



Measuring attention performance among ADHD versus non ADHD children

Journal:	<i>Developmental Neuropsychology</i>
Manuscript ID:	Draft
Manuscript Type:	Original Article
Keywords:	ADHD, CPT, validity

SCHOLARONE™
Manuscripts

1
2
3 **Measuring attention performance among ADHD versus non ADHD children**
4
5
6

7 Itai Berger ^a, Merav About ^a, Julia Melamed ^a, Hanoch Cassuto ^b
8
9

10
11 ^a The Neuro-Cognitive Center, Pediatric Division, Hadassah-Hebrew University Medical
12 Center, Jerusalem, Israel
13
14

15 ^b Leumit HMO, Jerusalem, Israel
16
17
18
19
20
21
22
23
24
25
26

27 Corresponding author
28

29 Itai Berger, MD
30

31 The Neuro-Cognitive Center, Pediatric Division
32

33 Hadassah - Hebrew University Medical Center
34

35 Mount Scopus, POB 24035, Jerusalem 91240, Israel
36

37 Tel: 972-2-5844903
38

39 Fax: 972-2-5328963
40

41 E-mail: itberg@hadassah.org.il
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Abstract

This study examined the validity of a Continuous Performance Test (MOXO-CPT) among 798 children aged 7-12 years. Receiver Operating Characteristic (ROC) analyses showed that the MOXO-CPT was highly accurate in identifying ADHD children who were previously diagnosed by using DSM-IV-TR criteria. In addition, the test significantly discriminated ADHD children from non-ADHD children.

These findings emphasize the importance of incorporating distracters into CPT and integrating several different attention parameters when measuring attention functions.

In light of the criticism voiced against the low validity of CPT's, a valid CPT would be valuable for theory, research, and clinical work.

Introduction

Attention-deficit hyperactivity disorder (ADHD) is among the most common neurobehavioral disorders of childhood, characterized by inattention, impulsivity and hyperactivity. Using the DSM-IV criteria (APA, 1994), prevalence rates in the United States ranged from 7.4% to 9.9% (Barkley, 2006; CDC, 2010).

In the absence of available biological markers that would support conferring diagnoses, information about the symptoms is usually collected by using interviews based on DSM-IV-TR criteria of ADHD and validated behavioral rating scales (AAP, 2001; APA, 2000; Skounti, Philalithis, & Galanakis, 2007). The subjective nature of these methods makes them vulnerable to clinician and informant biases (Rousseau, Measham, & Bathiche-Suidan, 2008; Serra-Pinheiro, Mattos, & Regalla, 2008; Skounti et al., 2007).

As a result, there has long been interest in developing objective laboratory-based measures that could support the clinical diagnosis of ADHD. One of the most popular laboratory-based tools is the computerized continuous performance test (CPT), which was originally developed as a measure of vigilance (Rosvold, Mirsky, Sarason, Bransome & Beck, 1956). Generally, CPT tasks require the subjects to maintain vigilance and react to the presence (or absence) of a specific stimulus within a set of distracters presented continuously.

The use of the CPT as an objective measure of attention in ADHD has several advantages. It can measure the ability to concentrate on a single task for a certain length of time. In addition, it is considered an objective tool to gather quantifiable information on the changes of attention as a result of a medical or non-medical treatment. Finally, CPT is inexpensive, easy to administer, and some versions include appropriate age norms.

Despite its vast popularity in clinical and empirical settings, many authors have identified concerns about using CPT as a diagnostic tool. One of the major controversies regarding the CPT is related to its low sensitivity and specificity rates (Edwards et al., 2007; McGee, Clark

1
2
3 & Symons, 2000; Riccio, Waldrop, Reynolds, & Lowe, 2001; Skounti et al., 2007). Although
4
5 some studies (Aaron, Joshi, and Phipps, 2004; Epstein et al., 2003; Seidel & Joschko, 1990)
6
7 have demonstrated differences in CPT performance between ADHD and normal controls,
8
9 many others have questioned its ability to consistently discriminate ADHD children from
10
11 normal controls, psychiatric controls or learning disabilities (Corkum & Siegel, 1993;
12
13 DeShazo, Grofer, Lyman, Bush, & Hawkins, 2001; Schachar, Logan, Wachsmuth, &
14
15 Chajczyk, 1988; Trommer, Hoepfner, Lorber, & Armstrong, 1988; Werry, Reeves, & Elkind,
16
17 1987).

18
19
20 The CPT was also criticized for its low ecological validity (Barkley, 1991; Pelham et al.,
21
22 2011; Rapport, Chung, Shore, Denney, & Isaacs, 2000). That is, the CPT ability to simulate
23
24 the difficulties of ADHD patients in everyday life. Being administered in laboratory
25
26 conditions (Barkley, 1991; Gutiérrez-Maldonado, Letosa-Porta, Rus-Calafell, & Peñaloza-
27
28 Salazar, 2009), CPT are usually free of distracting stimuli, which are thought to impair the
29
30 cognitive performance of ADHD children (APA, 1994; 2000).

31
32
33 In light of the limitations of the existing CPTs, the American Academy of Pediatrics did not
34
35 support the use of CPT tests in the diagnostic process of ADHD (AAP, 2001). At the same
36
37 time, the inaccuracy of the subjective measurement tools of ADHD still calls for a reliable
38
39 and valid CPT tests (AAP, 2001; Dickerson Mayes, Calhoun, & Crowell, 2001; Skounti et
40
41 al., 2007).

42
43
44 The current study examined the validity of the MOXO-CPT (Berger & Goldzweig, 2010) in
45
46 the diagnosis of ADHD in children aged 7-12 years. This study had two objectives: the first
47
48 one was to assess the MOXO-CPT's ability to measure differences in attention performance
49
50 among ADHD versus non-ADHD children. The second objective was to evaluate the
51
52 construct validity of the MOXO-CPT in the diagnosis of ADHD, using the DSM-IV-TR
53
54 criteria (APA, 2000) as the 'gold standard'.
55
56
57
58
59
60

1
2
3 The term 'MOXO' derives from the world of Japanese martial arts and means a 'moment of
4 lucidity'. It refers to the moments preceding the fight, when the warrior clears his mind from
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

The term 'MOXO' derives from the world of Japanese martial arts and means a 'moment of lucidity'. It refers to the moments preceding the fight, when the warrior clears his mind from distracting, unwanted thoughts and feelings.

Results of a pilot study with a small group of children (Berger & Goldzweig, 2010) showed that the MOXO-CPT was valid for ADHD diagnosis in children, and was more sensitive to ADHD than other CPT tests, such as the T.O.V.A (Greenberg, 1997) and the Conners CPT (Conners, 2000).

Methods

Participants

Participants in this study were 798 children aged 7 to 12 years, of them 493 boys and 305 girls. The study group included 339 children diagnosed with ADHD (Mean age, 9.27, S.D=1.65) and the control group included 459 children without ADHD (Mean age =9.71, S.D=1.64).

The children were divided to six different age categories (7, 8, 9, 10, 11, and 12 years). For example, the category of "8 years" included children who were equal or older than 8, but younger than 9.

As can be seen in Table 1, within each age category, the study and control group did not differ in gender distributions.

Participants in the ADHD group were recruited from children referred to the out-patient pediatric clinics of the Neuro-Cognitive Center, based in a tertiary care university hospital.

The children were referred through their pediatrician, general practitioner, teacher, psychologist, or directly by the parents.

1
2
3 Inclusion criteria for participants in the ADHD group were:
4

- 5 1. Each child met the criteria for ADHD according to DSM-IV-TR criteria (APA, 2000), as
6 assessed by a certified pediatric neurologist. The diagnostic procedure included an interview
7 with the child and parents, fulfillment of questionnaires, and medical/neurological
8 examination that confirmed ADHD diagnosis.
9
10 2. Each child scored above the standard clinical cutoffs for ADHD symptoms on Conners'
11 ADHD/DSM-IV Scales (Conners, 1997a; Conners, 1997b, APA, 2000).
12
13 3. All children were drug naïve.
14
15
16
17
18
19

20 Participants in the control group were randomly recruited from pupils in primary schools.
21

22 Inclusion criteria for participants in the control group were:
23

- 24 1. Each child scored below the clinical cutoff point for ADHD symptoms on Conners'
25 ADHD/DSM-IV Scales (Conners, 1997a; Conners, 1997b).
26
27 2. Absence of academic or behavioral problems, as reported by parents and teachers.
28
29
30

31 Exclusion criteria were intellectual disability, other chronic condition, chronic use of
32 medications, and other primary psychiatric diagnosis (e.g., depression, anxiety, and
33 psychosis).
34
35
36
37

38 All participants agreed to participate in the study and their parents gave written informed
39 consent to the study, approved by the Helsinki committee (IRB) of Hadassah-Hebrew
40 University Medical Center (Jerusalem, Israel).
41
42
43
44
45
46

47 *Measures*

48 Measurement of child behavior - The parent and teacher forms of the Conner's
49 ADHD/DSM-IV Scales were used to assess the level of children's ADHD behaviors
50 (Conners, 1997a; Conners, 1997b; APA 2000).
51
52
53
54
55
56
57
58
59
60

MOXO- CPT Description

This version of the CPT is a computerized performance test as previously described (Berger & Goldzweig, 2010). A set of target and non-target stimuli were shown sequentially in the middle of a computer screen. The child was instructed to respond as quickly as possible to the target stimuli by pressing the keyboard's space bar once, and only once. In addition, the child was instructed to avoid responding to all other stimuli or pressing any other key. While performing the CPT, the children were accompanied by technician who made sure that the children understood the instructions and watched them throughout the test without interfering.

Both target and non-target stimuli were cartoon pictures that did not include any letters or numbers (see Figure 1). These features are significant, given that some children with ADHD also demonstrate learning difficulties (e.g., dyslexia) that may be confounded with CPT performance (Seidman, Biederman, Monuteaux, Doyle, & Faraone, 2001).

The MOXO-CPT duration was 15.2 minutes, contained eight levels, each of them 114 seconds long. Every level included three types of elements: a target stimulus, a non-target stimulus, and a "void" period. First, a stimulus (target/ non-target) was presented for a changing duration of time (3 sec, 1 sec, or 0.5 seconds). Then, the stimulus was followed by a "void" period (blank screen) of the same duration. Prior to the void period, the stimulus (target / non-target) was presented on the screen whether or not the participant responded to it. In other words, pressing the keyboard's space bar did not eliminate the stimulus.

This method of presentation enabled to measure the timing of the response (whether the response occurred during stimulus presentation or during the void period) as well as the accuracy of the press (whether the response occurred at all). Each level included 33 targets stimuli, 20 non-target stimuli, and 53 void periods.

1
2
3 Distracters - In order to simulate everyday environment, the MOXO-CPT contained
4
5 interfering stimuli that serve as distracters. The distracters included three types of basic
6
7 elements that characterize the child's environment: a) pure visual distracters (e.g., flying
8
9 birds, magician's wand), b) pure auditory distracters (e.g., a voice of a gong, squeaking birds),
10
11 and c) combination of both the visual and auditory distracters. Overall, six different
12
13 distracters were presented (Figure 2). Every one of the eight levels of the MOXO-CPT
14
15 included a different set of distracters: two levels (1 and 8) contained only target and non-
16
17 target stimuli without distracters, two levels (2 and 3) contained pure visual stimuli, two
18
19 levels (4 and 5) contained pure auditory stimuli, and two levels (6 and 7) contained a
20
21 combination of visual and auditory stimuli.
22
23

24
25 While the target stimulus was presented at the center of the screen, the visual distracters
26
27 appeared at one of the four sides of the display: down, up, left or right. The sequence of
28
29 distracters and their exact position on the display were predefined for each level. Distracters
30
31 were displayed for varied durations ranging from for 3.5 to 14.7 seconds, with a constant void
32
33 interval of 0.5 second between two sequential distracting elements.
34
35

36 The burden of the interfering stimuli increased in the odd number levels. That is, the third,
37
38 fifth, and seventh levels included higher burden of distracters than the second, fourth and
39
40 sixth levels, respectively.
41
42

43 *Performance indices* – The MOXO-CPT included four indices named: Attention, Timing,
44
45 Impulsivity, and Hyperactivity.
46
47

48 Attention – This parameter included the number of correct responses (pressing the key in
49
50 response to a target stimulus), which were performed either during the stimulus presentation
51
52 on the screen or during the void period that followed. Thus, it was possible to evaluate
53
54 whether the participant responded correctly to the target (was attentive to the target)
55
56 independently of how fast he was. Knowing how many responses are expected, it was also
57
58
59
60

1
2
3 possible to calculate the number of times the target was presented, but the patient did not
4
5 respond to it (omission errors).
6

7 Timing – This parameter included the number of correct responses (pressing the key in
8
9 response to a target stimulus) which were performed only while the target stimulus was still
10
11 presented on the screen. This parameter did not include responses that were performed during
12
13 the void period (after the stimulus has disappeared).
14

15
16 According to the National Institute of Mental Health (2012), inattention problems in
17
18 ADHD may be expressed in "difficulties in processing information as quickly and accurately
19
20 as others". Traditionally, difficulties in timing at a CPT are evaluated by mean response time
21
22 for correct responses to the target (which is interpreted as a measure of information
23
24 processing and motor response speed) and by the standard deviation of response time for
25
26 correct responses to the target (which is interpreted as a measure of variability or consistency)
27
28 (Greenberg & Waldman, 1993; Halperin, Matier, Bedi, Sharma, & Newcorn, 1992). In these
29
30 paradigms the stimulus is presented for short and fixed periods of time and the response
31
32 occurs after the stimulus has disappeared. Given the short, fixed presentation, accurate but
33
34 slow participants may be mistakenly diagnosed as inattentive. While a group of patients
35
36 would respond correctly if allowed more time, inattentive patients would not respond at all
37
38 because they were not alert to the target. Therefore, the measurement of response time per-se,
39
40 addresses only the ability to respond quickly, but not the ability to respond accurately.
41
42

43
44 By implanting a void period after each stimulus and using variable presentation durations of
45
46 the elements, the MOXO-CPT could distinguish accurate responses performed in "good
47
48 timing" (quick and correct responses to the target performed during stimulus presentation)
49
50 from accurate but slow responses (correct responses to the target performed after the stimulus
51
52 presentation; during the void period). These two aspects of timing correspond to the two
53
54
55
56
57
58
59
60

1
2
3 different problems of ADHD described by the National Institute of Mental Health (2012):
4
5 responding quickly and responding accurately.
6

7 Impulsivity - This parameter included the number of commission errors (responses to a non-
8 target stimulus), performed as the initial response to the non-target stimuli. Usually,
9 commission errors are coded in any case of inappropriate response to the target (e.g., pressing
10 a random key) (Greenberg & Waldman, 1993). In contrast, the MOXO-CPT's impulsivity
11 parameter considered as impulsive behavior only the first pressing on the keyboard's space-
12 bar in response to non-target stimulus. All other non-inhibited responses (e.g., pressing the
13 keyboard more than once) were not coded as impulsive responses (as will describe in the next
14 paragraph).
15
16
17
18
19
20
21
22
23

24 Hyperactivity - This parameter included all types of commission responses that are not coded
25 as impulsive responses. Several examples are: 1. Multiple responses- pressing the keyboard's
26 space bar more than once (in response to target/ non-target), which is commonly interpreted
27 as a measure of motor hyper-responsivity (Greenberg & Waldman, 1993). The MOXO-CPT
28 considered as multiple responses only the second press and above (the first response would
29 be considered as correct response with good timing, as correct response with poor timing, or
30 as impulsive response, depends on the type of element appearing on the screen). 2. Random
31 key pressing - pressing any keyboard button other than the space bar. By separating
32 commission errors due to impulsive behavior from commission errors due to motor hyper-
33 responsivity, it was possible to identify the multiple sources of response inhibition problems.
34 Thus, the MOXO- CPT was able to differentiate impulsive responses from hyperactive
35 responses.
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Data Analyses

All analyses were conducted with Matlab version R2011b. In order to compare the performance of ADHD children and non-ADHD children, independent samples T-tests were performed, for each one of the four MOXO-CPT parameters. The diagnostic value of the MOXO-CPT was assessed by calculating the areas under the receiver operating characteristic (ROC) curves, which were used to assess the best cutoff points to distinguish between ADHD and non-ADHD children.

Results

Differentiating Between ADHD and non-ADHD children

Differences between the study and the control group in the four parameters of performance in the MOXO-CPT (attention, timing, hyperactivity, and impulsivity) were examined by two tailed T-test analyses for independent samples. In addition, differences between the groups were measured by comparing the total score of the MOXO-CPT, which takes into account all four parameters (Table 2). Results of the analyses revealed that in all age categories, significant differences were found between ADHD and non-ADHD children. As can be seen in table 2, ADHD children received significantly lower scores in the Attention and Timing parameters than normal controls. That is, ADHD children were less attended to the stimuli and performed less reactions on accurate time. Furthermore, ADHD children received significantly higher scores in the Hyperactivity and Impulsivity parameters than normal controls. Thus, ADHD children produced more Hyperactive and Impulsive responses as compared to non-ADHD children. Finally, ADHD children received higher total scores in the MOXO-CPT as compared to non-ADHD children. That is, ADHD children's general performance in the MOXO-CPT was worse than their unaffected peers of the same age. It should also be noted that using the total score of the MOXO-CPT produced the highest

1
2
3 difference between ADHD and non-ADHD performance, as compared to any single
4
5 parameter.
6
7

8 9 *Diagnostic Utility of the MOXO-CPT*

10 Since inclusion criteria required that each participating child (in the ADHD group) met the
11 criteria for ADHD diagnosis according to DSM-IV-TR (APA, 2000), the sensitivity and
12 specificity of the MOXO-CPT were calculated using these criteria. Results of ROC analyses
13 are presented in table 3. The table shows the cut-off points, sensitivity and specificity rates of
14 the MOXO-CPT, based on the total scores of the MOXO-CPT (taking into account all four
15 parameters). Different sensitivity and specificity rates could be used for different purposes of
16 the test (e.g., screening, diagnosis). However, we have used the optimal value which
17 represents the maximized classification accuracy with the highest sensitivity and specificity
18 rates. Results showed that in all age categories, the optimal cut-off points were associated
19 with both high sensitivity and specificity rates (all above 80%).
20
21
22
23
24
25
26
27
28
29
30
31
32
33

34 Figure 3 presents an example of a ROC analysis, in a group of children aged 8-9 years. As
35 can be seen in the figure, the total score of the MOXO-CPT produced the highest sensitivity
36 and specificity rates, as compared to any single parameter.
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Discussion

The current study investigated the diagnostic utility of the MOXO-CPT (Berger & Goldzweig, 2010) for the assessment of ADHD in a sample of children aged 7-12 years. Results showed that the MOXO-CPT significantly discriminated between children with ADHD and their unaffected peers of the same age. As measured by the MOXO-CPT, children with ADHD were more inattentive, more impulsive and more hyperactive than normal controls of the same age. In addition, they had more difficulties in responding on accurate timing. The largest difference between ADHD and non-ADHD children was revealed in the total score of the test. Moreover, the total score of the MOXO-CPT yielded the highest sensitivity and specificity rates, as compared to any single parameter. Given the complexity of ADHD etiology and clinical manifestation, it is little wonder that the total score of the MOXO-CPT was superior to any single parameter in identifying ADHD. This finding emphasizes the importance of integrating several different attention parameters in measuring attention functions.

Results of the ROC analyses showed that the MOXO-CPT was highly accurate in identifying participants with ADHD, based on the DSM-IV-TR (APA, 2000) criteria. For all ages, optimal cutoff values were associated with both high sensitivity and specificity rates (above 80%).

Selection of a threshold for a screening test is best achieved according to the needs of the specific setting in which it is to be used. 'Optimal' cutoff values vary depending on the risk-benefit ratio between false positive and false negative test results and the base rate of the target disorder in the population at hand. Important information may be lost when defining sensitivity and specificity in relation to a single cutoff value of a continuous variable (Sox,

1
2
3 1986). The discussion regarding which are the best criteria for diagnosis is beyond the scope
4
5 of this study.
6

7
8 The literature has long been debating the reliability and validity of using CPT tests for case
9
10 identification and diagnosis of ADHD (Dickerson et al., 2001; Skounti et al., 2007). Low
11
12 validity of CPT tests may not only lead to inaccurate diagnosis but could also prevent
13
14 effective intervention and might further complicate the symptoms in the long term (Sonuga-
15
16 Barke, Koerting, Smith, McCann, & Thompson, 2011).
17

18
19 The MOXO-CPT has several advantages that may make it preferable for use in clinical and
20
21 diagnostic settings. Due to the presence of distracters, the MOXO-CPT could be construed as
22
23 more ecologically valid. It also allows monitoring the impact of distracting stimuli on the
24
25 attention performance of ADHD children.
26

27
28 In addition, the tests' indices of ADHD symptoms are more accurately defined. Thus, the test
29
30 could distinguish hyperactive behavior from impulsive behavior. Moreover, the timing ability
31
32 was re-conceptualized, so the test could measure two different types of problems: difficulties
33
34 to sustain attention and difficulties in responding on accurate timing. The findings of this
35
36 study are therefore of great value since they offer a sensitive, objective assessment tool in
37
38 assessing ADHD symptomatology.
39

40
41 Several limitations of this study should be considered. The first limitation results from the
42
43 study's sampling method. Participation in the study was based on a voluntary agreement of
44
45 children and their parents. This self-selected sampling strategy tends to be biased towards
46
47 favoring more cooperative and motivated individuals. Therefore, it is not possible to
48
49 determine whether this sample also represents other children that were not recruited and
50
51 whether cooperation is confounded with ADHD variables. This limitation is typical to most
52
53 clinic-based ADHD studies around the world (Gau et al., 2010; Lee & Ausley, 2006).
54
55

56
57 Moreover, the clinics from which ADHD children were recruited were based in tertiary care
58
59
60

1
2
3 hospital. This population has heterogeneous background characteristics including those
4
5 correlates of ADHD. On the other hand, the fact that the control group was recruited from a
6
7 random population supports our findings by showing that the test is able to identify the
8
9 ADHD children from a random population sample.
10

11 Another limitation of the study is the exclusion of ADHD children with severe comorbidities.
12
13 Since ADHD is associated with many psychiatric disorders (Gentile, Atiq, & Gillig, 2006)
14
15 this exclusion limits the generalization of our results.
16
17

18 Future research should explore the psychometric properties of the MOXO-CPT in other age
19
20 groups, in samples with comorbid features, and in different sub-types of ADHD.
21
22

23 Despite its shortcomings, this study suggests important information about using CPT in
24
25 clinical and empirical settings, and may be a first step towards a more accurate and objective
26
27 diagnostic process of ADHD.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

References

Aaron, P. G., Joshi, R. M., and Phipps, J. (2004). A cognitive tool to diagnose predominantly inattentive ADHD behavior. *Journal of Attention Disorders*, 7, 125–135.

doi:10.1177/108705470400700301

American Academy of Pediatrics (2001). Subcommittee on attention-deficit/hyperactivity disorder and committee on quality improvement. Clinical practice guideline: treatment of the school-aged child with attention deficit/hyperactivity disorder. *Pediatrics*, 108, 1033-1044.

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

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders text revision (DSM-IV-TR)*. 4th edn.-text revision. Washington, DC: American Psychiatric Association.

Barkley, R. A. (1991). The ecological validity of laboratory and analogue assessment methods of ADHD symptoms. *Journal of Abnormal Child Psychology*, 19, 149–178.

doi:10.1007/BF00909976

Barkley, R. A. (2006). *Attention deficit hyperactivity disorder: A handbook for diagnosis and treatment* (3rd edn.). New York: Guilford Press. doi:10.1177/1087054706288111

Berger, I., & Goldzweig, G. (2010). Objective measures of attention-deficit/hyperactivity disorder – a pilot study. *Israel Medical Association Journal*, 12, 531-535.

Centers for disease control and prevention (2010. November 12). Increasing prevalence of parent-reported attention-deficit/hyperactivity disorder among children-United States, 2003 and 2007. *Morbidity and Mortality Weekly Report (MMWR)*, 59(44), 1439-1443

Christensen, K.M., & Joschko, M. (2001). Construct validity of the Continuous Attention Test for Children. *The Clinical Neuropsychologist*, 15, 2, 203-209.

doi:10.1076/clin.15.2.203.1899

Conners, C.K. (1997a). *Conners' Parent Rating Scale - Revised (L)*. New York: Multi-Health Systems Inc.

Conners, C.K. (1997b). *Conners' Teacher Rating Scale - Revised (L)*. New York: Multi-Health Systems Inc.

Conners, C.K. (2000). *Conners' continuous performance test II*. Toronto, ON, Canada: Multi-Health Systems Inc.

Corkum, P., & Siegel, L. (1993). Is the continuous performance task a valuable research tool for use with children with attention-deficit-hyperactivity disorder? *Journal of Child Psychology and Psychiatry*, 34, 1217-1239. DOI: 10.1111/j.1469-7610.1993.tb01784.x

DeShazo, T.B., Grofer, L.K., Lyman, R.D., Bush, D., & Hawkins, L. (2001). Visual selective attention versus sustained attention in boys with Attention-Deficit/ Hyperactivity Disorder. *Journal of Attention Disorders*, 4, 193-202.

1
2
3 Dickerson Mayes, S., Calhoun, S.L., & Crowell, E.W. (2001). Clinical validity and
4 interpretation of the Gordon Diagnostic System in ADHD assessments. *Child*
5 *Neuropsychology*, 7, 32-41. doi:10.1076/chin.7.1.32.3151
6
7
8
9

10
11 Edwards, M.C., Gardner, E.S., Chelonis, J.J., Schulz, E.G., Flake, R.A., & Diaz, P.F. (2007).
12 Estimates of the validity and utility of the Conner's CPT in the assessment of inattentive
13 and/or hyperactive impulsive behaviors in children. *Journal of Abnormal Child Psychology*,
14 35,393-404. doi:10.1007/s10802-007-9098-3
15
16
17
18
19

20
21 Epstein, J. N., Erkanli, A., Conners, C. K., Klaric, J., Costello, J. E., & Angold, A. (2003).
22 Relations between continuous performance test performance measures and ADHD behaviors.
23 *Journal of Abnormal Child Psychology*, 31, 543–554. doi:10.1023/A:1025405216339
24
25
26
27
28

29
30 Gau, S., Lin, Y. Shang, C. Liu, S., Chiu, Y., & Soong, W. (2010). Emotional/ behavioral
31 problems and functional impairment in clinic and community-based children with attention-
32 deficit/hyperactivity disorder in Taiwan. *Abnormal Child Psychology*, 38, 521-532.
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

51
52
53
54
55
56
57
58
59
60

Gentile, J., Atiq, R. & Gillig, P.M. (2006). Adult ADHD: Diagnosis, differential diagnosis,
and medication management. *Psychiatry*, 3, 25-30.

Greenberg, L.M. (1997). T.O.V.A Visual continuous performance 15. test. Los Alamitos,
CA: Universal Attention Disorders Inc.

1
2
3 Greenberg M, & Waldman, I. (1993). Developmental normative data on The Test of
4 Variables of Attention (T.O.V.A™). *Journal of Child Psychology and Psychiatry*, 34, 1019-
5 1030. doi:10.1111/j.1469-7610.1993.tb01105.x
6
7
8

9
10
11 Gutiérrez-Maldonado, J., Letosa-Porta , A., Rus-Calafell, M., & Peñaloza-Salazar,C. (2009).
12 The assessment of Attention Deficit Hyperactivity Disorder in children using continuous
13 performance tasks in virtual environments. *Anuario de Psicología*, 40, 211-222.
14
15
16
17
18

19
20 Halperin, J. M., Matier, K., Bedi, G., Sharma, V., & Newcorn, J. H. (1992). Specificity of
21 inattention, impulsivity, and hyperactivity to the diagnosis of attention-deficit hyperactivity
22 disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, 31, 190–196.
23
24
25
26 . doi:10.1097/00004583-199203000-00002
27
28
29

30
31 Lee, D.O., & Ousley, O.Y. (2006). Attention-deficit hyperactivity disorder symptoms in a
32 clinic sample of children and adolescents with pervasive developmental disorders. *Journal of*
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Child and Adolescent Psychopharmacology, 16, 737-746. doi:10.1089/cap.2006.16.737.

McGee, R.A., Clark, S.E., & Symons, D.K. (2000). Does the Conners' Continuous
Performance Test aid in ADHD diagnosis? *Journal of Abnormal Child Psychology*, 28, 415–
442. doi:10.1023/A:1005127504982

National institute of mental health. (2012, January). *Attention deficit hyperactivity disorder*.
Retrieved from: [http://www.nimh.nih.gov/health/publications/attention-deficit-hyperactivity-
disorder/complete-index.shtml](http://www.nimh.nih.gov/health/publications/attention-deficit-hyperactivity-disorder/complete-index.shtml).

1
2
3 Pelham, W.E., Waschbusch, D. A., Hoza, B. Gnagy, E.M., Greiner, A.R., Sams, S.E.,
4
5 Vallano, G., Majumdar, A., & Carter, R.L. (2011). Music and video as distractors for boys
6
7 with ADHD in the classroom: Comparison with controls, individual differences, and
8
9 medication effects . *Journal of Abnormal Child Psychology*, 39, 1085-1098. doi:
10
11 10.1007/s10802-011-9529-z
12

13
14
15
16 Rapport, M. D., Chung, K. M., Shore, G., Denney, C. B., & Issacs, P. (2000). Upgrading the
17
18 science and technology of assessment and diagnosis: Laboratory and clinic-based assessment
19
20 of children with ADHD. *Journal of Clinical Child Psychology*, 29, 555-568.
21
22 doi:10.1207/S15374424JCCP2904_8
23

24
25
26
27 Riccio, C.A., Waldrop, J.J., Reynolds, C.R., & Lowe, P. (2001). Effects of stimulants on the
28
29 continuous performance test (CPT): implications for CPT use and interpretation. *The Journal*
30
31 *of Neuropsychiatry and Clinical Neurosciences*, 13, 326-335.
32
33 doi:10.1176/appi.neuropsych.13.3.326
34
35

36
37
38 Rosvold, H.E., Mirsky, A.F., Sarason, I., Bransome, Jr E.D., & Beck, L.H. (1956). A
39
40 continuous performance test of brain damage. *Journal of Consultant Psychology*, 20, 343–
41
42 350. doi:10.1037/h0043220
43
44

45
46
47 Rousseau, C., Measham, T., & Bathiche-Suidan, M. (2008). DSM -IV, culture and child
48
49 psychiatry. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, 17, 69-75.
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Schachar, R., Logan, G., Wachsmuth, R., & Chajczyk, D.(1988). Attaining and maintaining
4 preparation: A comparison of attention in hyperactive, normal, and disturbed control children.
5
6
7 *Journal of Abnormal Child Psychology*, 16, 361–378. doi:10.1007/BF00914169
8
9

10
11 Seidel, W., & Joschko, M. (1990). Evidence of difficulties in sustained attention in children
12 with ADHD. *Journal of Abnormal Child Psychology*, 18, 217–229. doi:10.1007/BF00910732
13
14
15

16
17
18 Seidman, L.J., Biederman, J., Monuteaux, M., Doyle, A.E., & Faraone, S.V. (2001). Learning
19 disabilities and executive dysfunction in boys with attention deficit hyperactivity disorder.
20
21
22 *Neuropsychology*, 15, 544-556. doi:10.1037//0894-4105.15.4.544
23
24
25

26
27 Serra-Pinheiro, M.A., Mattos, P., & Regalla, A.M. (2008). Inattention, hyperactivity, and
28 oppositional-defiant symptoms in Brazilian adolescents: gender prevalence and agreement
29 between teachers and parents in a non-English speaking population. *Journal of Attention*
30
31
32 *Disorders*, 12, 135-140.
33
34
35

36
37
38 Skounti, M., Philalithis, A., & Galanakis, E. (2007). Variations in prevalence of attention
39 deficit hyperactivity disorder worldwide. *European Journal of Pediatrics*, 166, 117-123. doi:
40
41
42 10.1007/s00431-006-0299-5
43
44
45

46
47 Sonuga-Barke E.J., Koerting, J., Smith, E., McCann, D.C., & Thompson, M. (2011). Early
48 detection and intervention for attention-deficit/hyperactivity disorder. *Expert Review of*
49
50
51 *Neurotherapeutics*, 11, 557-563. doi:10.1586/ern.11.39
52
53
54
55
56
57
58
59
60

1
2
3 Sox, H.C.J. (1986). Probability theory in the use of diagnostic tests. *Annals of Internal*
4
5 *Medicine*, 104, 60-66.
6
7

8
9
10 Trommer, B.L., Hoepfner, J.B., Lorber, R., & Armstrong, K. (1988). Pitfalls in the use of a
11
12 continuous performance test as a diagnostic tool in attention deficit disorder. *Journal of*
13
14 *Developmental and Behavioral Pediatrics*, 9, 339-345. doi:10.1097/00004703-198812000-
15
16 00005
17

18
19
20 Werry, J.S., Reeves, J. C., & Elkind, G.S. (1987). Attention deficit, conduct, oppositional,
21
22 and anxiety disorders in children: A review of research on differentiating characteristics.
23
24 *Journal of the American Academy of Child and Adolescent Psychiatry*, 26, 133-143.
25
26
27 doi:10.1097/00004583-198703000-00003
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Abstract

This study examined the validity of a Continuous Performance Test (MOXO-CPT) among 798 children aged 7-12 years. Receiver Operating Characteristic (ROC) analyses showed that the MOXO-CPT was highly accurate in identifying ADHD children who were previously diagnosed by using DSM-IV-TR criteria. In addition, the test significantly discriminated ADHD children from non-ADHD children.

These findings emphasize the importance of incorporating distracters into CPT and integrating several different attention parameters when measuring attention functions.

In light of the criticism voiced against the low validity of CPT's, a valid CPT would be valuable for theory, research, and clinical work.

Introduction

Attention-deficit hyperactivity disorder (ADHD) is among the most common neurobehavioral disorders of childhood, characterized by inattention, impulsivity and hyperactivity. Using the DSM-IV criteria (APA, 1994), prevalence rates in the United States ranged from 7.4% to 9.9% (Barkley, 2006; CDC, 2010).

In the absence of available biological markers that would support conferring diagnoses, information about the symptoms is usually collected by using interviews based on DSM-IV-TR criteria of ADHD and validated behavioral rating scales (AAP, 2001; APA, 2000; Skounti, Philalithis, & Galanakis, 2007). The subjective nature of these methods makes them vulnerable to clinician and informant biases (Rousseau, Measham, & Bathiche-Suidan, 2008; Serra-Pinheiro, Mattos, & Regalla, 2008; Skounti et al., 2007).

As a result, there has long been interest in developing objective laboratory-based measures that could support the clinical diagnosis of ADHD. One of the most popular laboratory-based tools is the computerized continuous performance test (CPT), which was originally developed as a measure of vigilance (Rosvold, Mirsky, Sarason, Bransome & Beck, 1956). Generally, CPT tasks require the subjects to maintain vigilance and react to the presence (or absence) of a specific stimulus within a set of distracters presented continuously.

The use of the CPT as an objective measure of attention in ADHD has several advantages. It can measure the ability to concentrate on a single task for a certain length of time. In addition, it is considered an objective tool to gather quantifiable information on the changes of attention as a result of a medical or non-medical treatment. Finally, CPT is inexpensive, easy to administer, and some versions include appropriate age norms.

Despite its vast popularity in clinical and empirical settings, many authors have identified concerns about using CPT as a diagnostic tool. One of the major controversies regarding the CPT is related to its low sensitivity and specificity rates (Edwards et al., 2007; McGee, Clark

1
2
3 & Symons, 2000; Riccio, Waldrop, Reynolds, & Lowe, 2001; Skounti et al., 2007). Although
4
5 some studies (Aaron, Joshi, and Phipps, 2004; Epstein et al., 2003; Seidel & Joschko, 1990)
6
7 have demonstrated differences in CPT performance between ADHD and normal controls,
8
9 many others have questioned its ability to consistently discriminate ADHD children from
10
11 normal controls, psychiatric controls or learning disabilities (Corkum & Siegel, 1993;
12
13 DeShazo, Grofer, Lyman, Bush, & Hawkins, 2001; Schachar, Logan, Wachsmuth, &
14
15 Chajczyk, 1988; Trommer, Hoepfner, Lorber, & Armstrong, 1988; Werry, Reeves, & Elkind,
16
17 1987).

18
19
20 The CPT was also criticized for its low ecological validity (Barkley, 1991; Pelham et al.,
21
22 2011; Rapport, Chung, Shore, Denney, & Isaacs, 2000). That is, the CPT ability to simulate
23
24 the difficulties of ADHD patients in everyday life. Being administered in laboratory
25
26 conditions (Barkley, 1991; Gutiérrez-Maldonado, Letosa-Porta, Rus-Calafell, & Peñaloza-
27
28 Salazar, 2009), CPT are usually free of distracting stimuli, which are thought to impair the
29
30 cognitive performance of ADHD children (APA, 1994; 2000).

31
32
33 In light of the limitations of the existing CPTs, the American Academy of Pediatrics did not
34
35 support the use of CPT tests in the diagnostic process of ADHD (AAP, 2001). At the same
36
37 time, the inaccuracy of the subjective measurement tools of ADHD still calls for a reliable
38
39 and valid CPT tests (AAP, 2001; Dickerson Mayes, Calhoun, & Crowell, 2001; Skounti et
40
41 al., 2007).

42
43
44 The current study examined the validity of the MOXO-CPT (Berger & Goldzweig, 2010) in
45
46 the diagnosis of ADHD in children aged 7-12 years. This study had two objectives: the first
47
48 one was to assess the MOXO-CPT's ability to measure differences in attention performance
49
50 among ADHD versus non-ADHD children. The second objective was to evaluate the
51
52 construct validity of the MOXO-CPT in the diagnosis of ADHD, using the DSM-IV-TR
53
54 criteria (APA, 2000) as the 'gold standard'.
55
56
57
58
59
60

1
2
3 The term 'MOXO' derives from the world of Japanese martial arts and means a 'moment of
4 lucidity'. It refers to the moments preceding the fight, when the warrior clears his mind from
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

The term 'MOXO' derives from the world of Japanese martial arts and means a 'moment of lucidity'. It refers to the moments preceding the fight, when the warrior clears his mind from distracting, unwanted thoughts and feelings.

Results of a pilot study with a small group of children (Berger & Goldzweig, 2010) showed that the MOXO-CPT was valid for ADHD diagnosis in children, and was more sensitive to ADHD than other CPT tests, such as the T.O.V.A (Greenberg, 1997) and the Conners CPT (Conners, 2000).

Methods

Participants

Participants in this study were 798 children aged 7 to 12 years, of them 493 boys and 305 girls. The study group included 339 children diagnosed with ADHD (Mean age, 9.27, S.D=1.65) and the control group included 459 children without ADHD (Mean age =9.71, S.D=1.64).

The children were divided to six different age categories (7, 8, 9, 10, 11, and 12 years). For example, the category of "8 years" included children who were equal or older than 8, but younger than 9.

As can be seen in Table 1, within each age category, the study and control group did not differ in gender distributions.

Participants in the ADHD group were recruited from children referred to the out-patient pediatric clinics of the Neuro-Cognitive Center, based in a tertiary care university hospital.

The children were referred through their pediatrician, general practitioner, teacher, psychologist, or directly by the parents.

1
2
3 Inclusion criteria for participants in the ADHD group were:

- 4
5 1. Each child met the criteria for ADHD according to DSM-IV-TR criteria (APA, 2000), as
6
7 assessed by a certified pediatric neurologist. The diagnostic procedure included an interview
8
9 with the child and parents, fulfillment of questionnaires, and medical/neurological
10
11 examination that confirmed ADHD diagnosis.
12
13 2. Each child scored above the standard clinical cutoffs for ADHD symptoms on Conners'
14
15 ADHD/DSM-IV Scales (Conners, 1997a; Conners, 1997b, APA, 2000).
16
17 3. All children were drug naïve.
18
19

20 Participants in the control group were randomly recruited from pupils in primary schools.

21
22 Inclusion criteria for participants in the control group were:

- 23
24 1. Each child scored below the clinical cutoff point for ADHD symptoms on Conners'
25
26 ADHD/DSM-IV Scales (Conners, 1997a; Conners, 1997b).
27
28 2. Absence of academic or behavioral problems, as reported by parents and teachers.
29
30

31
32 Exclusion criteria were intellectual disability, other chronic condition, chronic use of
33
34 medications, and other primary psychiatric diagnosis (e.g., depression, anxiety, and
35
36 psychosis).
37

38
39 All participants agreed to participate in the study and their parents gave written informed
40
41 consent to the study, approved by the Helsinki committee (IRB) of Hadassah-Hebrew
42
43 University Medical Center (Jerusalem, Israel).
44
45

46 47 *Measures*

48
49 Measurement of child behavior - The parent and teacher forms of the Conner's
50
51 ADHD/DSM-IV Scales were used to assess the level of children's ADHD behaviors
52
53 (Conners, 1997a; Conners, 1997b; APA 2000).
54
55
56
57
58
59
60

MOXO- CPT Description

This version of the CPT is a computerized performance test as previously described (Berger & Goldzweig, 2010). A set of target and non-target stimuli were shown sequentially in the middle of a computer screen. The child was instructed to respond as quickly as possible to the target stimuli by pressing the keyboard's space bar once, and only once. In addition, the child was instructed to avoid responding to all other stimuli or pressing any other key. While performing the CPT, the children were accompanied by technician who made sure that the children understood the instructions and watched them throughout the test without interfering.

Both target and non-target stimuli were cartoon pictures that did not include any letters or numbers (see Figure 1). These features are significant, given that some children with ADHD also demonstrate learning difficulties (e.g., dyslexia) that may be confounded with CPT performance (Seidman, Biederman, Monuteaux, Doyle, & Faraone, 2001).

The MOXO-CPT duration was 15.2 minutes, contained eight levels, each of them 114 seconds long. Every level included three types of elements: a target stimulus, a non-target stimulus, and a "void" period. First, a stimulus (target/ non-target) was presented for a changing duration of time (3 sec, 1 sec, or 0.5 seconds). Then, the stimulus was followed by a "void" period (blank screen) of the same duration. Prior to the void period, the stimulus (target / non-target) was presented on the screen whether or not the participant responded to it. In other words, pressing the keyboard's space bar did not eliminate the stimulus.

This method of presentation enabled to measure the timing of the response (whether the response occurred during stimulus presentation or during the void period) as well as the accuracy of the press (whether the response occurred at all). Each level included 33 targets stimuli, 20 non-target stimuli, and 53 void periods.

1
2
3 Distracters - In order to simulate everyday environment, the MOXO-CPT contained
4 interfering stimuli that serve as distracters. The distracters included three types of basic
5 elements that characterize the child's environment: a) pure visual distracters (e.g., flying
6 birds, magician's wand), b) pure auditory distracters (e.g., a voice of a gong, squeaking birds),
7 and c) combination of both the visual and auditory distracters. Overall, six different
8 distracters were presented (Figure 2). Every one of the eight levels of the MOXO-CPT
9 included a different set of distracters: two levels (1 and 8) contained only target and non-
10 target stimuli without distracters, two levels (2 and 3) contained pure visual stimuli, two
11 levels (4 and 5) contained pure auditory stimuli, and two levels (6 and 7) contained a
12 combination of visual and auditory stimuli.
13

14 While the target stimulus was presented at the center of the screen, the visual distracters
15 appeared at one of the four sides of the display: down, up, left or right. The sequence of
16 distracters and their exact position on the display were predefined for each level. Distracters
17 were displayed for varied durations ranging from for 3.5 to 14.7 seconds, with a constant void
18 interval of 0.5 second between two sequential distracting elements.
19

20 The burden of the interfering stimuli increased in the odd number levels. That is, the third,
21 fifth, and seventh levels included higher burden of distracters than the second, fourth and
22 sixth levels, respectively.
23

24 *Performance indices* – The MOXO-CPT included four indices named: Attention, Timing,
25 Impulsivity, and Hyperactivity.
26

27 Attention – This parameter included the number of correct responses (pressing the key in
28 response to a target stimulus), which were performed either during the stimulus presentation
29 on the screen or during the void period that followed. Thus, it was possible to evaluate
30 whether the participant responded correctly to the target (was attentive to the target)
31 independently of how fast he was. Knowing how many responses are expected, it was also
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 possible to calculate the number of times the target was presented, but the patient did not
4
5 respond to it (omission errors).
6

7 Timing – This parameter included the number of correct responses (pressing the key in
8
9 response to a target stimulus) which were performed only while the target stimulus was still
10
11 presented on the screen. This parameter did not include responses that were performed during
12
13 the void period (after the stimulus has disappeared).
14

15
16 According to the National Institute of Mental Health (2012), inattention problems in
17
18 ADHD may be expressed in "difficulties in processing information as quickly and accurately
19
20 as others". Traditionally, difficulties in timing at a CPT are evaluated by mean response time
21
22 for correct responses to the target (which is interpreted as a measure of information
23
24 processing and motor response speed) and by the standard deviation of response time for
25
26 correct responses to the target (which is interpreted as a measure of variability or consistency)
27
28 (Greenberg & Waldman, 1993; Halperin, Matier, Bedi, Sharma, & Newcorn, 1992). In these
29
30 paradigms the stimulus is presented for short and fixed periods of time and the response
31
32 occurs after the stimulus has disappeared. Given the short, fixed presentation, accurate but
33
34 slow participants may be mistakenly diagnosed as inattentive. While a group of patients
35
36 would respond correctly if allowed more time, inattentive patients would not respond at all
37
38 because they were not alert to the target. Therefore, the measurement of response time per-se,
39
40 addresses only the ability to respond quickly, but not the ability to respond accurately.
41
42

43
44 By implanting a void period after each stimulus and using variable presentation durations of
45
46 the elements, the MOXO-CPT could distinguish accurate responses performed in "good
47
48 timing" (quick and correct responses to the target performed during stimulus presentation)
49
50 from accurate but slow responses (correct responses to the target performed after the stimulus
51
52 presentation; during the void period). These two aspects of timing correspond to the two
53
54
55
56
57
58
59
60

1
2
3 different problems of ADHD described by the National Institute of Mental Health (2012):
4
5 responding quickly and responding accurately.
6

7 Impulsivity - This parameter included the number of commission errors (responses to a non-
8 target stimulus), performed as the initial response to the non-target stimuli. Usually,
9 commission errors are coded in any case of inappropriate response to the target (e.g., pressing
10 a random key) (Greenberg & Waldman, 1993). In contrast, the MOXO-CPT's impulsivity
11 parameter considered as impulsive behavior only the first pressing on the keyboard's space-
12 bar in response to non-target stimulus. All other non-inhibited responses (e.g., pressing the
13 keyboard more than once) were not coded as impulsive responses (as will describe in the next
14 paragraph).
15
16
17
18
19
20
21
22
23

24 Hyperactivity - This parameter included all types of commission responses that are not coded
25 as impulsive responses. Several examples are: 1. Multiple responses- pressing the keyboard's
26 space bar more than once (in response to target/ non-target), which is commonly interpreted
27 as a measure of motor hyper-responsivity (Greenberg & Waldman, 1993). The MOXO-CPT
28 considered as multiple responses only the second press and above (the first response would
29 be considered as correct response with good timing, as correct response with poor timing, or
30 as impulsive response, depends on the type of element appearing on the screen). 2. Random
31 key pressing - pressing any keyboard button other than the space bar. By separating
32 commission errors due to impulsive behavior from commission errors due to motor hyper-
33 responsivity, it was possible to identify the multiple sources of response inhibition problems.
34 Thus, the MOXO- CPT was able to differentiate impulsive responses from hyperactive
35 responses.
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Data Analyses

All analyses were conducted with Matlab version R2011b. In order to compare the performance of ADHD children and non-ADHD children, independent samples T-tests were performed, for each one of the four MOXO-CPT parameters. The diagnostic value of the MOXO-CPT was assessed by calculating the areas under the receiver operating characteristic (ROC) curves, which were used to assess the best cutoff points to distinguish between ADHD and non-ADHD children.

Results

Differentiating Between ADHD and non-ADHD children

Differences between the study and the control group in the four parameters of performance in the MOXO-CPT (attention, timing, hyperactivity, and impulsivity) were examined by two tailed T-test analyses for independent samples. In addition, differences between the groups were measured by comparing the total score of the MOXO-CPT, which takes into account all four parameters (Table 2). Results of the analyses revealed that in all age categories, significant differences were found between ADHD and non-ADHD children. As can be seen in table 2, ADHD children received significantly lower scores in the Attention and Timing parameters than normal controls. That is, ADHD children were less attended to the stimuli and performed less reactions on accurate time. Furthermore, ADHD children received significantly higher scores in the Hyperactivity and Impulsivity parameters than normal controls. Thus, ADHD children produced more Hyperactive and Impulsive responses as compared to non-ADHD children. Finally, ADHD children received higher total scores in the MOXO-CPT as compared to non-ADHD children. That is, ADHD children's general performance in the MOXO-CPT was worse than their unaffected peers of the same age. It should also be noted that using the total score of the MOXO-CPT produced the highest

1
2
3 difference between ADHD and non-ADHD performance, as compared to any single
4
5 parameter.
6
7

8 9 *Diagnostic Utility of the MOXO-CPT*

10 Since inclusion criteria required that each participating child (in the ADHD group) met the
11 criteria for ADHD diagnosis according to DSM-IV-TR (APA, 2000), the sensitivity and
12 specificity of the MOXO-CPT were calculated using these criteria. Results of ROC analyses
13 are presented in table 3. The table shows the cut-off points, sensitivity and specificity rates of
14 the MOXO-CPT, based on the total scores of the MOXO-CPT (taking into account all four
15 parameters). Different sensitivity and specificity rates could be used for different purposes of
16 the test (e.g., screening, diagnosis). However, we have used the optimal value which
17 represents the maximized classification accuracy with the highest sensitivity and specificity
18 rates. Results showed that in all age categories, the optimal cut-off points were associated
19 with both high sensitivity and specificity rates (all above 80%).
20
21
22
23
24
25
26
27
28
29
30
31
32
33

34 Figure 3 presents an example of a ROC analysis, in a group of children aged 8-9 years. As
35 can be seen in the figure, the total score of the MOXO-CPT produced the highest sensitivity
36 and specificity rates, as compared to any single parameter.
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Discussion

The current study investigated the diagnostic utility of the MOXO-CPT (Berger & Goldzweig, 2010) for the assessment of ADHD in a sample of children aged 7-12 years. Results showed that the MOXO-CPT significantly discriminated between children with ADHD and their unaffected peers of the same age. As measured by the MOXO-CPT, children with ADHD were more inattentive, more impulsive and more hyperactive than normal controls of the same age. In addition, they had more difficulties in responding on accurate timing. The largest difference between ADHD and non-ADHD children was revealed in the total score of the test. Moreover, the total score of the MOXO-CPT yielded the highest sensitivity and specificity rates, as compared to any single parameter. Given the complexity of ADHD etiology and clinical manifestation, it is little wonder that the total score of the MOXO-CPT was superior to any single parameter in identifying ADHD. This finding emphasizes the importance of integrating several different attention parameters in measuring attention functions.

Results of the ROC analyses showed that the MOXO-CPT was highly accurate in identifying participants with ADHD, based on the DSM-IV-TR (APA, 2000) criteria. For all ages, optimal cutoff values were associated with both high sensitivity and specificity rates (above 80%).

Selection of a threshold for a screening test is best achieved according to the needs of the specific setting in which it is to be used. 'Optimal' cutoff values vary depending on the risk-benefit ratio between false positive and false negative test results and the base rate of the target disorder in the population at hand. Important information may be lost when defining sensitivity and specificity in relation to a single cutoff value of a continuous variable (Sox,

1
2
3 1986). The discussion regarding which are the best criteria for diagnosis is beyond the scope
4
5 of this study.

6
7 The literature has long been debating the reliability and validity of using CPT tests for case
8
9 identification and diagnosis of ADHD (Dickerson et al., 2001; Skounti et al., 2007). Low
10
11 validity of CPT tests may not only lead to inaccurate diagnosis but could also prevent
12
13 effective intervention and might further complicate the symptoms in the long term (Sonuga-
14
15 Barke, Koerting, Smith, McCann, & Thompson, 2011).

16
17 The MOXO-CPT has several advantages that may make it preferable for use in clinical and
18
19 diagnostic settings. Due to the presence of distracters, the MOXO-CPT could be construed as
20
21 more ecologically valid. It also allows monitoring the impact of distracting stimuli on the
22
23 attention performance of ADHD children.

24
25 In addition, the tests' indices of ADHD symptoms are more accurately defined. Thus, the test
26
27 could distinguish hyperactive behavior from impulsive behavior. Moreover, the timing ability
28
29 was re-conceptualized, so the test could measure two different types of problems: difficulties
30
31 to sustain attention and difficulties in responding on accurate timing. The findings of this
32
33 study are therefore of great value since they offer a sensitive, objective assessment tool in
34
35 assessing ADHD symptomatology.

36
37 Several limitations of this study should be considered. The first limitation results from the
38
39 study's sampling method. Participation in the study was based on a voluntary agreement of
40
41 children and their parents. This self-selected sampling strategy tends to be biased towards
42
43 favoring more cooperative and motivated individuals. Therefore, it is not possible to
44
45 determine whether this sample also represents other children that were not recruited and
46
47 whether cooperation is confounded with ADHD variables. This limitation is typical to most
48
49 clinic-based ADHD studies around the world (Gau et al., 2010; Lee & Ausley, 2006).

50
51 Moreover, the clinics from which ADHD children were recruited were based in tertiary care
52
53
54
55
56
57
58
59
60

1
2
3 hospital. This population has heterogeneous background characteristics including those
4
5 correlates of ADHD. On the other hand, the fact that the control group was recruited from a
6
7 random population supports our findings by showing that the test is able to identify the
8
9 ADHD children from a random population sample.
10

11 Another limitation of the study is the exclusion of ADHD children with severe comorbidities.
12
13 Since ADHD is associated with many psychiatric disorders (Gentile, Atiq, & Gillig, 2006)
14
15 this exclusion limits the generalization of our results.
16
17

18 Future research should explore the psychometric properties of the MOXO-CPT in other age
19
20 groups, in samples with comorbid features, and in different sub-types of ADHD.
21
22

23 Despite its shortcomings, this study suggests important information about using CPT in
24
25 clinical and empirical settings, and may be a first step towards a more accurate and objective
26
27 diagnostic process of ADHD.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

References

Aaron, P. G., Joshi, R. M., and Phipps, J. (2004). A cognitive tool to diagnose predominantly inattentive ADHD behavior. *Journal of Attention Disorders*, 7, 125–135.

doi:10.1177/108705470400700301

American Academy of Pediatrics (2001). Subcommittee on attention-deficit/hyperactivity disorder and committee on quality improvement. Clinical practice guideline: treatment of the school-aged child with attention deficit/hyperactivity disorder. *Pediatrics*, 108, 1033-1044.

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

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders text revision (DSM-IV-TR)*. 4th edn.-text revision. Washington, DC: American Psychiatric Association.

Barkley, R. A. (1991). The ecological validity of laboratory and analogue assessment methods of ADHD symptoms. *Journal of Abnormal Child Psychology*, 19, 149–178.

doi:10.1007/BF00909976

Barkley, R. A. (2006). *Attention deficit hyperactivity disorder: A handbook for diagnosis and treatment* (3rd edn.). New York: Guilford Press. doi:10.1177/1087054706288111

Berger, I., & Goldzweig, G. (2010). Objective measures of attention-deficit/hyperactivity disorder – a pilot study. *Israel Medical Association Journal*, 12, 531-535.

Centers for disease control and prevention (2010. November 12). Increasing prevalence of parent-reported attention-deficit/hyperactivity disorder among children-United States, 2003 and 2007. *Morbidity and Mortality Weekly Report (MMWR)*, 59(44), 1439-1443

Christensen, K.M., & Joschko, M. (2001). Construct validity of the Continuous Attention Test for Children. *The Clinical Neuropsychologist*, 15, 2, 203-209.

doi:10.1076/clin.15.2.203.1899

Conners, C.K. (1997a). *Conners' Parent Rating Scale - Revised (L)*. New York: Multi-Health Systems Inc.

Conners, C.K. (1997b). *Conners' Teacher Rating Scale - Revised (L)*. New York: Multi-Health Systems Inc.

Conners, C.K. (2000). *Conners' continuous performance test II*. Toronto, ON, Canada: Multi-Health Systems Inc.

Corkum, P., & Siegel, L. (1993). Is the continuous performance task a valuable research tool for use with children with attention-deficit-hyperactivity disorder? *Journal of Child Psychology and Psychiatry*, 34, 1217-1239. DOI: 10.1111/j.1469-7610.1993.tb01784.x

DeShazo, T.B., Grofer, L.K., Lyman, R.D., Bush, D., & Hawkins, L. (2001). Visual selective attention versus sustained attention in boys with Attention-Deficit/ Hyperactivity Disorder. *Journal of Attention Disorders*, 4, 193-202.

1
2
3 Dickerson Mayes, S., Calhoun, S.L., & Crowell, E.W. (2001). Clinical validity and
4 interpretation of the Gordon Diagnostic System in ADHD assessments. *Child*
5
6
7 *Neuropsychology*, 7, 32-41. doi:10.1076/chin.7.1.32.3151
8
9

10
11 Edwards, M.C., Gardner, E.S., Chelonis, J.J., Schulz, E.G., Flake, R.A., & Diaz, P.F. (2007).
12 Estimates of the validity and utility of the Conner's CPT in the assessment of inattentive
13 and/or hyperactive impulsive behaviors in children. *Journal of Abnormal Child Psychology*,
14 35,393-404. doi:10.1007/s10802-007-9098-3
15
16
17
18
19

20
21
22 Epstein, J. N., Erkanli, A., Conners, C. K., Klaric, J., Costello, J. E., & Angold, A. (2003).
23 Relations between continuous performance test performance measures and ADHD behaviors.
24
25
26
27 *Journal of Abnormal Child Psychology*, 31, 543–554. doi:10.1023/A:1025405216339
28
29

30
31 Gau, S., Lin, Y. Shang, C. Liu, S., Chiu, Y., & Soong, W. (2010). Emotional/ behavioral
32 problems and functional impairment in clinic and community-based children with attention-
33 deficit/hyperactivity disorder in Taiwan. *Abnormal Child Psychology*, 38, 521-532.
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
214

1
2
3 Greenberg M, & Waldman, I. (1993). Developmental normative data on The Test of
4 Variables of Attention (T.O.V.A™). *Journal of Child Psychology and Psychiatry*, 34, 1019-
5 1030. doi:10.1111/j.1469-7610.1993.tb01105.x
6
7
8

9
10
11 Gutiérrez-Maldonado, J., Letosa-Porta , A., Rus-Calafell, M., & Peñaloza-Salazar,C. (2009).
12 The assessment of Attention Deficit Hyperactivity Disorder in children using continuous
13 performance tasks in virtual environments. *Anuario de Psicología*, 40, 211-222.
14
15
16
17
18

19
20 Halperin, J. M., Matier, K., Bedi, G., Sharma, V., & Newcorn, J. H. (1992). Specificity of
21 inattention, impulsivity, and hyperactivity to the diagnosis of attention-deficit hyperactivity
22 disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, 31, 190–196.
23
24
25
26 . doi:10.1097/00004583-199203000-00002
27
28
29

30
31 Lee, D.O., & Ousley, O.Y. (2006). Attention-deficit hyperactivity disorder symptoms in a
32 clinic sample of children and adolescents with pervasive developmental disorders. *Journal of*
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Child and Adolescent Psychopharmacology, 16, 737-746. doi:10.1089/cap.2006.16.737.

McGee, R.A., Clark, S.E., & Symons, D.K. (2000). Does the Conners' Continuous
Performance Test aid in ADHD diagnosis? *Journal of Abnormal Child Psychology*, 28, 415–
442. doi:10.1023/A:1005127504982

National institute of mental health. (2012, January). *Attention deficit hyperactivity disorder*.
Retrieved from: [http://www.nimh.nih.gov/health/publications/attention-deficit-hyperactivity-
disorder/complete-index.shtml](http://www.nimh.nih.gov/health/publications/attention-deficit-hyperactivity-disorder/complete-index.shtml).

1
2
3 Pelham, W.E., Waschbusch, D. A., Hoza, B. Gnagy, E.M., Greiner, A.R., Sams, S.E.,
4
5 Vallano, G., Majumdar, A., & Carter, R.L. (2011). Music and video as distractors for boys
6
7 with ADHD in the classroom: Comparison with controls, individual differences, and
8
9 medication effects . *Journal of Abnormal Child Psychology*, 39, 1085-1098. doi:
10
11 10.1007/s10802-011-9529-z
12

13
14
15
16 Rapport, M. D., Chung, K. M., Shore, G., Denney, C. B., & Issacs, P. (2000). Upgrading the
17
18 science and technology of assessment and diagnosis: Laboratory and clinic-based assessment
19
20 of children with ADHD. *Journal of Clinical Child Psychology*, 29, 555-568.
21
22 doi:10.1207/S15374424JCCP2904_8
23

24
25
26
27 Riccio, C.A., Waldrop, J.J., Reynolds, C.R., & Lowe, P. (2001). Effects of stimulants on the
28
29 continuous performance test (CPT): implications for CPT use and interpretation. *The Journal*
30
31 *of Neuropsychiatry and Clinical Neurosciences*, 13, 326-335.
32
33 doi:10.1176/appi.neuropsych.13.3.326
34
35

36
37
38 Rosvold, H.E., Mirsky, A.F., Sarason, I., Bransome, Jr E.D., & Beck, L.H. (1956). A
39
40 continuous performance test of brain damage. *Journal of Consultant Psychology*, 20, 343–
41
42 350. doi:10.1037/h0043220
43
44

45
46
47 Rousseau, C., Measham, T., & Bathiche-Suidan, M. (2008). DSM -IV, culture and child
48
49 psychiatry. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, 17, 69-75.
50
51

1
2
3 Schachar, R., Logan, G., Wachsmuth, R., & Chajczyk, D.(1988). Attaining and maintaining
4 preparation: A comparison of attention in hyperactive, normal, and disturbed control children.
5
6
7 *Journal of Abnormal Child Psychology*, 16, 361–378. doi:10.1007/BF00914169
8
9

10
11 Seidel, W., & Joschko, M. (1990). Evidence of difficulties in sustained attention in children
12 with ADHD. *Journal of Abnormal Child Psychology*, 18, 217–229. doi:10.1007/BF00910732
13
14
15

16
17
18 Seidman, L.J., Biederman, J., Monuteaux, M., Doyle, A.E., & Faraone, S.V. (2001). Learning
19 disabilities and executive dysfunction in boys with attention deficit hyperactivity disorder.
20
21
22 *Neuropsychology*, 15, 544-556. doi:10.1037//0894-4105.15.4.544
23
24
25

26
27 Serra-Pinheiro, M.A., Mattos, P., & Regalla, A.M. (2008). Inattention, hyperactivity, and
28 oppositional-defiant symptoms in Brazilian adolescents: gender prevalence and agreement
29 between teachers and parents in a non-English speaking population. *Journal of Attention*
30
31
32 *Disorders*, 12, 135-140.
33
34
35

36
37
38 Skounti, M., Philalithis, A., & Galanakis, E. (2007). Variations in prevalence of attention
39 deficit hyperactivity disorder worldwide. *European Journal of Pediatrics*, 166, 117-123. doi:
40
41
42 10.1007/s00431-006-0299-5
43
44
45

46
47 Sonuga-Barke E.J., Koerting, J., Smith, E., McCann, D.C., & Thompson, M. (2011). Early
48 detection and intervention for attention-deficit/hyperactivity disorder. *Expert Review of*
49
50
51 *Neurotherapeutics*, 11, 557-563. doi:10.1586/ern.11.39
52
53
54
55
56
57
58
59
60

1
2
3 Sox, H.C.J. (1986). Probability theory in the use of diagnostic tests. *Annals of Internal*
4
5 *Medicine*, 104, 60-66.
6
7

8
9
10 Trommer, B.L., Hoepfner, J.B., Lorber, R., & Armstrong, K. (1988). Pitfalls in the use of a
11
12 continuous performance test as a diagnostic tool in attention deficit disorder. *Journal of*
13
14 *Developmental and Behavioral Pediatrics*, 9, 339-345. doi:10.1097/00004703-198812000-
15
16 00005
17

18
19
20 Werry, J.S., Reeves, J. C., & Elkind, G.S. (1987). Attention deficit, conduct, oppositional,
21
22 and anxiety disorders in children: A review of research on differentiating characteristics.
23
24 *Journal of the American Academy of Child and Adolescent Psychiatry*, 26, 133-143.
25
26
27 doi:10.1097/00004583-198703000-00003
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1: Participants' Background Variables

Age		ADHD (N=339)	Control (N=459)	
7	N	62	64	
	Male	40 (64.52)	37 (57.81)	$\chi^2(1, N=798) = 1.14, p=0.29$
	female	22 (35.48)	30 (42.19)	
8	N	67	75	
	Male	47 (70.15)	50 (66.67)	$\chi^2(1, N=798) = 0.37, p=0.55$
	female	20 (29.85)	25 (33.33)	
9	N	67	71	
	Male	37 (64.91)	46 (64.69)	$\chi^2(1, N=798) = 0.0004, p=0.98$
	female	30 (35.09)	25 (35.31)	
10	N	62	87	
	Male	35 (56.45)	47 (54.02)	$\chi^2(1, N=798) = 0.15, p=0.70$
	female	27 (44.55)	40 (45.98)	
11	N	51	87	
	Male	32 (62.74)	55 (63.21)	$\chi^2(1, N=798) = 0.01, p=0.94$
	female	19 (37.26)	32 (27.79)	
12	N	40	74	
	Male	24 (60)	44 (59.46)	$\chi^2(1, N=798) = 0.01, p=0.94$
	female	16 (40)	30 (40.54)	

Table 2: Differences between ADHD children and non-ADHD children in MOXO-CPT performance

Age category (Years)	MOXO-CPT parameter	ADHD (N=339)	Control (N=459)	t	df	p(2-tailed)
		Mean (S.D)	Mean (S.D)			
7	Attention	216.05 (28.44)	248.92 (9.57)	-8.75	124	<0.001
	Timing	138.10 (31.35)	190.17 (22.94)	-10.66	124	<0.001
	Hyperactive	54.81 (43.38)	28.70 (19.04)	4.40	124	<0.001
	Impulsivity	19.32 (11.65)	14.73 (8.72)	2.51	124	0.01
	Total Score	262.38 (78.96)	138.78 (42.23)	11.00	124	<0.001
8	Attention	228.90 (23.07)	251.36 (9.02)	-7.79	140	<0.001
	Timing	148.10 (28.74)	197.32 (23.29)	-11.26	140	<0.001
	Hyperactive	52.54 (37.69)	23.13 (16.37)	6.14	140	<0.001
	Impulsivity	20.13 (18.88)	14.59 (8.61)	2.29	140	0.02
	Total Score	229.04 (67.32)	120.30 (39.20)	11.91	140	<0.001
9	Attention	237.19 (23.88)	253.93 (8.79)	-5.47	136	<0.001
	Timing	167.32 (33.17)	207.89 (23.79)	-8.05	136	<0.001
	Hyperactive	42.65 (30.72)	21.97 (15.90)	4.91	136	<0.001
	Impulsivity	19.35 (12.92)	13.97 (7.91)	2.90	136	0.004
	Total Score	189.71 (55.46)	107.04 (33.24)	10.44	136	<0.001
10	Attention	247.19 (14.68)	256.55 (7.34)	-5.12	147	<0.001
	Timing	184.89 (31.20)	220.14 (20.94)	-8.20	147	<0.001
	Hyperactive	41.37 (31.69)	18.16 (12.39)	6.21	147	<0.001

	Impulsivity	20.61	(14.42)	14.06	(6.37)	3.76	147	<0.001
	Total Score	159.70	(46.35)	85.47	(31.18)	11.69	147	<0.001
11	Attention	247.88	(14.81)	257.24	(6.22)	-5.17	136	<0.001
	Timing	192.67	(28.28)	224.71	(20.45)	-7.69	136	<0.001
	Hyperactive	43	(37.01)	15.48	(12.18)	6.38	136	<0.001
	Impulsivity	19.84	(14.58)	12.85	(6.85)	3.81	136	<0.001
	Total Score	151.29	43.97	75.02	(29.51)	12.18	136	<0.001
12	Attention	249.50	(15.74)	258.44	(4.98)	-4.50	112	<0.001
	Timing	202.73	(26.84)	228.13	(16.90)	-6.19	112	<0.001
	Hyperactive	40.55	(52.15)	13.013	(10.23)	4.40	112	<0.001
	Impulsivity	18.70	(13.26)	12.42	(7.15)	3.29	112	0.001
	Total Score	134.70	(59.01)	66.82	(23.64)	8.71	112	<0.001

Table 3: Psychometric Properties of the MOXO-CPT

Age category (years)		Optimal
7	cutoff	184.60
	Sensitivity	86%
	Specificity	85%
8	cutoff	167.98
	Sensitivity	91%
	Specificity	88%
9	cutoff	144.98
	Sensitivity	90%
	Specificity	85%
10	cutoff	110.88
	Sensitivity	81%
	Specificity	85%
11	cutoff	107.89
	Sensitivity	86%
	Specificity	89%
12	cutoff	91.82
	Sensitivity	85%
	Specificity	85%

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



Figure 1
67x38mm (300 x 300 DPI)

Review Only

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

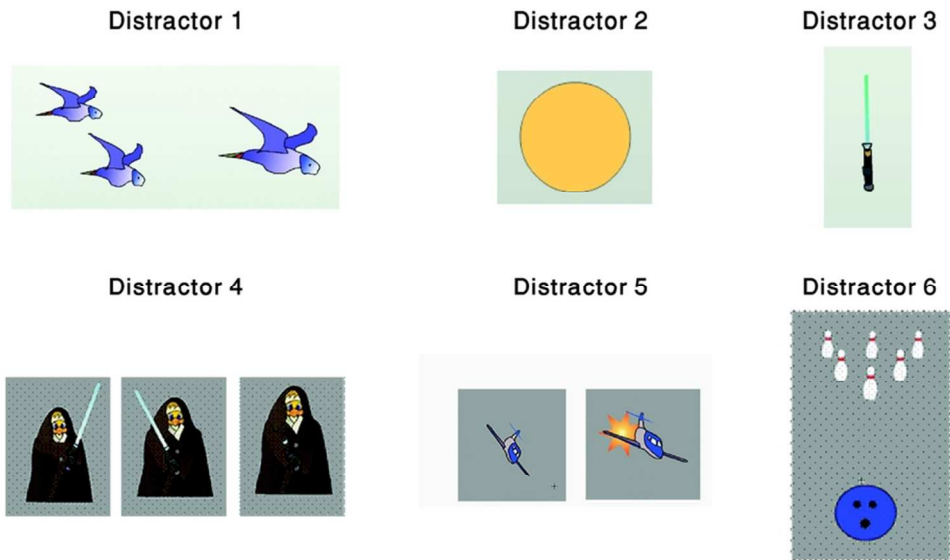
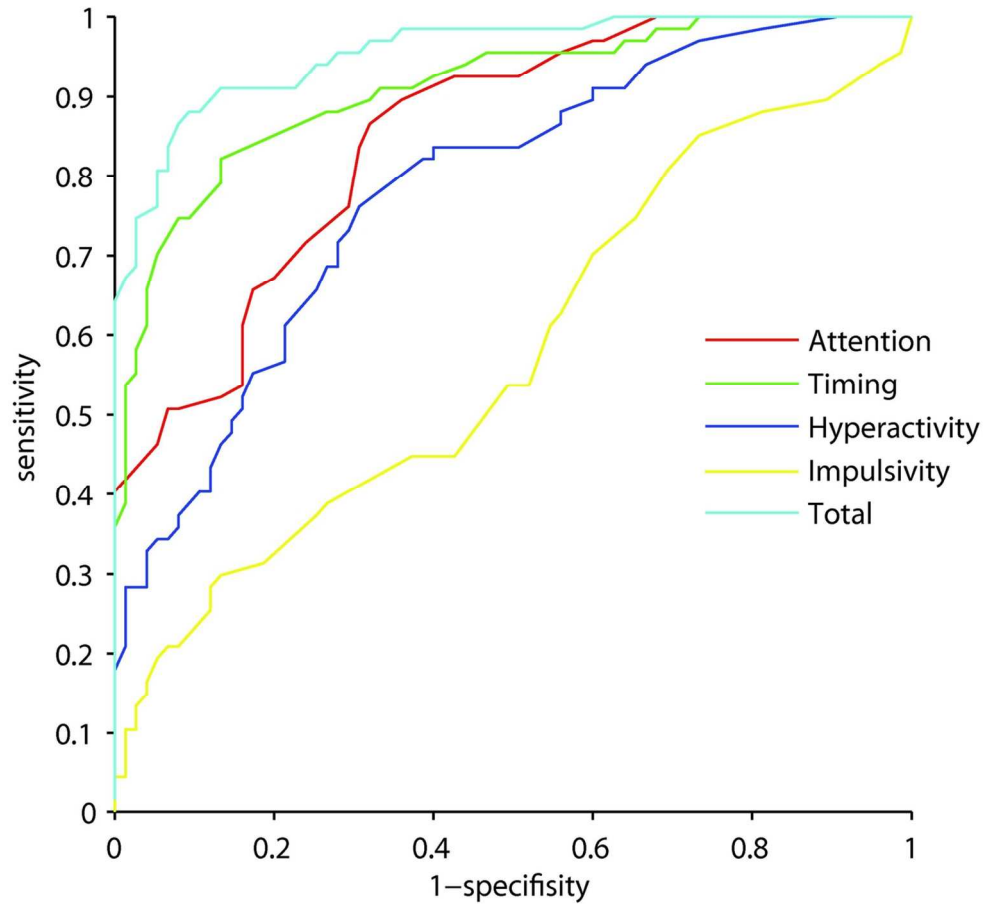


Figure 2
81x46mm (300 x 300 DPI)

Review Only

Figure 3: Roc analysis for children aged 8-9 years

Figure 3
117x122mm (300 x 300 DPI)