*Article*

# Cross-validating the Dot Counting Test Among an Adult ADHD Clinical Sample and Analyzing the Effect of ADHD Subtype and Comorbid Psychopathology

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## Abstract

This study cross-validated the dot counting test (DCT) as a performance validity test (PVT) in an adult attention-deficit/hyperactivity disorder (ADHD) clinical population and examined the effect of ADHD subtype and psychiatric comorbidity on accuracy for detecting invalidity. DCT performance was assessed among 210 consecutive adult ADHD referrals who underwent neuropsychological evaluation and were classified into valid ($n = 175$) or invalid ($n = 35$) groups based on seven independent criterion PVTs. The invalid group had significantly worse DCT performance than the valid group using both the standard and unrounded scoring procedure ($\eta_p^2 = .28$). Classification accuracy was excellent, with 54.3% sensitivity/92% specificity at optimal cut-scores of ≥14 (rounded) and ≥13.38 (unrounded). Nonsignificant DCT performance differences emerged based on ADHD subtype or the presence/absence of comorbid psychopathology. The DCT functions well as a nonmemory-based PVT in an ethnoracially diverse ADHD population, supporting its clinical utility for detecting invalid neurocognitive performance during ADHD evaluations.

## Keywords

ADHD, adult ADHD, validity

The capacity of any given neuropsychological evaluation to produce accurate data, meaningful diagnostic impressions, and useful treatment recommendations hinges on the degree to which test scores represent a valid reflection of an examinee's true cognitive abilities. As such, objective assessment of performance validity (i.e., the degree to which an examinee exhibits adequate test engagement and effort) is a critical component of any neuropsychological evaluation. Although typically associated with forensic settings, performance invalidity has also been shown to be a significant problem across a variety of nonforensic settings. For example, invalidity base rates in the context of adult attention-deficit/hyperactivity disorder (ADHD) evaluations vary from 20% in a survey of clinical practitioners across various settings (Martin & Schroeder, 2020) to 31% to 50% in studies employing a single performance validity test (PVT; Suhr et al., 2008; Sullivan et al., 2007).

The incentives for exaggeration or feigning of ADHD symptomology are well documented (e.g., academic accommodations and access to psychostimulant medications; Advokat et al., 2008; Musso & Gouvier, 2014; Teter et al., 2005), as are difficulties with accurate classification of invalid performance in adult ADHD assessments (e.g., Fischer & Watkins, 2008; Hirsch & Christiansen, 2018; Marshall et al., 2016; Musso & Gouvier, 2014; Quinn, 2003; Sollman et al., 2010; White, Ovsiew, et al., 2020). Current professional guidelines support the inclusion of multiple PVTs throughout an evaluation to ensure accuracy by identifying inadequate test engagement, impression management, or the magnification or feigning of symptoms (American Academy of Clinical Neuropsychology, 2007; Sweet et al., 2021). Integrating multiple PVTs throughout a testing battery allows for continuous monitoring of performance quality, which helps identify cases in which

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fluctuating levels of engagement during the several hours required for a neuropsychological evaluation may interfere with accurate data collection. To this end, many freestanding and embedded PVTs have been developed and cross-validated for use in clinical settings.

The challenge of adopting an approach to validity assessment that is both continuous and parsimonious is further complicated by the importance of gathering data that is nonredundant. Examinees may exaggerate or feign impairments in particular cognitive domains depending on their motivation (Boone, 2009, 2013), suggesting that it is prudent to assess validity across a variety of cognitive domains. Given that invalid performance commonly occurs in the memory domain, many PVTs are (or appear to be) memory based (Martin et al., 2015; Sharland & Gfeller, 2007). However, memory-based PVTs may not hold the same utility for ADHD evaluations, thereby underscoring the importance of identifying cases in which invalid performance may be present in nonmemory domains.

The dot counting test (DCT; Boone, Lu, & Herzberg, 2002) is one solution to the aforementioned challenge of accurately and efficiently assessing performance validity in adult ADHD evaluations, given that it is a well-validated PVT that uses a speed-based paradigm, rather than the more commonly employed forced-choice "memory" paradigms. In addition, the DCT has brief administration and scoring procedures for a standalone PVT that does not significantly extend battery length. Moreover, it has been cross-validated in neuropsychiatric (McCaul et al., 2018; Rhoads, Resch, et al., 2021), veteran (Bailey et al., 2021; Soble et al., 2018), and Spanish-speaking (Burton et al., 2012; Robles et al., 2015) populations, as well as in populations outside North America (Vilar-López et al., 2008; Weiss & Rosenfeld, 2010).

Within the DCT scoring manual, the recommended cut-score for normal efforts groups combined is ≥19, yielding 72% sensitivity/95% specificity (Boone, Lu, & Herzberg, 2002). However, various DCT cut-scores have been established for more specific diagnostic groups (e.g., stroke, dementia, traumatic brain injury [TBI]), as the rates of false-positive classifications vary in these groups (Boone, Lu, Back, et al., 2002). These population-specific cut-scores are also provided as part of the standard interpretation guidelines in the scoring manual (Boone, Lu, & Herzberg, 2002). That being said, an optimal cut-score has yet to be established for patients diagnosed with ADHD. The current iteration of the scoring manual does not clearly indicate which normative comparison group cut-score (e.g., depression, nonclinical, learning disability group, and all normal effort groups combined) should be used to determine performance invalidity among an ADHD population, although the normal effort groups combined cut-score is suggested as a potentially appropriate option. Further complicating this picture, the scoring manual indicates that individuals with a primary ADHD diagnosis were excluded from the learning disorder reference group, potentially rendering this normative group an inappropriate comparison. Indeed, a recent study of the DCT's utility in ADHD assessments found the E-score of ≥14 to be insufficient in the detection of invalid performance (Marshall et al., 2016). Given that different DCT cut-scores have been proposed based on the known or suspected diagnostic groups, the ambiguity surrounding which normative group to select for comparison among patients with ADHD is concerning and may lead to selection of inappropriate cut-scores, increasing risk of false-positive or false-negative errors.

With these considerations in mind, the purpose of this study was to cross-validate the classification accuracy of the DCT in a well-defined, adult ADHD clinical population to provide a recommendation of a specific cut-score to use for validity interpretation. Furthermore, this study aimed to specifically determine whether there were differences in DCT performance based on subtype of ADHD (i.e., ADHD-predominantly inattentive subtype vs combined subtype) and whether performance was differentially affected if an active comorbid psychiatric disorder was present.

## Method

### *Participants*

This cross-sectional study included data from a sample of 247 consecutive adult patients referred for neuropsychological evaluation at an academic medical center from 2018 to 2021. Patients were referred for evaluation by their treating providers (most commonly their psychiatrist or primary care/family medicine physician) specifically for the purposes of diagnostic clarification and/or updated treatment planning related to ADHD. One patient was not administered the DCT, and four were each missing a criterion PVT. As such, these five cases were excluded from subsequent analysis, which resulted in a total sample of 242. The overall sample was 42% male ($n = 89$) and 58% female ($n = 121$) with a mean age of 27.47 ($SD = 6.89$) and mean educational attainment of 15.63 years ($SD = 2.07$). Racial/ethnic distribution was 49% white ($n = 104$), 22% Hispanic ($n = 47$), 12% black ($n = 12$), 9% Asian ($n = 19$), and 7% other race/ethnicity ($n = 14$). The majority of individuals referred for evaluation were current college students ($n = 170$; 69%), with 38% ($n = 92$) being undergraduate and 31% ($n = 75$) being graduate/professional students. Validity groups were determined by a battery of seven criterion PVTs that consisted of one freestanding and six embedded PVTs (Table 1). In total, 207 patients failed one or fewer criterion PVTs and were classified as the valid group, whereas the remaining 35 failed two or more criterion measures and constituted the invalid group. This grouping approach is consistent with current practice standards and

**Table 1.** Criterion Performance Validity Tests (N = 210).

| Performance validity test | Failure cut-score(s) | Sensitivity/Specificity | Reference | Sample failure rate |
|---|---|---|---|---|
| BVMT-R | Recognition discrimination ≤ 4 | 40%–50%/90%–93% | Bailey et al. (2018)<br>Resch et al. (2020) | 9/233 (4%) |
| RAVLT | E-score ≤ 12 | 73%–76%/90% | Boone et al. (2005)<br>Pliskin et al. (2020) | 35/207 (15%) |
| Rey 15-Item Test | Recall + Recognition ≤ 22 | 61%/90% | Poynter et al. (2019) | 8/234 (3%) |
| Stroop Color Word Test | Word Reading T-score ≤ 21 | 54%/91% | White, Korinek, et al. (2020) | 19/223 (9%) |
| Trail Making Test | Part A T-score ≤ 34 | 35%–53%/89%–95% | White, Korinek, et al. (2020)<br>Ashendorf et al. (2017) | 27/215 (11%) |
| Verbal Fluency | F/A/S T-score ≤ 31 | 39%/93% | White, Korinek, et al. (2020) | 17/225 (7%) |
| WAIS-IV Digit Span | Reliable Digit Span ≤ 7 | 22%–58%/85%–94% | Marshall et al. (2010)<br>Schroeder et al. (2012) | 29/213 (12%) |

*Note*. BVMT-*R* = Brief Visuospatial Memory Test—Revised; RAVLT = Rey Auditory Verbal Learning Test; WAIS-IV = Wechsler Adult Intelligence Scale—Fourth Edition.

empirical support for using two or more independent PVT failures to identify invalidity (e.g., Critchfield et al., 2019; Jennette et al., 2021; Larrabee, 2008; Meyers et al., 2014; Rhoads, Neale, et al., 2021; Sherman et al., 2020; Soble et al., 2020; Webber et al., 2020). The base rate of invalidity in this sample was 15%, which approximates the 20% invalidity base rate for adult ADHD evaluations found among adult-focused neuropsychologists across diverse clinical nonforensic contexts and practice settings in a recent large survey (Martin & Schroeder, 2020).

Of the 207 patients in the valid group, 175 met *Diagnostic and Statistical Manual of Mental Disorders—Fifth Edition* (*DSM*-5; American Psychiatric Association, 2013) diagnostic criteria for ADHD. The remaining 32 patients did not meet diagnostic criteria for ADHD and were excluded from further analysis, resulting in a final valid group of 175. Of these, approximately 41% ($n = 71$) had previously documented ADHD prior to their current evaluation. Irrespective of an established ADHD diagnosis, all patients underwent a uniform and multimethod diagnostic protocol as part of their neuropsychological evaluation to establish the presence/absence of ADHD. This comprehensive protocol, which is in line with acceptable practices for establishing ADHD among adults (Riccio et al., 2005; Wasserstein, 2005) included: (1) a full medical/psychiatric record review (including review of prior ADHD evaluations/diagnostic work ups, when available); (2) a semistructured clinical interview which systematically gathered all relevant background information (e.g., ADHD symptom onset/course and associated functional impairment; medical, psychiatric, substance use, developmental, academic, and psychosocial history) and thoroughly assessed formal *DSM-5* ADHD diagnostic criteria as well as comorbid psychopathology; (3) administration of an ADHD symptom inventory (i.e., Clinical Assessment of Attention Deficit—Adult [CAT-A; Bracken & Boatwright, 2005]), which contains embedded symptom validity scales to identify noncredible symptom reporting (Leib et al., 2021; White, Ovsiew, et al., 2020) and provides objective, normative-based qualification of ADHD symptomatology in both childhood and adulthood; (4) administration of a standardized core neuropsychological test battery which comprehensively assessed examinees' cognition across all major cognitive domains; and (5) administration of a validity-controlled inventory of personality and psychopathology (i.e., Minnesota Multiphasic Personality Inventory-2-Restructured Form [MMPI-2-RF; Ben-Porath & Tellegen, 2008]) to objectively assess for active comorbid psychological symptoms. Integration of all of the aforementioned, multi-pronged data and history gathered as part of each patient's comprehensive neuropsychological evaluation was used to determine ADHD diagnoses and rule-out comorbid conditions as the primary etiology. All evaluations were conducted in person, and all ADHD diagnoses were rendered by a board-certified clinical neuropsychologist. Among the 175 patients diagnosed with ADHD in the valid group, 45% ($n = 78$) were diagnosed with ADHD-Predominantly Inattentive Subtype and 55% ($n = 97$) were diagnosed with ADHD-Combined Subtype. Finally, among those diagnosed with ADHD 38% ($n = 66$) were diagnosed solely with ADHD, whereas the remaining 62% ($n = 109$) were diagnosed with ADHD and an active comorbid psychiatric disorder. Primary comorbid psychiatric disorders were mood disorder ($n = 63$), anxiety ($n = 34$), posttraumatic stress disorder ($n = 3$), substance use disorder ($n = 7$), or other disorder ($n = 2$).

## Measures

The DCT is a freestanding PVT with brief administration time and scoring procedures (see Boone, Lu, & Herzberg, 2002 for more information on the test). Interpretation of the validity index on the DCT (i.e., E-Score) is based on comparison to cut-scores developed for various normative clinical groups. Two DCT scoring methods have been proposed.

**Table 2.** Correlations Between Performance Validity Tests Among the Valid Group (n = 175.).

| Performance validity test | DCT-ES | DCT-UR | RDS | RFIT | RAVLT | BVMT | TMT-A | Stroop | FAS |
|---|---|---|---|---|---|---|---|---|---|
| DCT-ES | — | .98** | −.21** | −.23** | .16* | .03 | −.19* | −.32** | −.10 |
| DCT-UR | — | — | −.22** | −.24** | −.16* | −.01 | −.18* | −.33** | −.11 |
| RDS | — | — | — | .21** | .12 | .01 | −.003 | .18* | .08 |
| RFIT | — | — | — | — | .17* | .07 | −.02 | −.05 | −.05 |
| RAVLT | — | — | — | — | — | .12 | .09 | .002 | .07 |
| BVMT | — | — | — | — | — | — | .09 | −.11 | .14 |
| TMT-A | — | — | — | — | — | — | — | .21** | .23** |
| Stroop | — | — | — | — | — | — | — | — | .24** |
| FAS | — | — | — | — | — | — | — | — | — |

*Note.* DCT-ES = DCT E-score; DCT-UR = unrounded DCT E-score; RDS = Reliable Digit Span; RFIT = Rey-15 Item Test; RAVLT = Rey Auditory Verbal Learning Test; BVMT = Brief Visuospatial Memory Test; TMT A = Trail Making Test A; FAS = Verbal Fluency Test.
*$p < .05$. **$p < .01$.

The standard method outlined in the manual (Boone, Lu, & Herzberg, 2002) involves rounding any final E-score with a decimal to the nearest whole number, whereas a more recent cross-validation study (McCaul et al., 2018) argued that forgoing the rounding procedure and using the unrounded E-score may yield improved sensitivity. For this study, both the standard/rounded and unrounded E-scores were examined.

### *Statistical Analyses*

Spearman correlations assessed relationships between DCT E-scores and criterion PVTs. Analyses of variance (ANOVAs) tested differences in standard/rounded versus unrounded DCT E-scores between validity groups (i.e., valid/invalid), ADHD subtype (i.e., predominantly inattentive subtype and combined subtype), and ADHD only versus ADHD with active comorbid psychiatric diagnosis. Receiver operator characteristic (ROC) curve analyses evaluated classification accuracy of DCT E-scores and established optimal cut-scores for identification of performance invalidity. Per Hosmer et al. (2013) criteria, ROC areas under the curve (AUCs) were interpreted as having poor (0.50–0.69), acceptable (0.70–0.79), excellent (0.80–0.89), or outstanding (≥0.90) classification accuracy. Finally, given that some (e.g., Schroeder et al., 2019) have noted the potential for differential classification accuracy when patients with one criterion PVT failure are retained in the valid group, particularly at higher base rates of invalidity, ROC analyses were re-run after excluding those with one PVT failure for comparison purposes.

### *Results*

Nonsignificant to small correlations emerged between the DCT scores and the criterion PVTs among the valid group, suggesting that these measures were largely independent (Table 2). As noted in Table 3, compared to the valid group, the invalid group had significantly higher scores (i.e., worse performance) across both the standard/rounded and unrounded DCT E-scores, with large effect sizes. ROC curve analyses (Table 4) demonstrated that both the standard/rounded and unrounded DCT E-scores had excellent classification accuracy, with nearly equivalent AUCs. Likewise, both E-scores had identical sensitivity (54.3%) and specificity (92.0%) at their respective optimal cut-scores of ≥14 (standard/rounded) and ≥13.38 (unrounded). Finally, a series of ANOVAs revealed nearly identical DCT performance between ADHD subtypes (i.e., predominately inattentive vs combined) and the presence/absence of comorbid psychopathology (Table 3), suggesting that these clinical factors did not meaningfully affect DCT performance. As such, separate ROC curves to delineate alternate cut-scores were not needed. Finally, as conveyed in Table 5, comparison of the supplemental ROC analyses after excluding the 45 patients with one criterion PVT failure from the valid group (i.e., 0 vs ≥2 criterion PVT fails) revealed nearly identical classification accuracy, optimal cut-scores, and sensitivity/specificity values as the original ROC analyses that retained those with one criterion PVT failure in the valid group.

## Discussion

This study served as a cross-validation to assess the utility of the DCT for detecting invalid performance in an ethnoracially diverse clinical sample of patients with ADHD diagnoses. Several study findings are notable. First, both the standard/rounded and unrounded DCT E-scores demonstrated comparably excellent classification accuracy for distinguishing valid from invalid neurocognitive performance. The standard/rounded DCT E-score and the unrounded E-score also yielded the same degree of sensitivity (54.3%) and specificity (92.0%) with similar cut-scores of ≥14 and

**Table 3.** Dot Counting Test Performance by Validity Group.

| Dot counting test score | Valid ($n$ = 175) $M$ ($SD$) | Invalid ($n$ = 35) $M$ ($SD$) | $F$ | $\eta_p^2$ |
|---|---|---|---|---|
| *E*-score | 9.50 (2.66) | 14.94 (5.30) | 82.07*** | .283 |
| Unrounded *E*-Score | 9.557 (2.62) | 14.952 (5.34) | 81.53*** | .282 |
| | Inattentive type ($n$ = 78) $M$ ($SD$) | Combined type ($n$ = 97) $M$ ($SD$) | | |
| *E*-score | 9.51 (2.65) | 9.49 (2.69) | .002 | .000 |
| Unrounded *E*-Score | 9.524 (2.64) | 9.583 (2.62) | .02 | .000 |
| | ADHD only ($n$ = 66) $M$ ($SD$) | ADHD + Psych ($n$ = 109) $M$ ($SD$) | | |
| *E*-score | 9.20 (2.53) | 9.69 (2.73) | 1.40 | .008 |
| Unrounded *E*-Score | 9.243 (2.52) | 9.747 (2.67) | 1.52 | .009 |

*Note.* ADHD = attention-deficit/hyperactivity disorder.
*$p < .05$. **$p < .01$. ***$p < .001$.

**Table 4.** Sensitivity and Specificity Values for DCT E-Scores (Standard and Unrounded) for the Entire Sample (N = 210).

| | Valid ($n$ = *175*) vs invalid ($n$ = *35*) | | | 30% base rate | | 20% base rate | | 10% base rate | |
|---|---|---|---|---|---|---|---|---|---|
| DCT score | Cutoff | SN (%) | SP (%) | PPV | NPV | PPV | NPV | PPV | NPV |
| **E-Score** | | | | | | | | | |
| **AUC = .845*** ** | ≥9 | 97.1 | 44.0 | 0.43 | 0.97 | 0.30 | 0.98 | 0.16 | 0.99 |
| | ≥10 | 91.4 | 53.7 | 0.46 | 0.94 | 0.33 | 0.96 | 0.18 | 0.98 |
| | ≥11 | 80.0 | 68.0 | 0.52 | 0.89 | 0.38 | 0.93 | 0.22 | 0.97 |
| | ≥12 | 71.4 | 74.9 | 0.55 | 0.86 | 0.42 | 0.91 | 0.24 | 0.96 |
| | ≥13 | 62.9 | 85.1 | 0.64 | 0.84 | 0.51 | 0.90 | 0.32 | 0.95 |
| | **≥14** | **54.3** | **92.0** | 0.74 | 0.82 | 0.63 | 0.89 | 0.43 | 0.95 |
| | ≥15 | 40.0 | 97.1 | 0.86 | 0.79 | 0.78 | 0.87 | 0.61 | 0.94 |
| | ≥16 | 31.4 | 97.7 | 0.85 | 0.77 | 0.77 | 0.85 | 0.60 | 0.93 |
| | ≥17 | 28.6 | 98.9 | 0.92 | 0.76 | 0.87 | 0.85 | 0.74 | 0.93 |
| | ≥18 | 22.9 | 99.4 | 0.94 | 0.75 | 0.91 | 0.84 | 0.81 | 0.92 |
| | ≥19 | 20.0 | 1.00 | 1.00 | 0.74 | 1.00 | 0.83 | 1.00 | 0.92 |
| **Unrounded E-Score** | | | | | | | | | |
| **AUC = .843*** ** | ≥13.05 | 60.0 | 87.4 | 0.67 | 0.84 | 0.54 | 0.90 | 0.35 | 0.95 |
| | ≥13.13 | 57.1 | 87.4 | 0.66 | 0.83 | 0.53 | 0.89 | 0.33 | 0.95 |
| | ≥13.18 | 54.3 | 88.6 | 0.67 | 0.82 | 0.54 | 0.89 | 0.35 | 0.95 |
| | ≥13.25 | 54.3 | 89.1 | 0.68 | 0.82 | 0.55 | 0.89 | 0.36 | 0.95 |
| | ≥13.31 | 54.3 | 89.7 | 0.69 | 0.82 | 0.57 | 0.89 | 0.37 | 0.95 |
| | ≥13.33 | 54.3 | 90.3 | 0.71 | 0.82 | 0.58 | 0.89 | 0.38 | 0.95 |
| | **≥13.38** | **54.3** | **92.0** | 0.74 | 0.82 | 0.63 | 0.89 | 0.43 | 0.95 |
| | ≥13.46 | 51.4 | 92.0 | 0.73 | 0.82 | 0.62 | 0.88 | 0.42 | 0.94 |
| | ≥13.65 | 51.4 | 93.1 | 0.76 | 0.82 | 0.65 | 0.88 | 0.45 | 0.95 |
| | ≥13.81 | 42.9 | 93.1 | 0.73 | 0.79 | 0.61 | 0.87 | 0.41 | 0.94 |
| | ≥13.91 | 42.9 | 95.4 | 0.80 | 0.80 | 0.70 | 0.87 | 0.51 | 0.94 |
| | ≥14.00 | 42.9 | 96.0 | 0.82 | 0.80 | 0.73 | 0.87 | 0.54 | 0.94 |

*Note*. Bolded/highlighted rows denote optimal cut-scores for identifying invalid performance. DCT = dot counting test; SN = sensitivity; SP = specificity; PPV = positive predictive value; NPV = negative predictive value; AUC = area under the curve.
***$p < .001$.

**Table 5.** Sensitivity and Specificity Values for DCT E-Scores (Standard and Unrounded) Excluding the 45 Patients in the Valid Group With One Criterion Performance Validity Test Failure (n = 165).

| | Valid (*n = 130*) vs invalid (*n = 35*) | | | 30% base rate | | 20% base rate | | 10% base rate | |
|---|---|---|---|---|---|---|---|---|---|
| DCT score | Cutoff | SN (%) | SP (%) | PPV | NPV | PPV | NPV | PPV | NPV |
| **E-Score** | | | | | | | | | |
| **AUC=.868*** ** | ≥9 | 97.1 | 50.8 | 0.46 | 0.98 | 0.33 | 0.99 | 0.18 | 0.99 |
| | ≥10 | 91.4 | 60.8 | 0.50 | 0.94 | 0.37 | 0.97 | 0.21 | 0.98 |
| | ≥11 | 80.0 | 75.4 | 0.58 | 0.90 | 0.45 | 0.94 | 0.27 | 0.97 |
| | ≥12 | 71.4 | 79.2 | 0.60 | 0.87 | 0.46 | 0.92 | 0.28 | 0.96 |
| | ≥13 | 62.9 | 86.9 | 0.67 | 0.85 | 0.55 | 0.90 | 0.35 | 0.95 |
| | **≥14** | **54.3** | **92.3** | 0.75 | 0.82 | 0.64 | 0.89 | 0.44 | 0.95 |
| | ≥15 | 40.0 | 96.9 | 0.85 | 0.79 | 0.76 | 0.87 | 0.59 | 0.94 |
| | ≥16 | 31.4 | 97.7 | 0.85 | 0.77 | 0.77 | 0.85 | 0.60 | 0.93 |
| | ≥17 | 28.6 | 99.2 | 0.94 | 0.76 | 0.90 | 0.85 | 0.80 | 0.93 |
| | ≥18 | 22.9 | 1.00 | 1.00 | 0.75 | 1.00 | 0.84 | 1.00 | 0.92 |
| | ≥19 | 20.0 | 1.00 | 1.00 | 0.74 | 1.00 | 0.83 | 1.00 | 0.92 |
| **Unrounded E-Score** | | | | | | | | | |
| **AUC=.864*** ** | ≥13.05 | 60.0 | 89.2 | 0.70 | 0.84 | 0.58 | 0.90 | 0.38 | 0.95 |
| | ≥13.13 | 57.1 | 89.2 | 0.69 | 0.83 | 0.57 | 0.89 | 0.37 | 0.95 |
| | ≥13.18 | 54.3 | 89.2 | 0.68 | 0.82 | 0.56 | 0.89 | 0.36 | 0.95 |
| | ≥13.26 | 54.3 | 90.0 | 0.70 | 0.82 | 0.58 | 0.89 | 0.38 | 0.95 |
| | ≥13.32 | 54.3 | 90.8 | 0.72 | 0.82 | 0.60 | 0.89 | 0.40 | 0.95 |
| | **≥13.38** | **54.3** | **92.3** | 0.75 | 0.82 | 0.64 | 0.89 | 0.44 | 0.95 |
| | ≥13.46 | 51.4 | 92.3 | 0.74 | 0.82 | 0.63 | 0.88 | 0.43 | 0.94 |
| | ≥13.65 | 51.4 | 93.8 | 0.78 | 0.82 | 0.67 | 0.89 | 0.48 | 0.95 |
| | ≥13.81 | 45.7 | 93.8 | 0.76 | 0.80 | 0.65 | 0.87 | 0.45 | 0.94 |
| | ≥13.91 | 42.9 | 95.4 | 0.80 | 0.80 | 0.70 | 0.87 | 0.51 | 0.94 |
| | ≥14.30 | 40.0 | 96.9 | 0.85 | 0.79 | 0.76 | 0.87 | 0.59 | 0.94 |

*Note.* Bolded/highlighted rows denote optimal cut-scores for identifying invalid performance. DCT = dot counting test; SN = sensitivity; SP = specificity; PPV = positive predictive value; NPV = negative predictive value; AUC = area under the curve.
***$p < .001$.

≥13.38, respectively. Second, DCT performance did not significantly differ between ADHD subtypes (i.e., ADHD-predominantly inattentive subtype vs combined subtype) or if comorbid psychopathology was present, suggesting that separate subtype-specific cut-scores are not needed. When compared with cut-scores provided in the DCT manual, results from this ADHD sample are most consistent with previously established cut-scores for the depression and nonclinical comparison groups (E-score ≥ 14; Boone, Lu, & Herzberg, 2002). Taken together, results reveal the DCT to be a robust PVT for patients diagnosed with ADHD. Beyond its brief administration time, the DCT has particular value within this population, given the 20% base rate of performance invalidity estimated by neuropsychologists conducting adult ADHD evaluations (Martin & Schroeder, 2020). Finally, results revealed remarkably stable classification accuracy, optimal cut-scores, and sensitivity/specificity values regardless of whether those with a single PVT failure were retained or removed from the valid group. This finding is consistent with several recent studies (e.g., McCaul et al., 2018; Rhoads, Neale, et al., 2021; Soble et al., 2021) showing no differences if those with one PVT fail are retained, even in samples with a high base rate of external incentive (e.g., Resch et al., 2021). In addition, this finding supports the inclusion of those with one embedded PVT failure as valid in PVT cross-validation studies using clinical samples, given that their inclusion reflects actual clinical practice, does not reduce sample sizes, and does not artificially deflate neurocognitive test results or inflate PVT classification accuracy statistics, regardless of the presence of external incentive (Jennette et al., 2021).

The literature examining the DCT in the context of adult ADHD is sparse at this time. Boone, Lu, Back, et al. (2002) published cut-scores suitable for patients with learning disabilities (i.e., ≥15; 85.9% sensitivity/96.8% specificity), although the specific type of learning disability was not reported. Notably, individuals with a primary diagnosis of ADHD were excluded from the learning disability validation sample. In addition, the DCT manual suggests that the normal effort groups combined cut-score (i.e., ≥19) may be

appropriate when a patient's presenting complaint involves "cognitive deficits due to toxic exposure, recent surgery to remove a brain tumor, or a diagnosis of adult attention-deficit disorder" (p. 14). Given differential expectations for processing speed impairment across such diverse clinical conditions, development of population-specific cut-scores, specifically for patients diagnosed with ADHD, is warranted. Results from this study indicated that a lowered cut-score (i.e., ≥14), relative to that recommended for patients with learning disabilities, yields adequate psychometric properties among a rigorously defined sample of patients formally diagnosed with ADHD. In comparison, Marshall et al. (2016) sought to establish a DCT cut-score by examining a sample of 268 patients clinically referred for ADHD assessment. In their study, a standard/rounded DCT E-score of ≥14 yielded 34% sensitivity and 95% specificity, which is considered insufficient sensitivity for determining invalid performance (Sherman et al., 2020). In contrast, this study's results yielded significantly higher sensitivity (i.e., 54.3%). This may have been due to differences in sample characteristics, as this study included patients formally diagnosed with ADHD, rather than those simply referred for ADHD evaluation, as was done in the Marshall et al. (2016) study. An additional strength of this study was the comprehensive approach toward examining both rounded and unrounded E-scores similar to previous cross-validations of the DCT (Bailey et al., 2021; McCaul et al., 2018; Rhoads, Resch, et al., 2021). This aspect of this study led to the conclusion that both rounded and unrounded E-scores produce similarly robust psychometric properties when evaluating patients with ADHD.

This study exhibited multiple methodological strengths, including the use of a large, demographically and ethnoracially diverse sample, the application of criterion PVTs to independently establish validity classifications (denoted by failure on ≥2 PVTs; Critchfield et al., 2019; Larrabee, 2008; Meyers et al., 2014; Sherman et al., 2020; Soble et al., 2020; Webber et al., 2020), and exclusion of individuals who did not meet the *DSM-5* criteria for ADHD diagnoses as established via a uniform, multimethod diagnostic protocol that supplemented clinical interview and medical record review with objective assessment of ADHD symptoms via a validity-controlled measure as well as complete assessment of neurocognitive functioning through administration of a comprehensive neuropsychological test battery and current psychological symptomology via the MMPI-2-RF. In addition, given the extensive nature of the diagnostic protocol, this study effectively assessed for active, comorbid psychopathology, which was present in 62% of the current sample. This aligns with previously published findings of base rates of psychiatric comorbidity in ADHD, such that adults with ADHD have been shown to be four to nine times more likely to be diagnosed with a comorbid psychological disorder (Kessler et al., 2006; Solberg et al., 2018).

Despite the strengths of this study, some limitations were notable. First, data were collected retrospectively, resulting in the exclusion of a small number of patients due to missing data. Moreover, no informant report data were available to corroborate adult ADHD diagnoses; however, this limitation is often characteristic of adult ADHD assessments, and unlike assessment of children, some studies have shown that informant reports offer no incremental validity beyond self-report in assessing childhood symptoms among adults being evaluated for ADHD (Breda et al., 2016). Nonetheless, the lack of informant data may have led to increased false-positive rates of ADHD diagnosis among the sample. In addition, the mean education attainment (i.e., 15.63 years) of the sample was high, as the majority of participants were college undergraduates, graduate students, or medical students. Furthermore, many of the criterion PVTs used to determine validity status were embedded measures, which are typically considered less psychometrically robust than freestanding PVTs (e.g., Bain et al., 2021; Ovsiew et al., 2020; Pliskin et al., 2020). That being said, seven criterion PVTs were used across the neuropsychological battery, many of which have demonstrated good pass/failure concordance with well-validated freestanding PVTs, to offset concerns about inflated false-positive or false-negative classification errors (Larrabee, 2008; Messerly et al., 2019). However, as with any criterion validity grouping procedure, it is not possible to entirely rule out the presence of examinees who are exaggerating symptoms and thus go undetected within the "valid" group (i.e., false negatives), which will vary based on the specific criterion PVTs used (e.g., Soble et al., 2020). Nonetheless, future research should aim to replicate these findings through prospective study designs in samples with greater educational heterogeneity and consider the use of more robust criterion PVTs cross-validated in ADHD populations (e.g., Victoria Symptom Validity Test; Frazier et al., 2008). Finally, as the pediatric PVT literature is currently in its infancy, researchers may wish to cross-validate the utility of the DCT for use in pediatric neuropsychological assessments, as ADHD is commonly diagnosed in childhood or adolescence.

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