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Original Article

Comparing the Mathematics Continuous Performance Test With Other Measures of Tests of Attention

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Abstract. Several studies have shown that Continuous Performance Tests (CPT) can diagnose Attention Deficit Hyperactivity Disorder (ADHD) better than other tests. Research reporting comparisons of two or more CPT-type tests is scarce. The purpose of the study was to compare the Mathematics Continuous Performance Test (MATH-CPT) with another CPT-type test (CPT II) and a questionnaire (the Brown Scale). The comparison was carried out by looking at correlations among subscales and checking the precision of detecting ADHD. Ninety-five high school and college students participated in the study, 41 with ADHD were the research group and 54 were the control group. The participants performed the two tests and answered the questionnaire. The results showed that the MATH-CPT correctly identified 74.50% of the participants of both groups as compared to the 71.60% of the CPT II. Correlations between the two CPT-type tests were moderate; however, they were similar to correlations found in other studies comparing similar tools. The MATH-CPT, final attention formula, showed significant correlations with the Brown scales, while the CPT II, confidence index associated with ADHD assessment, showed nonsignificant correlations with the questionnaire. The study indicated that MATH-CPT can be used with a clinical population of ADHD and for research purposes.

Keywords: Continuous Performance Test, MATH-CPT, CPT II, Brown-ADD Questionnaire

The Mathematics Continuous Performance Test (MATH-CPT) is a relatively new test (Lufi & Fichman, 2012) aimed at assessing the attention level in research and in clinical settings for adolescents and adults (12 years and older). The MATH-CPT has been used in a few studies to assess attention levels (Lufi, 2011; Lufi & Fichman, 2012; Lufi, Tzchishinky, & Hadar, 2011). The test has several unique new qualities such as using open time format, more complex cognitive processing of calculations more suitable for adolescents and adults, and four different measures of sustained attention. The authors of the MATH-CPT claimed that it measures more accurately the sluggish cognitive tempo aspect of attention disorder. Sluggish cognitive tempo (SCT), a term coined and discussed by Milich, Ballentine, and Lynam (2006), is a problem appearing in children characterized as daydreaming, passive, confused, hypoactive, slow-moving, and sluggish. The goal of this paper is to compare the MATH-CPT to two widely-used researched measures: The Conners' Continuous Performance Test II (CPT II; Conners & MHS Staff, 2000) and a questionnaire, the Brown Attention-Deficit Disorder Scale (Brown-ADD, 1996). This comparison was done by assessment of the correlations between the MATH-CPT and the CPT II, and the Brown-ADD scale and their subscales, and by checking the precision of detecting ADHD.

The first Continuous Performance Test (CPT) was constructed by Rosvold, Mirsky, Sarson, Bransome, and Beck (1956). The purpose of the original CPT was to assess impairment in attention or alertness among brain damaged individuals. Since 1956 many different CPT-type tests have been developed for research and clinical purposes.

Several studies have shown that CPT-type tests can diagnose Attention Deficit Hyperactivity Disorder (ADHD) better than other tests designed for the same purpose (Bennett, Zentall, & French, 2006; Clifford, Corman, Lawrence, Greenberg, & Ross, 2000; Mahone, Pillion, Hoffman, Hiemenz, & Denckla, 2005; Soreni, Crosbie, Ickowicz, & Schachar, 2009). Other studies have shown good diagnostic power of the CPT-type tests in various clinical problems:

(1) learning disability (Beale, Matthew, Oliver, & Corballis, 1987; Swanson, 1981);
(2) behavioral disorders among children (Dougherty, Bjork, Marsh, & Moeller, 2000; Klee & Garfinkel, 1983; Shapiro & Garfinkel, 1986);
(3) those with schizophrenic disorder (Liu et al., 2002; Ozgürdal et al., 2009; Suwa, Matsushima, Ohta, & Mori, 2004);
(4) adults who were diagnosed as having depression or mania (Emre, Simavi, & Fisun, 2006; Koetsier et al., 2002; Najt et al., 2005);
(5) adults with a schizotypal personality disorder (Moriarty et al., 2003); and
(6) in the assessment of impulsivity among children with ADHD (Rauch, Gold, & Schmitt, 2012).

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Research reporting comparisons of two or more CPT-type tests is scarce. The most extensive comparison of CPT-type tests was performed by Borgaro et al. (2003): they compared three different CPT-type tests with different sensory modalities and different types of tests. They found average correlations of 0.42 between tests, average correlations of 0.48 between visual tests, and average correlations of 0.45 between auditory tests. Reddy, Newman, Pedigo, and Scott (2010) used the CPT II (Conners & MHS Staff, 2000) and the TOVA (the Test of Variables of Attention (Greenberg, Kindschi, & Corman, 1999) to validate another instrument, Pediatric Attention Disorders Diagnostic Screener for Children (PADDS; Pedigo, Pedigo, & Scott, 2006). They found correlations ranging from 0.02 to 0.43 between the TOVA and the PADDS, and correlations ranging from 0.13 to 0.52 between the CPT II and the PADDS.

The purpose of the present study was to compare the results of the MATH-CPT to those of other well-established tests, the CPT II, and a questionnaire, the Brown Attention-Deficit Disorder Scale (Brown-ADD, 1996). This procedure should serve as validation of the MATH-CPT. Since all three instruments used in the study are designed to find difficulties in attention and to diagnose ADHD it was expected to find high correlation between the measures of the different instruments, especially when variables of the instruments assess similar domains.

Method

Participants

Ninety-five high school and college students, with ages ranging from 12 to 29 years, participated in the study; 42 were boys and 53 were girls. Forty-one of them had been diagnosed as having ADHD; they served as the research group (mean age 20.50, *SD* = 5.73) and 54 served as a normal control group (mean age 19.34, *SD* = 4.44). No significant differences were found between the groups with regard to age ($t_{(93)} = 1.08$, $p > .05$). The diagnosis of the research group was based on the DSM-IV-TR (APA, 2000) criteria of having at least six of nine symptoms of inattention and/or six of nine symptoms of hyperactivity-impulsivity. All participants were from a middle range socio-economic status, recruited from various high schools and colleges in northern Israel. All the participants were tested with two CPT-type tests, the MATH-CPT (Lufi & Fichman, 2012) and the CPT II (Conners & MHS Staff, 2000), and a questionnaire, the Brown Attention-Deficit Disorder Scale (Brown-ADD, 1996). Criteria for inclusion in the research group were:

(a) a primary diagnosis of ADHD in the past by a qualified psychiatrist, neurologist, or psychologist. All participants in the research group met the DSM-IV-TR (APA, 2000);
(b) had taken medication (various forms of Ritalin) in the past or in the present prior to the beginning of the research;
(c) having no neurological disorders other than ADHD, based on the psychiatric or neurological evaluation;
(d) having no other psychiatric disorders as judged by their medical records; and
(e) having no comorbid conditions based on their medical record.

Criteria for inclusion in the control group were:

(a) having no neurological disorders such as ADHD or learning disability, based on their past history; and
(b) having no other psychiatric disorders as judged by their medical records.

The clinical experiment conformed to the principles outlined by the Declaration of Helsinki, and the complete study protocol was approved by the institutional Ethics Committee of the Academic College of Yezreel Valley. After receiving a complete description of the study, all participants, or their parents in the case of adolescents, gave their written informed consent.

Instruments

The Mathematics Continuous Performance Test (MATH-CPT; Lufi & Fichman, 2012) is a computerized CPT-type test designed to assess attention. The MATH-CPT uses a sequence of 450 simple mathematical problems involving addition, subtraction, multiplication, and division. The answer is not greater than nine and was projected onto a computer screen to serve as a visual stimulus. During the test, one mathematical problem appeared on the screen together with a result that could be either right or wrong (e.g., 1 + 4 = 5 or 4 × 2 = 7). The participants observed one problem at a time on the computer screen and had to decide whether the solution was correct or incorrect by pressing "1" for a correct answer or "2" for an incorrect answer. The test stimuli were more complicated than most other CPT-type tests, so an open reaction time allowed participants to react at their individual rate of activity. The test lasted approximately 10–20 min depending on the reaction time of each participant. The test included the following main measures: Final overall attention level formula to assess the participant's overall attention level; reaction time (time taken to complete the test); standard deviation of reaction time (a measure of reaction time variability); impulsive responses (a fast guessing response given at a speed less than 0.5 s, and incorrect responses given faster than the average of the mean reaction time of all the problems of each participant; together both were considered measures of impulsivity); and accuracy of responses (correct answers, considered a measure of attention). In addition, the results were presented in three and nine performance blocks from the beginning to the end of the test, each block of 50 mathematical problems. The test's secondary measures were as follows: sustained attention-time (a measure of sustained attention of reaction time over nine parts of the test); sustained attention *SD* (sustained attention of reaction time *SD* over nine parts of the test);

sustained attention correct responses (sustained attention of correct responses over nine parts of the test); sustained attention impulsivity (a measure of sustained attention of impulsivity over nine parts of the test). These four measures of sustained attention assessed a possible reduction of performance on measures in their respective areas and were based on an algorithm designed specifically to assess these domains. The algorithm to assess sustained attention was based on a calculation of the nine blocks. Each block, from the first to the ninth in ascending order, contributed more to the measure of sustained attention; a single number assessing sustained attention in the four measures mentioned above is presented. During construction of the MATH-CPT, test-retest reliability after 1 week of testing indicated an average correlation of 0.73 for the test's main measures. During development of the MATH-CPT, a discriminant function analysis was used to compare a control group (without ADHD) to a group with ADHD. The results indicated that the test can correctly identify 90.8% of the participants in both groups.

The Conners' Continuous Performance Test, *Ver 5.2* (CPT II; Conners & Multi-Health Systems [MHS] Staff, 2000) is a commercial test based on visual stimuli administered individually. The test was constructed in the US and is used for research and clinical purposes in many countries all over the world. It is one of the most popular CPT-type tests for ages six and above, and lasts for approximately 14 min. Before starting the test, participants received a chance to practice for a few minutes with the test's stimuli. During the test the participants are exposed repeatedly to a single English letter and are required to respond by pressing the computer's space bar. The participants are required to inhibit their response when the letter "X" appears on the screen. The letters appear on the screen for 25 ms when there are six equal testing blocks with three subblocks of 20 trials for each interstimulus interval. The interval between one response to another varies between 1 s, 2 s, and 4 s, allowing assessing the ability of the person tested to adjust to the changing tempo. The results reported are based on the following variables: inattention (omission errors, commission errors, hit reaction time, hit reaction standard error, variability of standard error, detectability [*d'*], and hit reaction time interstimulus interval change, hit standard error of reaction time interstimulus interval change); impulsivity (commissions, hit reaction time perseveration); vigilance (hit reaction block change and hit standard error block change). A final score of the test is a "confidence index associated with ADHD assessment" which is reported as a percentage of the person tested to be matched against a clinical profile versus the percentage of the person tested to match a Nonclinical profile. The results are reported with tables and graphs. The results are based on American norms, based on the idea that intercultural differences do not influence attention level. The tester manual describes norms of 1,190 people in eight age groups, with half of the participants coming from a clinical group. Test-retest reliability at the construction of the test was reported as 0.89 for participants with ADHD.

The Brown Attention-Deficit Disorder Scale (Brown-ADD, 1996**)** is a questionnaire of 40 questions. It evaluates ADHD with a five cluster measure associated with ADHD and a total score which is the summation of the five clusters. The questionnaire was constructed and standardized in the US for adolescents and adults, and has been translated and standardized for the Israeli population (Psychtech, 2012). There are two versions: one for adolescents and one for adults. The two versions are similar in structure; the description of the questions is slightly different to allow easier understanding among adolescents. The five clusters of the scale are:

(1) Organizing, prioritizing, and activating to work;
(2) Focusing, sustaining, and shifting attention to tasks;
(3) Regulating alertness, sustaining effort, and processing speed;
(4) Managing frustration and modulating emotions; and
(5) Utilizing working memory and accessing recall.

In addition to the five clusters there is a total score which is a summation of the five clusters. Reliability of the test during the adaptation to the Israeli adult population was 0.96. In the present study the Cronbach alpha reliability of the total score was 0.93.

Procedure

The participants were recruited for the study from one high school and one college in northern Israel. The participants in the research were diagnosed as having ADHD by psychiatrists, neurologists, or psychologists prior to entering the study. All of the participants in the research group were being treated with either Ritalin or Concerta at the present time and/or in the past. Those who were treated with a medication at the time of the research were not given their medication for at least 24 hr prior to performing the tests to ensure that the medication would not influence their performance. Half of the participants performed the MATH-CPT first and 1 week later they performed the Conners CPT II. The other half performed the tests in reverse order. This crossover procedure was used to avoid any chance that practice effect acquired during the first testing might influence the results of the second test. All the participants performed the computerized tests in the morning to avoid being tired later in the day. Following their performance on the first computerized test, the participants answered the questionnaire, the Brown Attention-Deficit Disorder Scale (Brown-ADD, 1996).

Results

A discriminant function analysis (stepwise procedure) was used to assess the ability of each computerized test to distinguish between the research and the control group. Using 10 measures of the MATH-CPT (without the formula to assess attention) showed that three measures (Fast Wrong Responses; *SD* of Total Time; and Sustained Reaction Time) identified 74.50% of the participants in both groups.

Using 12 measures of the CPT II (without the main measure assessing the percentage of chance being diagnosed as ADHD) showed that two measures (Detectability d' [d-prime] and Hit Rate) identified 71.6% of both groups. Using all 22 measures of both computerized tests showed that six measures had a correct identification of 77.7% of all the participants (Detectability d' [d-prime]; Hit Rate; Hit Rate Interstimulus Interval; Impulsive Responses; Sustained Reaction Time; and *SD* of Total Time). Comparison of the ability of each test to deal with "sensitivity" (the probability that positive cases are correctly classified) and "specificity" (the probability that negative cases are correctly classified) showed that the MATH-CPT had a better sensitivity, while the CPT II had a slightly better specificity. These results can be seen in Table 1.

Table 1. Comparison of the MATH-CPT and the CPT II to identify correctly all the participants in the study, reported in percentages (N = 95)

Tests	Predicted group membership: ADHD	Non-ADHD	Sensitivity %	Specificity %
MATH-CPT				
ADHD	61.00	39.00	76.00	74.00
Non-ADHD	15.10	84.90		
CPT II				
ADHD	70.70	29.30	66.00	76.00
Non-ADHD	27.80	72.20		
Both tests together				
ADHD	73.20	26.80	75.00	80.00
Non-ADHD	18.90	81.10		

Notes. Sensitivity = percentage of the probability that positive cases are correctly classified. Specificity = percentage of the probability that negative cases are correctly classified.

Finding the correlations between the two CPT-type tests should show similarities or dissimilarities of the tests. Since there are 11 main variables of the MATH-CPT and 13 in the CPT II, only the measures assessing similar domains were compared. The results showed correlations of Pearson product-moment ranging from −0.10 to 0.39. The correlation between the two main measures of the tests, those indicating the existence or the lack of existence of ADHD, showed nonsignificant correlations of 0.20. Although a few of the correlations are significant, the level of the correlations between the tests can still be described only as moderate. These correlations are shown in Table 2.

The results of the MATH-CPT showed that the control group performed significantly better than the research group in six out of seven measures, indicating a better attention level in these variables (Final Attention Formula; Reaction time; *SD* of Total Time; Impulsive Responses [only Fast Wrong Responses]; and Correct Responses). Out of the four secondary measures of the MATH-CPT the control group performed significantly better in two measures of the variables assessing sustained attention (Sustained Attention Reaction Time and Sustained Attention Impulsivity). In the Conners CPT II measures the control group performed significantly better than the research group in seven of the 13 measures (Percent Diagnosed; Commission Responses; Hit Rate; Hit Rate Standard Error; Detectability d-prime [d']; Hit Rate Interstimulus Interval; Hit Standard Error Interstimulus Interval).

The raw scores of the Brown-ADD scale showed highly significant differences between the research group and the control group. In all five clusters and in the total score the research group scored higher, indicating more attention problems. The correlations between the total score of the questionnaire and the final attention formula of the MATH-CPT were significant (r = 0.35, p < .05). The correlations between the total score of the questionnaire and the CPT II main measure "confidence index associated with ADHD assessment" were not significant (r = 0.25,

Table 2. Correlations between variables assessing similar cognitive tasks of the MATH-CPT and the CPT II (N = 95)

Variables/CPT II MATH-CPT	Percent diagnosed[a]	Rate	Hit rate *SE*	Commission responses	Perseveration
Final attention formula	.20	.20	.14	.35**	.23*
Reaction time (minutes)	.31**	.01	.23*	.27**	.22*
SD of reaction time	.33**	−.01	.27**	.27**	.22*
Anticipatory responses	.12	−.03	.18	.23*	.16
Incorrect fast response	.06	−.03	.18	.23*	.23*

Notes. *p < .05, **p < .01. [a]This variable used an ordinal scale; therefore, a Spearman's correlation was calculated.
MATH-CPT Measures: Final Attention Formula = assesses participant's overall attention level; Reaction Time = time taken to complete the test, in minutes; Standard Deviation of Reaction Time = variability of the reaction time; Anticipatory Responses = guessing fast response given at a speed less than 0.5 s; Incorrect fast responses = incorrect responses, given at the speed faster than the average of the mean reaction time of all the problems.
CPT II Measures: Percent Diagnosed = percentage of the person tested to match a clinical profile; Hit Rate = the mean response time for all target responses; Hit Rate *SE* = the consistency of response times; Commission Responses = the number of times the individual responded to a nontarget ("X"); Perseveration = a response given in less than 100 ms following the stimulus.

$p > .05$). To further understand the relationships between the Brown-ADD scale and the two computerized tests, a regression analysis was performed. Using the five clusters of the Brown-ADD as independent variables and the "final attention formula" of the MATH-CPT as a dependent variable showed that the questionnaire measures explained 24% of the variance (method used: Enter, $r = 0.49$, $p < .05$). A similar analysis with the same independent variables and the "percentage of the person tested" to match a clinical profile versus the percentage of the person tested to match a Nonclinical profile of the CPT II showed that the questionnaire measures explained 18% of the variance (method used: Enter, $r = 0.42$, $p > .05$) of the score in the CPT II. Table 3 shows the correlations between the clusters of the Brown ADD scale and the main measures of the MATH-CPT and the main measures of the CPT II.

Discussion

The correlations between the two computerized tests can be considered as moderate. These results are similar to those of other studies comparing different CPT-type tests (Borgaro et al., 2003; Reddy et al., 2010). These findings can be explained by the fact that despite the similarities in the goal of the two tests there are still some substantial differences. Unlike some CPT-type tests, including the CPT II, the MATH-CPT uses an open time or self-paced format and more complex cognitive stimuli requiring more time to process the problem. In contrast to the CPT II, the appearance of the stimuli on the screen is fixed, 25 ms. Having different intervals between the presentations of the stimuli (interstimulus interval) presents a different demand of changing alertness on the person being tested. Another factor contributing to the low correlation between

Table 3. Correlations between the Brown scale to the main measures of the MATH-CPT and to the main measures of the CPT II ($N = 95$)

	The Brown scale (Brown-ADD, 1996)					
	1	2	3	4	5	6
MATH-CPT/The Brown scale						
Final attention formula[a]	.40**	.33*	.31*	.10	.33*	.35*
Reaction time (minutes)[a]	.20	.19	.16	−.12	.09	.14
SD of total time[a]	.33*	.23	.23	−.13	.12	.20
Impulsive responses[a]	.40**	.36*	.44**	.31*	.42**	.44**
Anticipatory responses	.08	−.04	.05	.09	.02	.04
Fast wrong responses	.40**	.37**	.45**	.31*	.43**	.45**
Correct responses	−.33*	−.30*	−.37**	−.23	−.36*	.44**
Conners CPT II/The Brown scale						
Percent diagnosed[a,b]	.14	.31*	.27*	.16	.22*	.27*
Omissions responses[a]	.03	.06	.06	.16	.05	.06
Commissions responses[a]	.38**	.42**	.34*	.23	.41**	.38**
Hit rate[a]	.01	.03	−.03	−.07	.01	.01
Hit rate SE[a]	.14	.30*	.11	.06	.19	.20
Variability of SE[a]	.07	.25	.17	.09	.19	.18
Detectability *d*-prime (d')	−.32*	−.34*	−.24	−.14	−.31*	−.29
Response style (beta)	−.11	−.20	.02	.10	−.13	−.08
Perseverations[a]	.01	.10	.01	.06	.09	.06

Notes. $*p < .05$, $**p < .01$. [a]Indicates that a lower score is a better performance. [b]This variable used an ordinal scale; therefore, a Spearman's correlation was calculated.
MATH-CPT variables: Final Attention Formula = summarizes the overall attention level of the test; Reaction Time = time taken to complete the test, in minutes; *SD* of Total Time = variability of the reaction time; Impulsive Responses = a combination of the anticipatory response and the fast wrong responses; Anticipatory Responses = guessing response faster than 500 ms; Fast Wrong Responses = wrong response answered faster than the average response time of the person tested; Correct Responses = total correct responses-measures of attention.
CPT II variables: Percent Diagnosed = percentage of the person tested to match a clinical profile; Omission Responses = the number of targets to which the person tested did not respond; Commission Responses = the number of times the individual responded to a nontarget ("X"); Hit Rate = the mean response time for all target responses; Hit Rate *SE* = the consistency of response times; Variability of Standard Error = standard deviation of the 18 standard error values calculated for each subblock; Detectability *d*-prime (d') = assess how well the person tested discriminates between targets and nontargets; Response Style (Beta) = evaluation of the speed/accuracy trade-off; Perseveration = a response given in less than 100 ms following the stimulus.
Brown Scale clusters: (1) organizing, prioritizing, and activating to work; (2) focusing, sustaining and shifting attention to tasks; (3) regulating alertness, sustaining effort, and processing speed; (4) managing frustration and modulating emotions; and (5) utilizing working memory and accessing recall; (6) total score which is a summation of the five clusters.

the two CPT-type tests was the level of working memory involved in the paradigm of each test. It is assumed that the MATH-CPT relies much more on working memory as compared to the CPT II. Lufi and Fichman (2012) explained the nature of the MATH-CPT as compared to other CPT-type tests. They stated:

> Having a forced procedure of limited time to respond, as in other CPT-type tests, is prompting or serving as a cue to the testee to be alert and respond quickly, often against a natural sluggishness, passivity, or day-dreaming. In other words, other CPT tasks may, in fact, disturb the natural tendency of the testee, forcing attentiveness to the task at hand. It is hypothesized that the new MATH-CPT can better recognize this slow cognitive tempo tendency of people with this type of attention difficulty. (p. 61).

These differences to assess diverse cognitive aspects may result in low correlations between the tests found in the present study. These differences may have an advantage by allowing the combination of the two tests to have a better diagnostic power than each test separately. In fact, the combination of the two tests can be complementary. As seen from the results of the discriminant function analysis of the two tests, the MATH-CPT is better in recognizing impulsivity, sustained attention of reaction time, and consistency of reaction. In contrast, the CPT II is better in recognizing fast uncontrolled response, discrimination between targets and nontargets, reaction time, and changes in reaction times over the three interstimulus intervals.

The correlations between the Brown-ADD scale and the two computerized tests are similar to other comparisons of CPT-type tests and questionnaires (Vaughn et al., 2011; Reddy et al., 2010). These results may be explained by the fact that a pencil and paper test without time pressure and without a need to be alert in order to provide a response has completely different requirements as compared to the computerized tests. The higher correlation between the MATH-CPT and the Brown ADD as compared to the non-significant correlation between the CPT II and Brown ADD confirmed the goal of this research, which was to demonstrate the convergence validity of the MATH-CPT.

Limitations of the study were that the level of attention difficulties in the research group was not assessed in the study. It is possible that with a different degree of difficulty the results would be different. Having additional clinical groups besides the ADHD and normal control group used here could make the results more robust. Additional measures assessing ADHD such as computerized tests, other cognitive measures, and questionnaires to the teachers and parents could provide more understanding of the difficult issue of diagnosing ADHD. Such tools can assess various cognitive measures such as working memory; other type of memories, processing speed, and more. Future research should use larger samples and, possibly, more culturally diverse samples. With these larger populations it will be possible to assess questionnaires even at the item level in addition to the subscales.

Conclusion

The fact that the combination of the two computerized tests used in this study improved the ability to diagnose ADHD to 77.70% is encouraging. These findings showed that possible solution to the difficulty of diagnosing ADHD lies in using more than one computerized measure. It is suggested here that using two computerized tests in order to diagnose ADHD should be a standard in diagnosing ADHD. It is possible that the addition of questionnaires distributed to the teachers, parents, and the person himself/herself may even improve the goal of accurate diagnosis. Nevertheless, this study offers support and validation for using the MATH-CPT in clinical practice for the assessment of adolescents and adults with ADHD, and for research purposes to investigate various aspects of attention.

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