. (2007). Hyperactive night and day? Actigraphy studies in adult ADHD: a baseline

comparison and the effect of methylphenidate. *Sleep*, *30,* 41-47.

Brocki, K. C., Tillman, C. M., & Bohlin, G. (2010). CPT performance, motor activity, and continuous relations to ADHD symptom domains: A developmental study. *European Journal of Developmental Psychology*, *7,* 178-197.

Cohen A. L., & Shapiro S. K. (2007). Exploring the performance differences on the flicker task and the Conners' Continuous Performance Test in adults with ADHD. *Journal of Attention Disorders, 11,* 49-63.

Conners, C. K. (1992). *Conners´ Continuous Performance Test user´s Manual*. Toronto, Canada: Multi-Health Systems.

Conners, C. K. (1995). *Conners´ Continuous Performance Test user´s Manual*. Toronto, Canada: Multi-Health Systems.

Davidson, M. A. (2008). ADHD in adults- a review of the literature. *Journal of Attention Disorders*, *11,* 628-641.

Downey, K. K., Stetson, F. W., Pomerleau, O. F., & Giordani, B. (1997). Adult attention deficit hyperactivity disorder: Psychological profile in a clinical population. *Journal of Nervous and Mental Disease*, *185,* 32-38.

Epstein, J. N., Johnson, D. E., Varia, I. M., & Conners, C. K. (2001). Neuropsychological assessment of response inhibition in adults with ADHD. *Journal of Clinical and Experimental Neuropsychology*, *23,* 362-371.

Epstein, J. N., Conners, C. K., Hervey, A. S., Tonev, S. T., Arnold, L. E., Abikoff, H. B.,…& The MTA Cooperative study Group. (2006). Assessing medication effects in the MTA study using neuropsychological outcomes. Journal of Child Psychology and Psychiatry, *47,* 446-456.

Gordon, M., Barkley, R. A., & Lovett, J. B. (2006). Tests and observational measures. In R. A. Barkley (Ed.), *Attention-deficit hyperactivity disorder- a handbook for diagnosis and treatment* (pp. 369-388). New York: The Guilford Press.

Grodzinsky, G. M., & Barkley, R. A. (1999). Predictive power of frontal lobe tests in the diagnosis of attention-deficit hyperactivity disorder. *Clinical Neuropsychologist*, *13,* 12-21.

Halperin, J. M., Matier, K., Bedi, G., Sharma, V., & Newcorn, J. H. (1992). Specificity of inattention, impulsivity and hyperactivity to the diagnosis of attention-deficit

hyperactivity disorder. *Journal of American Academy of Child and Adolescent Psychiatry, 31,* 190-196.

Halperin, J. M., Newcorn, J. H., Matier, K., Sharma, V., McKay, K. E., & Schwarts, S. (1993). Discriminant validity of attention-deficit hyperactivity disorder. *Journal of American Academy of Child and Adolescent Psychiatry*, *32,* 1038-1043.

Himelstein, J., & Halperin, J. M. (2000). Neuro-cognitive functioning in adults with attention-deficit/hyperactivity disorder. *CNS Spectrums*, *5*, 58-64.

Johnson, D. E., Epstein, J. N., Waid, R., Latham, P. K., Voronin, K. E., & Anton, R. F. (2001). Neuropsychological performance deficits in adults with attention deficit/hyperactivity disorder. *Archives of Clinical Neuropsychology*, *16,* 587-604.

Jucaite, A., Fernell, E., Halldin, C., Forssberg, H., & Farde, L. (2005). Reduced midbrain dopamine transporter binding in male adolescents with attention-deficit/hyperactivity disorder: association between striatal dopamine markers and motor hyperactivity. *Biological Psychiatry*, *57,* 229-238.

Kaplan, R. F., & Stevens, M. C. (2002). A review of adult ADHD: a neuropsychological and neuroimaging perspective, *CNS Spectrums*, *7,* 355-362.

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training for working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology*, *24,* 781-791.

Knagenhjelm, P., & Ulberstad, F. (2010). *QbTest-Technical manual*. Data on file.

Koelega, H. S. (1993). Stimulant drugs and vigilance performance: a review. *Psychopharmacology*, *111,* 1-16.

Konrad, K., Gunther, T., Hanisch, C., & Herpertz-Dahlman, B. (2004). Differential effects of methylphenidate on attentional functions in children with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 43,* 191-198.

Lis, S., Baer, N., Stein-en-Nosse, C., Gallhofer, B., Sammer, G., & Kirsch, P. (2010). Objective measurement of motor activity during cognitive performance in adults with attention deficit/hyperactivity disorder. *Acta Psychiatrica Scandinavia*, *122,* 285-294.

Losier, B. J., McGrath, P. J., & Klein, R. M. (1996). Error patterns on the continuous performance test in non-medicated and medicated samples of children with and

without ADHD: A meta-analysis review. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *37,* 971-987.

Luborsky L. (1962). Clinicians' judgements of mental health. *Archives of General Psychiatry*, *7,* 407-417.

McGough, J. J., Smalley, S. L., McCracken, J, T., Yang, M., Del´Homme, M., Lynn, D, E., & Loo, S. (2005). Psychiatric comorbidity in adult attention deficit hyperactivity disorder: findings from multiplex families. *American Journal of Psychiatry*, *162,* 1621-1627.

Murphy, K., & Barkley, R. A. (1996). Attention deficit hyperactivity disorder adults: comorbidities and adaptive impairments. *Comprehensive Psychiatry*, *37,* 393-401.

Murphy, K. R., Barkley, R. A., & Bush, T. (2001). Executive functions in young adults with attention deficit hyperactivity disorder. *Neuropsychology*, *15,* 211-220.

Murphy, K. R., Barkley, R. A., & Bush, T. (2002). Young adults with ADHD: subtype differences in comorbidity, educational, and clinical history. *The Journal of Nervous and Mental Disease, 190,* 147-157.

Nigg, J. T., Stavro, G., Ettenhofer, M., Hambrick, D., Miller, T., & Henderson, J. M. (2005). Executive functions and ADHD in adults: Evidence for selective effects on ADHD symptom domains. *Journal of Abnormal Psychology*, *114,* 706-717.

Ossman, J, M., & Mulligan, N. W. (2003). Inhibition and attention deficit hyperactivity disorder in adults. *American Journal of Psychology*, *116,* 35-50.

Porrino, L. J., Rapoport, J. L., Behar, D., Sceery, W., Ismond, D. R., & Bunney, W. E. Jr. (1983). A naturalistic assessment of the motor activity of hyperactive boys. 1. Comparison with normal controls. *Archives of General Psychiatry; 40,* 681-687.

Seidman, L. J., Biederman, J., Faraone, S. V., Weber, W., & Ouellette, C. (1997). Toward defining a neuropsychology of attention deficit-hyperactivity disorder: Performance of children and adolescents from a large clinically referred sample. *Journal of Consulting and Clinical Psychology, 65,* 150-160.

Seidman, L. J., Van Manen, K-J., Turner, W. M., Gamser, D. M., Faraone, S. V., Goldstein, J. M., & Tsuang, M. T. (1998). The effects of increasing resource demand on vigilance performance in adults with schizofrenia or developmental attentional/learning disorders: a preliminary study. *Schizofrenia Research, 34,* 101-112.

Simon, V., Czobor, P., Bálint, S., Meszaros, A., & Bitter, I. (2009). Prevalence and correlates of adult attention-deficit hyperactivity disorder: Meta-analysis. *British Journal of Psychiatry*, *194,* 204-211.

Tabori-Kraft, J., Sørensen, M. J., Dalsgaard, S., Kærgaard, M., & Thomsen, P. H. (2007). Is OPTAx useful for monitoring the effect of stimulants on hyperactivity and inattention? *European Child and Adolescent Psychiatry, 16,* 347-351.

Teicher, M. H., Ito, Y., Glod, C. A., & Barber, N. I. (1996). Objective measurement of hyperactivity and attentional problems in ADHD. *Journal of American Academy of Child and Adolescent Psychiatry*, *39,* 651-659.

Tuisku, K., Virkkunen, M., Holi, M., Lauerma, H., Naukkarinen, H., Rimon, R., & Wahlbeck, K. (2003). Antisocial violent offenders with attention deficit hyperactivity disorder demonstrate akathisia-like hyperactivity in three-channel actometry. *The Journal of Neuropsychiatry and Clinical Neuroscience, 15,* 194-199.

Vogt, C., & Williams, T. (2011). Early identification of stimulant responders, partial responders and non-responders using objective measures in children and adolescents with hyperkinetic disorder. *Child and Adolescent Mental Health*, online.

Weyandt, L. L., Mitzlaff, L., & Thomas, L. (2002). The relationship between intelligence and performance on the Test of Variables of Attention (TOVA). *Journal of Learning Disabilities*, *35,* 114-120.

Wilens, T. E., Biederman, J., & Spencer, T. J. (2002). Attention deficits/ hyperactivity disorder across the lifespan. *Annual Review of Medicine*, *53,* 113-131.

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