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Detection of Feigned ADHD Using the MOXO-d-CPT

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Abstract

Objective: The objective of this study was to assess the MOXO-d-CPT utility in detecting feigned ADHD and establish cutoffs with adequate specificity and sensitivity. **Method**: The study had two phases. First, using a prospective design, healthy adults who simulated ADHD were compared with healthy controls and ADHD patients who performed the tasks to the best of their ability ($n = 47$ per group). Participants performed the MOXO-d-CPT and an established performance validity test (PVT). Second, the MOXO-d-CPT classification accuracy, employed in Phase 1, was retrospectively compared with archival data of 47 ADHD patients and age-matched healthy controls. **Results**: Simulators performed significantly worse on all MOXO-d-CPT indices than healthy controls and ADHD patients. Three MOXO-d-CPT indices (attention, hyperactivity, impulsivity) and a scale combining these indices showed adequate discriminative capacity. **Conclusion**: The MOXO-d-CPT showed promise for the detection of feigned ADHD and, pending replication, can be employed for this aim in clinical practice and ADHD research. *(J. of Att. Dis. 2021; 25(7) 1032-1047)*

Keywords
ADHD, continuous performance tests (CPT), MOXO-d-CPT, feigned cognitive impairment, malingering

Introduction

The feigning of ADHD is a growing concern (Sagar, Miller, & Erdodi, 2017; Tucha, Fuermaier, Koerts, Groen, & Thome, 2015). It is fueled by external incentives which include, among others, access to academic accommodations and stimulant medications. Prevalence rates of feigned ADHD are estimated to be as high as 48% (Tucha et al., 2015), leading to a consensus among experts regarding the need for its evaluation (Fuermaier, Fricke, de Vries, Tucha, & Tucha, 2019). Regrettably, despite unmistakable evidence that clinical judgment and examinee self-reports are inadequate for its detection, research and development of detection techniques focusing on feigned ADHD have not progressed at a sufficient rate (e.g., Edmundson et al., 2017; J. A. Suhr, Cook, & Morgan, 2017). This has stimulated the study of embedded validity indicators that are based on the examinee's performance in routinely administered cognitive tasks and which are increasingly used in the assessment of a variety of neuropsychiatric disorders (Rickards, Cranston, Touradji, & Bechtold, 2018). They offer several advantages over the use of standalone performance validity tests (PVTs). First, they are more difficult to identify as validity indicators and, therefore, to manipulate. Second, they are gathered *while* the examinee engages in cognitive tasks (Cottingham & Boone, 2014). They, thereby, improve our ability to continuously monitor response bias (Boone, 2009). A related advantage is that they do not increase the duration of the assessment. Finally, while most standalone PVTs focus on the feigning of memory impairments, embedded measures cover a broad range of cognitive functions.

Continuous performance tests (CPTs) are commonly used to clarify the cognitive functioning of examinees undergoing an evaluation of ADHD (Albrecht, Uebel-von, Sandersleben, Wiedmann, & Rothenberger, 2015; Hall et al., 2016). They include rapidly presented stimuli (visual and/or auditory) over a relatively prolonged time. Examinees are requested to respond to certain stimuli (i.e., targets) while ignoring others (i.e., nontargets), and their performance (e.g., omission and commission errors) provides information about relevant cognitive functions, such as the ability to sustain attention over time and response inhibition. Considering the pervasive use of CPTs in ADHD evaluations (Hall et al., 2016), researchers have sought to examine their ability to detect feigned ADHD. Initial studies were encouraging. For example, Quinn (2003) found the Integrated Visual and

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Auditory Continuous Performance Test (IVA-CPT) to be highly sensitive (94%), while maintaining adequate specificity (91%), for the detection of feigned ADHD (see also Leark, Dixon, Hoffman, & Huynh, 2002). Later studies focused mainly on the Conners' CPT (Lee, Pella, Singh, & Drew, 2010; J. A. Suhr, Sullivan, & Rodriguez, 2011), though some studies were performed on other CPTs (e.g., Test of Variables of Attention [TOVA], Quantified Behavior Test Plus [Qb+] and the IVA-CPT; Hirsch & Christiansen, 2018; Leppma, Long, Smith, & Lassiter, 2018; Robinson & Rogers, 2017). These studies provide initial support for the use of CPTs in differentiating between feigned and genuine ADHD. For example, Lee et al. (2010) found that college students simulating ADHD had lower mean scores and more scale elevations in the Conners' CPT than controls (see also Leark et al., 2002; Leppma et al., 2018). At least some studies, however, pointed toward unacceptably high false-positive rates (Robinson & Rogers, 2017) or insufficient discriminative capacity of CPTs in detecting feigned ADHD. Regarding the latter, the noncredible group examinees in J. A. Suhr et al. (2011) differed from genuine ADHD patients on only two subtests of the Conners' CPT-II (see also Sollman, Ranseen, & Berry, 2010). Importantly, several of these studies have limitations that include lack of a clinical ADHD patient group (Leark et al., 2002), inclusion of participants who did not yet have definitive ADHD diagnoses (Leppma et al., 2018), or reliance on previously provided diagnoses (i.e., possibly contaminating the ADHD group with malingerers, for example, Sollman et al., 2010). Finally, a substantial number of studies were conducted on neuropsychiatric disorders other than ADHD, thus making conclusions regarding the detection of feigned ADHD difficult (e.g., Erdodi, Pelletier, & Roth, 2018; Sharland et al., 2018).

The MOXO-d-CPT is a standardized CPT which has attracted growing clinical and research attention. Studies were performed in both ADHD (Ben-Sheetrit et al., 2017; Berger, Slobodin, & Cassuto, 2017; Grossman, Hoffman, Berger, & Zivotofsky, 2015) and other neuropsychiatric disorders (Cohen-Cymberknoh et al., 2018; Cohen, Halevy, Aharon, & Shuper, 2018). It utilizes an online platform, does not require special equipment, and has high ecological validity. Regarding the latter, the MOXO-d-CPT simulates visual and auditory environmental distractions, which are present in real-world settings (e.g., a barking dog). By providing four performance indices (i.e., attention, timeliness, impulsivity, and hyperactivity), the examiner is provided with information that taps the major cognitive functions associated with ADHD (mainly, focused/sustained attention and response inhibition). Hence, the MOXO-d-CPT improves the ability to detect ADHD and aids clinical decision in young (Berger & Cassuto, 2014; Berger et al., 2017b; Cassuto, Ben-Simon, & Berger, 2013) as well as adult examinees (Grossman et al., 2015; Jacoby & Lavidor, 2018).

To date, no published study has assessed the utility of MOXO-d-CPT in detecting feigned ADHD. The current study aimed to assess the utility of the MOXO-d-CPT to detect feigned ADHD and, pending on its discriminative capacity, establish cutoffs with adequate specificity and sensitivity. To accomplish this goal, the study was divided into two parts: (a) Study 1 (Prospective): The performance of healthy participants requested to feign ADHD (i.e., simulators) was compared with ADHD patients and healthy controls. We hypothesized that simulators will exhibit significantly poorer performance in all MOXO-d-CPT indices compared with the ADHD patients and healthy controls. Combining the indices using logistic regression was hypothesized to provide enhanced discriminative capacity compared with that attained using the indices individually. (b) Study 2 (Retrospective): Archival data of ADHD patients and healthy controls, provided by the MOXO-d-CPT publishers (Neurotech Solutions Ltd.), were used to validate the findings of Study 1. As part of this study, the discriminative capacity of each CPT measure was calculated and compared with that found in Study 1. We expected stability in the discriminative capacity of the measures between the studies, enabling the establishment of cutoffs with adequate specificity (>90%) and sensitivity levels of >50% (as achieved using other CPTs, for example; Erdodi, Tyson, et al., 2017).

Study 1 (Prospective Study)

Method

Participants. Adult females and males were assessed for eligibility (N total = 189). They were undergraduate students who received course credit for participating in the study. Inclusion criteria were the following: (a) 18 to 65 years of age. (b) ADHD patients: Previous diagnosis of ADHD (314.0x according to the *Diagnostic and Statistical Manual of Mental Disorders* [5th ed.; *DSM-5*; American Psychiatric Association, 2013]), provided by a licensed clinician (i.e., psychiatrist and/or clinical psychologist). Candidates also had to meet current *DSM-5* diagnostic criteria for ADHD. This was confirmed using the Structured Clinical Interview for DSM-5 (SCID-5-RV; First, Williams, Karg, & Spitzer, 2015), conducted by a trained clinician upon study entry. Exclusion criteria were the following: (a) Past or present neurological disorders and/or neurosurgery (e.g., traumatic brain injury); (b) past or present psychiatric disorders, except ADHD for participants in the ADHD patient group; participants with personality disorders were not excluded from the study; (c) learning disabilities; (d) healthy participants: self-report of current attentional deficits, operationalized as total score ≥37 in the Adult ADHD Self-Report Scale (ASRS; criterion used, for example, by Lozano et al., 2016). Thereby, the inclusion of participants endorsing high

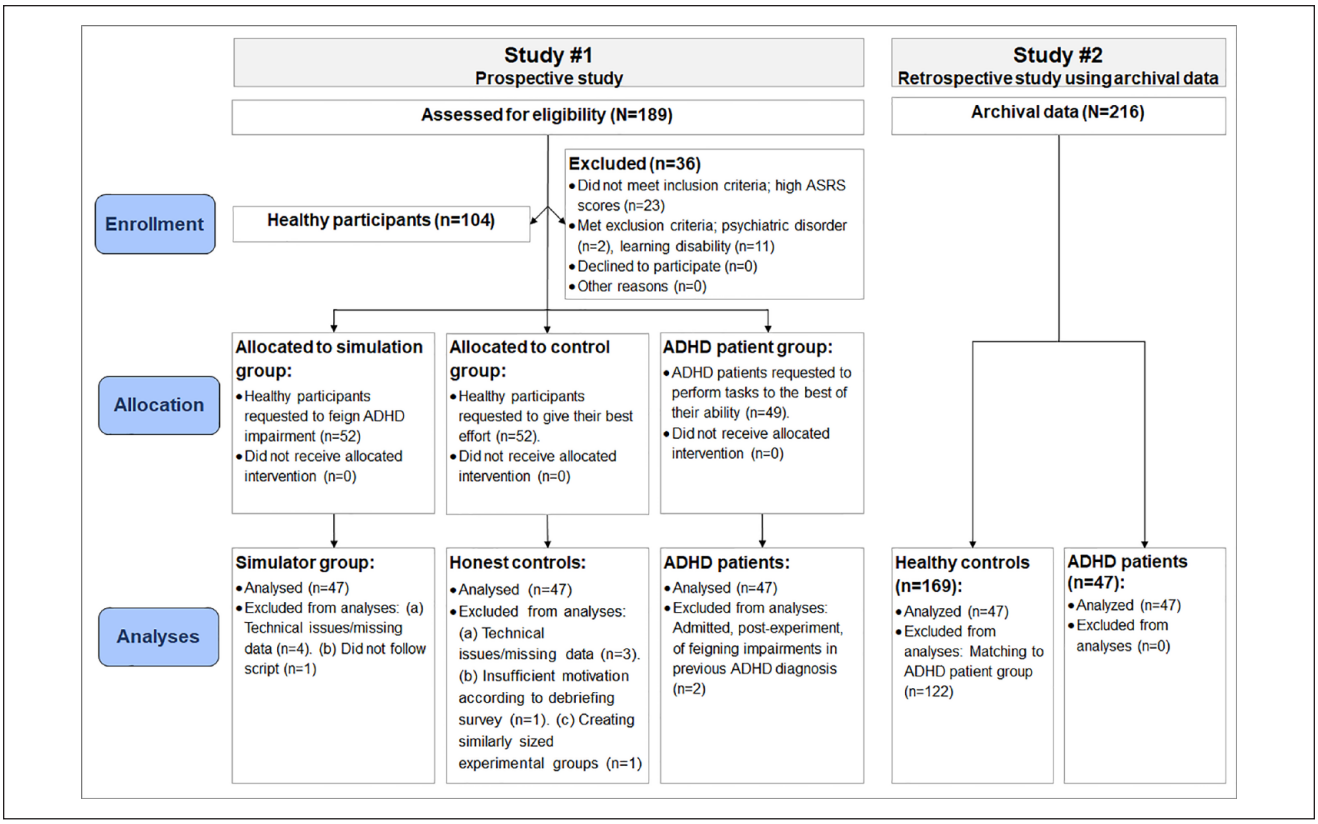

Figure 1. CONSORT flow of Study 1 (prospective study) and Study 2 (retrospective study using archival data).
Note. CONSORT = Consolidated Standards of Reporting Trials.

rates of attentional deficits at adulthood due to yet insufficiently understood etiology was minimized (e.g., patients with the currently debated diagnosis of "late-onset" ADHD; Caye, Sibley, Swanson, & Rohde, 2017; Solanto, 2018).

Candidates with psychiatric disorders other than ADHD ($n = 2$) and learning disabilities ($n = 11$), and healthy participants with self-reported current attentional impairments ($n = 23$) were excluded. Overall, 52 simulators, 49 ADHD patients, and 52 healthy controls participated in Study 1. The data of participants that either did not sufficiently comply with the experimental instructions and/or reported insufficient motivation in performing the study (<4 on a Likert-type scale that ranged from 0 to 7 in the debriefing survey) were excluded from analyses ($n = 2$). ADHD patients who admitted feigning impairments during their earlier diagnosis (see "Procedure" section for elaboration) were also excluded from analyses ($n = 2$). Four participants participated in an undergraduate course on ADHD. Fisher's exact test showed no significant association ($p = .77$) between group membership and this prior knowledge of ADHD. Finally, the data of one healthy control were randomly excluded from analyses to create similarly sized experimental groups. See Figure 1 for the study's Consolidated Standards of Reporting Trials (CONSORT) diagram.

The study was approved by the University's Institutional Review Board (IRB). All participants provided written informed consent and were free to withdraw, without repercussions, from the study at any time.

Materials

ADHD Self-Report Scale (ASRS). This is an 18-item self-report questionnaire, representing 18 ADHD symptoms in adulthood (Kessler et al., 2005). The items reflect the *DSM*'s diagnostic criteria for ADHD; nine items probe symptoms of inattention and nine items probe symptoms of hyperactivity/impulsivity. They are rated on a Likert-type scale from 0 (*never*) to 4 (*always*). The Hebrew version of the ASRS was shown to have excellent test–retest reliability and good internal consistency, and its validity was supported by comparing adults with ADHD to those without the disorder (Zohar & Konfortes, 2010).

Wender Utah Rating Scale (WURS). This is a 61-item self-report questionnaire, which provides a quantitative retrospective assessment regarding the presence and severity of ADHD in childhood (Ward, Wender, & Reimherr, 1993). Items are rated on a 5-point Likert-type scale (high scores indicating more severe symptoms). In the current study, we

used the 25 items of the WURS, which were found to best differentiate ADHD patients from healthy controls (Ward et al., 1993). This version of the WURS is commonly used in research (e.g., Barbaresi, Weaver, Voigt, Killian, & Katusic, 2018; Weibel et al., 2018).

MOXO-d-CPT. The CPT is an 18.2-min test which consists of eight blocks (53 trials in each block). In each trial, a stimulus (target or nontarget) is presented in the middle of the computer screen. It is followed by a "void" of the same duration, during which no stimuli are presented. Participants are requested to press the spacebar in response to targets and refrain from pressing it in response to nontargets. This is done while ignoring a series of visual and auditory distracters (e.g., animation of a barking dog). The CPT's blocks differ in cognitive load; two are distracter free, two include visual distracters, two include auditory distracters and, finally, two include combinations of visual and auditory distracters. The examiner is provided with four performance indices (see also Appendix A in Berger, Slobodin, Aboud, Melamed, & Cassuto, 2013): (a) *Attention*: Number of correct responses performed within a predefined response time frame (i.e., during stimulus presentation or the interstimulus interval [ISI] following it). (b) *Timeliness*: Number of correct responses performed *only* during the time in which the target stimulus was present on the screen. (c) *Hyperactivity*: Number of commission responses that were not coded as impulsive responses (e.g., multiple keystrokes in response to a target stimulus). (d) *Impulsivity*: Number of commission responses performed during the time in which a nontarget stimulus was present on the screen. Participants were provided with *z* scores for each of the indices, based on the MOXO-d-CPT's normative database.

Word Memory Test (WMT). This is a well-established verbal forced-choice recognition PVT (Green, 2003). It is widely used in both clinical (Martin, Schroeder, & Odland, 2015; Schroeder, Martin, & Odland, 2016) and research settings (e.g., Bryant et al., 2018; Lupu, Elbaum, Wagner, & Braw, 2018) and was found to have high sensitivity and adequate specificity in a variety of neurological conditions (Greve, Curtis, & Bianchini, 2013). The immediate recognition (IR)-score and delayed recognition (DR)-score (% correct responses in the IR and DR subtests, respectively), as well as the consistency score (CNS), were used to classify participants according to the WMT's classification scheme (Green, 2005). Additional information was not provided so as to maintain the WMT's confidentiality.

Procedure. Willing participants filled out questionnaires (i.e., demographics and health questionnaire, ASRS, WURS) and underwent the SCID-5-RV semistructured interview. They were then notified that they will perform cognitive tasks that the university's counseling center considers to integrate as part of their routine process for the diagnosis of ADHD . ADHD patients were requested to perform the tasks to the best of their ability while healthy participants were randomly assigned to one of two conditions[1]: (a) *Simulators*: Requested to play the part of an undergraduate student who attempts to receive academic accommodations (e.g., extended tests times) by being diagnosed with ADHD. (b) *Healthy controls*: Requested to perform the tasks to the best of their ability. Participants responded to three forced-choice questions assessing their understanding of the experimental instructions and any misunderstandings were clarified by the research team. To encourage ADHD patients and healthy controls to perform the tasks to the best of their ability, as well as discourage grossly impaired presentation by simulators, participants were informed that a $100 cash prize will be raffled among participants who acted in accordance with the experimental instructions. They also received a certification indicating that they are eligible for *additional* course credit which will be voided if their performance indicates insufficient effort (healthy controls / ADHD patients) or grossly impaired presentation by simulators (i.e., all participants received the credit at the end of the study). Participants were notified that no information regarding their performance in the study will be provided to them, discouraging any attempts to feign cognitive impairments in the study. All ADHD patients refrained from taking stimulant medications for $>$12 hr before testing.

The participants then performed the WMT's IR-subtest, MOXO-d-CPT, WMT's DR-subtest, and filled a debriefing survey. The latter reassessed their comprehension of the experimental instructions and their motivation to perform the tasks accordingly. Also, ADHD patients were provided with a brief questionnaire inquiring whether they feigned impairments during their previous diagnosis and, if so, to what extent. They were notified that their responses will be kept confidential and filled out the questionnaire while the experimenter was not present in the room. The participants then placed the questionnaire, identified using only the participant's identification code, in an envelope which was sealed and placed in a large basket containing additional envelopes.

Data analysis (pertaining to Studies 1 and 2). All analyses were based on two-tailed hypotheses, with $p < .05$ marking statistical significance. Categorization of effect sizes (Cohen's *d*) for group differences were based on the following standards: (a) moderate ≥ 0.75, (b) large ≥ 1.25, and (c) very large ≥ 1.50 (Rogers, 2018). Discriminative capacities of the measures were qualitatively interpreted based on area under the curve (AUC) in receiver operating characteristic (ROC) curve analyses (Hosmer, Lemeshow,

Table 1. Simultaneous Logistic Regression Based on Prospective Data (Study 1) of Simulators Compared With ADHD Patients (n = 47 in Each Group).

	Model statistics	Coefficients statistics		
Predictors	$\chi^2(df)$, p	B	SE	Wald statistic, p
	82.03(3), $p < .001$			
1. Attention (z score)		−0.172	0.060	8.148, $p = .004$
2. Hyperactivity (z score)		−0.226	0.084	7.178, $p = .007$
3. Impulsivity (z score)		−0.690	0.185	13.929, $p < .001$
Constant		−4.186	0.971	18.597, $p < .01$

Note. The combined feigned ADHD impairment probability scale equation:

$$P(Simulators) = \frac{1}{1+e^{-\left(\begin{array}{l}-0.172222\times \text{attention index} - 0.226241\times \\ \text{hyperactivity index} - 0.690418\times \\ \text{impulsivity index} - 4.185786\end{array}\right)}}$$

& Sturdivant, 2013). Sensitivity levels were qualitatively interpreted by the recommendations of Boone (2013).

Results

Combining MOXO-d-CPT indices into a unified scale (MOXO-d-CPT feigned ADHD scale) using logistic regression. A multivariate prediction model for discriminating simulators from ADHD patients was created using simultaneous logistic regression. The analysis was intended to assess group prediction (simulators / ADHD patients) based on a combination of the MOXO-d-CPT indices. Pearson product-moment correlations between MOXO-d-CPT indices and the variance inflation factor (VIF) of the indices were used to assess the possibility of multicollinearity. All indices had VIF < 4 (i.e., the multicollinearity criterion that was proposed by O'brien, 2007). However, the attention and timeliness indices were strongly correlated ($r = 0.80$, $p < .001$), raising the possibility of multicollinearity between the indices (see Supplementary Material 1 for the correlation matrix of the indices). Since timeliness had a lower effect size in the group comparisons (see Table 2), the index was excluded from the regression analysis. The regression model (i.e., attention, hyperactivity and impulsivity indices as predictors) significantly predicted group membership, $p < .001$. Based on its predicted values, 85.1% of ADHD patients, 87.2% of simulators, and 86.2% of the overall sample were correctly classified (a default cutoff of 0.5 was used to classify participants). All indices contributed significantly to the prediction of group membership ($p = .004$, $p = .007$, $p < .001$; for the attention, hyperactivity, and impulsivity indices, respectively). Next, the regression model was used to compute a scale (termed *MOXO-d-CPT feigned ADHD scale* or *combined scale*), which combined the unique contribution of each of the individual indices. The equation's outcome, P(simulators), estimates the probability (range = 0-1) of a participant being classified as a simulator, given the participant's scores in the indices (see Lupu et al., 2018). See Table 1 for the logistic regression analysis and the combined scale's equation.

Group comparisons in demographic/health measures, MOXO-d-CPT indices, and the combined scale. Analyses of variance (ANOVAs) comparing the groups (simulators / ADHD patients / healthy controls) by demographic variables indicated significant differences in education level, $p = .018$. Post hoc Tukey tests indicated a higher education level of ADHD patients compared with simulators. The difference is likely of minor importance because the groups were relatively similar in education level (mean ADHD patients = 13.00, mean simulators = 12.36). Also, the findings were virtually identical when education level was used as a covariate in parametric analyses, as well as when a subset of participants was analyzed (i.e., groups of 40 participants were created by excluding participants with low [simulators] or high [ADHD patients] education levels). No other group differences in demographic variables were found. Self-reported attentional impairments showed the expected group differences (i.e., ADHD patients had significantly higher WURS / ASRS total scores than both simulators and healthy controls; note that the questionnaires were filled out *before* the experimental manipulation). A chi-square analysis comparing the groups by the number of failures in the WMT was significant, $\chi^2(2) = 108.77$, $p < .001$. Post hoc chi-square analyses indicated that more simulators failed the WMT than both healthy controls and ADHD patients ($ps < .001$). Also, more ADHD patients failed the WMT than healthy controls ($p = .003$).

Multivariate analysis of variance (MANOVA) comparing the groups in the MOXO-d-CPT indices indicated significant group differences, $F(8, 270) = 21.07$, $p < .001$. Follow-up ANOVAs indicated significant differences in all MOXO-d-CPT indices (attention, hyperactivity, timeliness, and impulsivity, $ps<.001$). Post hoc Tukey tests indicated

Table 2. Prospective Data (Study 1) Descriptive Statistics and Statistical Analyses for Simulators, Healthy Controls, and ADHD Patients ($n = 47$ in Each Group).

Measures		Simulators (A)	ADHD patients (B)	Healthy controls (C)	Statistical analyses	Group differences	Effect size
		M ± *SD*	*M* ± *SD*	*M* ± *SD*	Parametric analyses		Cohen's *d*
Age (years)		22.70 ± 2.24	23.79 ± 2.17	23.15 ± 2.39	$F(2, 138) = 2.73$, $p = .069$	n.s.	n.s.
Education level (years)		12.36 ± 0.90	13.00 ± 1.30	12.62 ± 1.33	$F(2, 138) = 4.13$, $p = .018$	A < B	0.57
WURS 25-items (no.)		19.15 ± 10.38	32.75 ± 15.38	19.45 ± 9.59	$F(2, 138) = 19.50$, $p < .001$	A < B	1.12
						B > C	1.04
ASRS (no.)		22.81 ± 7.42	33.09 ± 10.71	24.043 ± 6.345	$F(2, 138) = 21.14$, $p < .001$	A < B	1.12
						B > C	1.03
MOXO-d-CPT	Attention index (z score)	−8.94 ± 7.36	−2.03 ± 5.03	−0.90 ± 2.59	$F(2, 138) = 31.05$, $p < .001$	A < B	1.10
						A < C	1.46
	Timeliness index (z score)	−3.29 ± 1.93	−1.66 ± 2.05	−0.73 ± 1.46	$F(2, 138) = 23.60$, $p < .001$	A < B	0.82
						B < C	0.52
						A < C	1.50
	Hyperactivity index (z score)	−10.35 ± 8.34	−2.05 ± 4.19	−1.07 ± 2.91	$F(2, 138) = 38.34$, $p < .001$	A < B	1.26
						A < C	1.49
	Impulsivity index (z score)	−6.78 ± 4.76	−1.03 ± 1.62	−0.33 ± 1.43	$F(2, 138) = 64.72$, $p < .001$	A < B	1.62
						A < C	1.84
	Combined scale (no.)	0.84 ± 0.25	0.17 ± 0.24	0.09 ± 0.20	$F(2, 138) = 149.65$, $p < .001$	A < B	2.74
						A > C	3.29
WMT	IR-score (%)	64.46 ± 11.95	93.74 ± 7.67	97.95 ± 2.99	$F(2, 138) = 222.68$, $p < .001$	A < B	2.92
						A < C	3.84
						B < C	0.72
	DR-score (%)	65.29 ± 10.64	92.40 ± 8.68	97.61 ± 3.25	$F(2, 138) = 213.07$, $p < .001$	A < B	2.79
						A < C	4.12
						B < C	0.79
	CNS (%)	60.73 ± 13.13	91.83 ± 9.17	96.86 ± 3.88	$F(2, 138) = 198.97$, $p < .001$	A < B	2.75
						A < C	3.73
						B < C	0.71
		Numbers	Numbers	Numbers	Nonparametric analyses		
Gender (male/female)		10 / 37	17 / 30	14 / 33	$\chi^2(2) = 2.55$, $p = .280$		
Family status (single/married)		42 / 4	38 / 9	39 / 8	$\chi^2(2) = 2.22$, $p = .330$		
Birth country (Israel/other)		41 / 6	44 / 3	46 / 1	$\chi^2(2) = 4.09$, $p = .129$		
Classification according to the WMT (suspected/not-suspected)		46 / 1	8 / 39	0 / 47	$\chi^2(2) = 108.77$, $p < .001$		

Note. ASRS = Adult ADHD Self-Report Scale; CNS = consistency score; DR = delayed recognition; IR = immediate recognition; OR = odds ratio; WMT = word memory test; WURS = Wender Utah Rating Scale.

that simulators performed significantly worse than both ADHD patients and healthy controls in all indices ($ps < .001$). In addition, ADHD patients performed significantly worse than healthy controls in the timeliness index ($p = .04$). No other significant differences between these two groups were found in the MOXO-d-CPT indices and combined scale. An ANOVA comparing the groups in the combined scale indicated significant group differences, mirroring those found in the other indices, $F(2, 138) = 149.650$, $p < .001$. Post hoc Tukey tests indicated that simulators performed worse than either ADHD patients or healthy controls, as well as between simulators and healthy controls (all $ps < .001$). Differences between ADHD patients and healthy controls were not significant ($p = .201$). Effect sizes of the comparisons between simulators and ADHD patients were very large (impulsivity index and combined scale), large (hyperactivity index), and moderate (attention and timeliness indices). The effects sizes for the comparisons between simulators and healthy controls were very large (timeliness index, impulsivity index, and combined scale) and large (attention and hyperactivity indices) (see Table 2).

Discriminative capacity and cutoffs of MOXO-d-CPT indices and the combined scale. ROC curve analyses were used to assess the capacity of each of the MOXO-d-CPT indices, as well as that of the combined scale, to discriminate between simulators and ADHD patients. The analyses pointed toward outstanding discriminative capacities of the impulsivity index and the combined scale (AUC = 0.907, AUC = 0.957, respectively). Discriminative capacities were excellent for the attention and hyperactivity

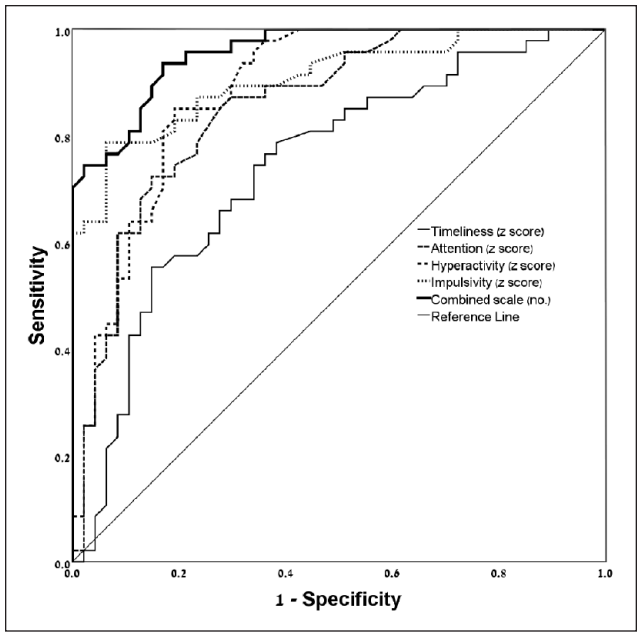

Figure 2. Differentiating simulators (n = 47) from ADHD patients (n = 47) in Study 1: Receiver operating characteristic curves for the MOXO-d-CPT indices (attention, timeliness, hyperactivity, and impulsivity), and the combined scale.

indices (AUC = 0.856; AUC = 0.884, respectively) and acceptable for the timeliness index (AUC = 0.741) (see Figure 2).

The classification accuracy of cutoffs for differentiating simulators from ADHD patients are presented in Table 3. As evident from the table, perfect specificity and sensitivity >50% was reached for two measures (impulsivity index and the combined scale). While perfect specificity could not be reached for the other indices, attention and hyperactivity still offered adequate discriminative capacity (e.g., the attention index, the stronger predictor of the two indices, enabled 61.70% sensitivity and 91.49% specificity to be reached using a $z = -5.30$ cutoff). Finally, a cutoff with >90% specificity and >50% sensitivity could *not* be reached for the timeliness index.

ROC curve analyses differentiating simulators and healthy controls were also performed. As expected, the discriminative capacities of the measures were stronger than in the previously described analyses (i.e., comparisons of simulators and ADHD patients). More specifically, discriminative capacities were outstanding for the attention, hyperactivity, and impulsivity indices, as well as the combined scale (AUC = 0.907, AUC = 0.933, AUC = 0.948, AUC = 0.978; respectively). It was excellent for the timeliness index (AUC = 0.851).

Exploratory analyses. Using the WMT's classification scheme (see classification scheme in Green, 2005), specificity was 82.98% and 100% (ADHD patients and healthy controls) while sensitivity was 95.83%.

Pearson product-moment correlations between the five MOXO-d-CPT measures (i.e., the four indices and the combined scale) and the three WMT validity indicators (IR-score, DR-score, CNS) were performed to clarify the associations of the MOXO-d-CPT measures with well-validated validity indicators. The magnitude of the correlation were than classified as weak ($r < .40$), moderate (r = .40-.69), or strong ($r \geq .70$), following Dancey and Reidy (2017). The analyses revealed that the correlations were highly significant ($ps < .001$; see Table 4). The impulsivity index and the combined scale were strongly correlated with the WMT validity indicators (.735 to .749, −.839 to −.833; respectively). The other correlations with the WMT validity indicators were moderate: attention (.507-.563), hyperactivity (.552-.622), and timeliness (.464-.542).

Study 2 (Validation Study Using Archival Data)

Method

Participants. We were provided with archival data by Neurotech Solutions Ltd. (i.e., the MOXO-d-CPT publishers; https://www.neurotech-solutions.com). The data were of 216 adult examinees who were assessed in research centers (i.e., universities) or university-affiliated medical centers, located in Australia, Hungary, Turkey, and Israel: – 47 ADHD patients (n males = 24; age: 27.32 ± 8.65 years) and 169 healthy controls. We matched the groups in age (±1 year) for a final group of 47 healthy controls (n males = 15; age: 27.28 ± 8.44). All participants fulfilled the study's inclusion/exclusion criteria detailed earlier, except Inclusion Criterion b; because the ADHD patients were diagnosed *at the time* he or she performed the MOXO-d-CPT, no previous diagnosis of ADHD was required.

The study was approved by each Institution's Review Board (IRB) committee. All participants provided written informed consent and were free to withdraw from the study at any point, without repercussions (see Figure 1).

Results

Preliminary analyses. A MANOVA of MOXO-d-CPT indices comparing archival (attention index: −1.47 ± 4.40; timeliness index: −1.69 ± 2.42; hyperactivity index: −3.30 ± 7.19; impulsivity index: −1.24 ± 4.70) and prospective data (i.e., assessed in Study 1) of ADHD patients was not significant, $F(4, 89) = 0.601$, $p = .663$. Similarly, no significant differences were found between archival (attention index: −0.63 ± 2.83; timeliness index: −0.82 ± 1.96; hyperactivity index: −1.55 ± 4.02; impulsivity index: 0.21 ± 2.52) and prospective data of healthy

Table 3. Classification Accuracy of MOXO-d-CPT Indices and the Combined Feigned Cognitive Impairment Scale, Based on Prospective Analyses of Simulators and ADHD Patients (Study 1).

Attention index			Timeliness index			Hyperactivity index			Impulsivity index			Combined scale (*z* score)		
Cutoff (*z* score)	SPEC (%)	SENS (%)	Cutoff (*z* score)	SPEC (%)	SENS (%)	Cutoff (*z* score)	SPEC (%)	SENS (%)	Cutoff (*z* score)	SPEC (%)	SENS (%)	Cutoff (no.)	SPEC (%)	SENS (%)
−30.43	100.00	2.13	−9.30	100.00	0.00	−21.59	100.00	8.51	**−5.83**	**100.00**	**61.70**	**0.885**	**100.00**	**70.21**
−26.35	97.87	2.13	−7.92	97.87	0.00	−19.93	97.87	8.51	**−5.64**	**97.87**	**61.70**	**0.825**	**97.87**	**72.34**
−22.50	97.87	4.26	−7.37	97.87	2.13	−19.38	97.87	10.64	**−5.02**	**97.87**	**63.83**	**0.765**	**97.87**	**74.47**
−21.32	97.87	6.38	−6.82	95.74	2.13	−18.34	97.87	12.77	**−4.57**	**93.62**	**63.83**	**0.725**	**95.74**	**74.47**
−20.10	97.87	8.51	−6.36	95.74	4.26	−17.35	97.87	14.89	**−4.53**	**93.62**	**65.96**	**0.670**	**93.62**	**74.47**
−19.22	97.87	10.64	−6.23	95.74	6.38	−16.68	97.87	17.02	**−4.37**	**93.62**	**68.09**	**0.635**	**93.62**	**76.60**
−17.95	97.87	14.89	−5.82	95.74	8.51	−15.69	97.87	19.15	**−4.15**	**93.62**	**70.21**	**0.610**	**91.49**	**76.60**
−17.27	97.87	17.02	−5.41	93.62	10.64	−14.25	97.87	21.28	**−4.05**	**93.62**	**72.34**	—	—	—
−16.81	97.87	19.15	−5.30	93.62	14.89	−13.35	97.87	23.40	**−3.79**	**93.62**	**74.47**	—	—	—
−15.64	97.87	21.28	−5.18	93.62	17.02	−13.19	97.87	25.53	**−3.28**	**93.62**	**78.72**	—	—	—
−13.67	97.87	23.40	−5.10	93.62	19.15	−12.85	95.74	25.53	**−2.84**	**91.49**	**78.72**	—	—	—
−12.41	97.87	25.53	−5.02	93.62	21.28	−12.36	95.74	27.66	—	—	—	—	—	—
−12.01	95.74	25.53	−4.95	91.49	23.40	−11.94	95.74	29.79	—	—	—	—	—	—
−11.62	95.74	27.66	−4.88	91.49	25.53	−11.77	95.74	31.91	—	—	—	—	—	—
−11.42	95.74	29.79	−4.74	91.49	27.66	−11.27	95.74	34.04	—	—	—	—	—	—
−11.13	95.74	31.91	—	—	—	−10.44	95.74	38.30	—	—	—	—	—	—
−10.69	95.74	34.04	—	—	—	−9.95	95.74	40.43	—	—	—	—	—	—
−10.21	95.74	36.17	—	—	—	−9.62	95.74	42.55	—	—	—	—	—	—
−9.86	93.62	38.30	—	—	—	−9.29	93.62	42.55	—	—	—	—	—	—
−9.73	93.62	42.55	—	—	—	−9.03	93.62	44.68	—	—	—	—	—	—
−9.63	91.49	42.55	—	—	—	−8.86	91.49	44.68	—	—	—	—	—	—
−9.28	91.49	44.68	—	—	—	−8.62	91.49	46.81	—	—	—	—	—	—
−8.69	91.49	46.81	—	—	—	−8.29	91.49	48.94	—	—	—	—	—	—
−7.81	**91.49**	**51.06**	—	—	—	**−7.96**	**91.49**	**53.19**	—	—	—	—	—	—
−7.03	**91.49**	**53.19**	—	—	—	—	—	—	—	—	—	—	—	—
−6.84	**91.49**	**55.32**	—	—	—	—	—	—	—	—	—	—	—	—
−6.35	**91.49**	**57.45**	—	—	—	—	—	—	—	—	—	—	—	—
−5.67	**91.49**	**59.57**	—	—	—	—	—	—	—	—	—	—	—	—
−5.30	**91.49**	**61.70**	—	—	—	—	—	—	—	—	—	—	—	—

Note. Combined scale: combined feigned ADHD impairment probability scale. Cutoffs with >90% specificity and >50% sensitivity for detecting feigned ADHD marked in bold; *Lower* scores in the MOXO-d-CPT indices and *higher* combined scale scores suggest the feigning of cognitive impairments. SENS = Sensitivity; SPEC = Specificity.

Table 4. Pearson Product-Moment Correlations Between the MOXO-d-CPT Measures and the Word Memory Test (WMT) Validity Indicators.

	Attention index	Timeliness index	Hyperactivity index	Impulsivity index	Combined scale
WMT IR-score (%)	$r = .546$, $p < .001$[b]	$r = .524$, $p < .001$[b]	$r = .622$, $p < .001$[b]	$r = .749$, $p < .001$[c]	$r = -.835$, $p < .001$[c]
WMT DR-score (%)	$r = .563$, $p < .001$[b]	$r = .542$, $p < .001$[b]	$r = .610$, $p < .001$[b]	$r = .748$, $p < .001$[c]	$r = -.839$, $p < .001$[c]
WMT CNS (%)	$r = .507$, $p < .001$[b]	$r = .464$, $p < .001$[b]	$r = .552$, $p < .001$[b]	$r = .735$, $p < .001$[c]	$r = -.833$, $p < .001$[c]

Note. CNS = consistency score; DR = delayed recognition; IR = immediate recognition; WMT = word memory test.
[a]Weak ($r < .40$). [b]Moderate ($r = .40$-$.69$). [c]Strong ($r \geq .70$).

Table 5. ROC Curve Analyses Differentiating Simulators (Prospective Data; Study 1) and (a) ADHD Patients (Prospective Data; Study 1), or (b) ADHD Patients (Archival Data; Study 2).

	Study 1	Study 2	Study 1	Study 2
MOXO-d-CPT measures	Simulators vs. ADHD patients	Simulators vs. ADHD patients (archival)	Simulators vs. healthy controls	Simulators vs. healthy controls (archival)
Attention index(AUC, *p*, 95% CI)	0.856, $p < .001$, [0.779, 0.932]	0.883, $p < .001$, [0.812, 0.953]	0.907, $p < .001$, [0.847, 0.968]	0.934, $p < .001$, [0.881, 0.986]
Timeliness index(AUC, *p*, 95% CI)	0.741, $p < .001$, [0.640, 0.842]	0.720, $p < .001$, [0.615, 0.826]	0.851, $p < .001$, [0.775, 0.927]	0.823, $p < .001$, [0.735, 0.910]
Hyperactivity index (AUC, *p*, 95% CI)	0.884, $p < .001$, [0.816, 0.953]	0.849, $p < .001$, [0.766, 0.933]	0.933, $p < .001$, [0.883, 0.983]	0.900, $p < .001$, [0.932, 0.967]
Impulsivity index (AUC, *p*, 95% CI)	0.907, $p < .001$, [0.848, 0.967]	0.834, $p < .001$, [0.748, 0.920]	0.948, $p < .001$, [0.905, 0.991]	0.938, $p < .001$, [0.884, 0.993]
Combined scale (AUC, *p*, 95% CI)	0.957, $p < .001$, [0.922, −0.991	0.904, $p < .001$, [0.841, 0.967]	0.978, $p < .001$, [0.953, 1.000]	0.977, $p < .001$, [0.942, 1.000]

Note. AUC = area under the curve; CI = confidence interval.

controls, $F(4, 89) = 0.423$, $p = .791$. In summary, archival data of MOXO-d-CPT performance did not differ significantly from that gathered in Study 1 (prospective).

Group comparisons MOXO-d-CPT indices and the combined scale. A MANOVA comparing ADHD patients (archival data), healthy controls (archival data), and simulators (assessed in Study 1) in MOXO-d-CPT indices was significant, $F(8, 272) = 14.927$, $p < .001$. Follow-up ANOVAs indicated significant differences in all indices, attention: $F(2, 138) = 36.296$, $p < .001$; timeliness: $F(2, 138) = 16.458$, $p < .001$; hyperactivity: $F(2, 138) = 22.264$, $p < .001$; impulsivity: $F(2, 138) = 34.466$, $p < .001$. Similar group differences were found in post hoc Tukey tests that were performed on each index; simulators performed significantly worse than both ADHD patients and healthy controls (largest $p = .001$), with no significant differences between the two latter groups. An ANOVA comparing the groups in the combined scale indicated significant group differences, mirroring the group differences that were found for the other indices, $F(2, 138) = 108.927$, $p < .001$ (*p*s of post hoc Tukey tests: <.001 to .017). Effects sizes of the comparisons between simulators and ADHD patients were very large (combined scale), moderate (attention, hyperactivity and impulsivity indices), and small (timeliness index). The effects sizes for the comparisons between simulators and healthy controls were very large (impulsivity index and combined scale) and large (attention, timeliness, and hyperactivity indices). A MANOVA comparing archival data of ADHD patients and healthy controls was not significant, $F(4, 89) = 1.839$, $p = .128$. It should be noted, however, that the group differences in timeliness approached significance in follow-up ANOVAs, $F(1, 92) = 3.694$, $p = .058$. The group differences in the other indices were not significant.

Discriminative capacities of the MOXO-d-CPT indices / combined scale and suggested cutoffs for further research. Discriminative capacity was outstanding for the combined scale (AUC = 0.904), and excellent for the attention, hyperactivity, and impulsivity indices (AUC = 0.883, AUC = 0.849, AUC = 0.834; respectively) in ROC curve analyses of ADHD patients (archival data) and simulators (assessed in Study 1). Acceptable discriminative capacity was found for the timeliness index (AUC = 0.720). Comparison of these findings with those of Study 1 (i.e., prospective data) indicated relative stability in the discriminative capacity of three indices; there was a 0.027, 0.021, and 0.035 change in the AUCs of the attention, timeliness, and hyperactivity indices (respectively). There were somewhat larger changes (i.e., decreases) in the AUCs of the impulsivity index and the combined scale (0.053 and 0.073, respectively) between the studies. Note, however, that the combined scale showed outstanding discriminative capacity in both studies.

See Table 5 for a comparison of the ROC curve analyses between the studies. The table also presents ROC curve analyses for differentiating healthy controls (archival data) and simulators (assessed in Study 1).

All but one of the MOXO-d-CPT measures (i.e., attention index) had lower discriminative capacities in Study 2 than in Study 1. A conservative approach (i.e., attempting to minimize false positives), therefore, calls for selecting cutoffs for these measures based on the findings of Study 2. The combined scale is especially attractive in this regard (see Table 6); all suggested cutoffs of the scale have >90% specificity, and three have >50% sensitivity (i.e., combined scale score ≥ 0.975). In contrast, the attention index showed lower discriminative capacity in Study 1 than in Study 2. A conservative approach, therefore, calls for using cutoffs for further research based on Study 1 (Table 3). Cutoffs proposed in Study 2 (Table 6), however, may also

Table 6. Classification Accuracy of MOXO-d-CPT Indices and the Combined Feigned Cognitive Impairment Scale, Based on Comparisons of Simulators (Prospective Data; Study 1) and ADHD Patients (Archival Data; Study 2).

Attention index			Timeliness index			Hyperactivity index			Impulsivity index			Combined scale (*z* score)		
Cutoff (*z* score)	SPEC (%)	SENS (%)	Cutoff (*z* score)	SPEC (%)	SENS (%)	Cutoff (*z* score)	SPEC (%)	SENS (%)	Cutoff (*z* score)	SPEC (%)	SENS (%)	Cutoff (no.)	SPEC (%)	SENS (%)
−27.25	100.00	2.13	−7.41	97.87	2.13	−36.21	100.00	4.26	−16.06	100.00	4.26	0.985	95.74	44.68
−23.17	97.87	2.13	−7.05	95.74	2.13	−30.27	97.87	4.26	−13.55	97.87	4.26	**0.975**	**93.62**	**53.19**
−22.50	97.87	4.26	−6.81	93.62	2.13	−25.03	95.74	4.26	−12.04	97.87	6.38	**0.965**	**91.49**	**57.45**
−21.32	97.87	6.38	−6.61	91.49	2.13	−23.36	95.74	6.38	−11.65	97.87	8.51	**0.955**	**91.49**	**59.57**
−20.10	97.87	8.51	−6.36	91.49	4.26	−22.09	95.74	8.51	−10.96	97.87	10.64	—	—	—
−19.22	97.87	10.64	−6.23	91.49	6.38	−20.44	93.62	8.51	−10.47	97.87	12.77	—	—	—
−17.95	97.87	14.89	−5.95	91.49	8.51	−19.38	93.62	10.64	−10.30	95.74	12.77	—	—	—
−17.27	97.87	17.02	—	—	—	−18.34	93.62	12.77	−9.91	93.62	14.89	—	—	—
−16.81	97.87	19.15	—	—	—	−17.35	93.62	14.89	−9.61	93.62	21.28	—	—	—
−15.67	97.87	21.28	—	—	—	−16.68	93.62	17.02	−9.22	93.62	23.40	—	—	—
−14.87	95.74	21.28	—	—	—	−15.69	93.62	19.15	−8.75	91.49	23.40	—	—	—
−13.67	95.74	23.40	—	—	—	−14.25	93.62	21.28	−8.55	91.49	25.53	—	—	—
−12.11	95.74	25.53	—	—	—	−13.35	93.62	23.40	—	—	—	—	—	—
−11.62	95.74	27.66	—	—	—	−13.11	93.62	25.53	—	—	—	—	—	—
−11.42	95.74	29.79	—	—	—	−12.78	91.49	25.53	—	—	—	—	—	—
−11.13	95.74	31.91	—	—	—	−12.36	91.49	27.66	—	—	—	—	—	—
−10.69	95.74	34.04	—	—	—	−11.94	91.49	29.79	—	—	—	—	—	—
−10.40	95.74	36.17	—	—	—	−11.77	91.49	31.91	—	—	—	—	—	—
−10.16	93.62	36.17	—	—	—	—	—	—	—	—	—	—	—	—
−9.86	93.62	38.30	—	—	—	—	—	—	—	—	—	—	—	—
−9.67	93.62	42.55	—	—	—	—	—	—	—	—	—	—	—	—
−9.28	93.62	44.68	—	—	—	—	—	—	—	—	—	—	—	—
−8.69	93.62	46.81	—	—	—	—	—	—	—	—	—	—	—	—
−7.85	**93.62**	**51.06**	—	—	—	—	—	—	—	—	—	—	—	—
−7.26	**91.49**	**51.06**	—	—	—	—	—	—	—	—	—	—	—	—
−7.03	**91.49**	**53.19**	—	—	—	—	—	—	—	—	—	—	—	—
−6.84	**91.49**	**55.32**	—	—	—	—	—	—	—	—	—	—	—	—
−6.35	**91.49**	**57.45**	—	—	—	—	—	—	—	—	—	—	—	—
−5.67	**91.49**	**59.57**	—	—	—	—	—	—	—	—	—	—	—	—
−5.08	**91.49**	**61.70**	—	—	—	—	—	—	—	—	—	—	—	—
−4.54	**91.49**	**63.83**	—	—	—	—	—	—	—	—	—	—	—	—
−4.25	**91.49**	**65.96**	—	—	—	—	—	—	—	—	—	—	—	—
−4.00	**91.49**	**68.09**	—	—	—	—	—	—	—	—	—	—	—	—

Note. Combined scale: Combined feigned ADHD impairment probability scale. Cutoffs with >90% specificity and >50% sensitivity for detecting feigned ADHD marked in bold; *Lower* scores in the MOXO-d-CPT indices and *higher* combined scale scores suggest the feigning of cognitive impairments. SENS = Sensitivity; SPEC = Specificity.

be considered since even the −5.30 *z*-score cutoff (i.e., lowest cutoff still associated with >90% specificity in Study 1) was associated with >90% specificity in Study 2.

Discussion

Study 1 investigated, for the first time, the ability of the MOXO-d-CPT to differentiate examinees feigning ADHD (i.e., simulators) from genuine ADHD patients and healthy controls. In this study, simulators performed worse than ADHD patients on all MOXO-d-CPT indices. ROC curves were then used to differentiate simulators and ADHD patients. The impulsivity index showed the highest discriminative capacity (i.e., in the outstanding range) of the four MOXO-d-CPT indices (AUC=0.907), followed by the attention and hyperactivity indices (AUC=0.884 and 0.856, respectively), in these analyses. The timeliness index, in contrast, showed only acceptable discriminative capacity (AUC=0.741). Finally, Study 1 also included the calculation of a validity index based on a multivariate prediction model for discriminating simulators from ADHD patients. The scale, combining all MOXO-d-CPT indices besides the

attention index, showed clinical promise for the detection of feigned ADHD. The scale differentiated simulators from ADHD patients better than each of the individual indices (AUC=0.957). In addition, all correlations between MOXO-d-CPT outcome measures and WMT validity indicators were highly significant. The impulsivity index and combined scale were strongly correlated with the validity indicators of the WMT. The remaining correlations were moderate, with the weakest correlations for timeliness (*r*s between .464 and .542). Notably, these correlations mirrored the earlier described discriminative capacities of the MOXO-d-CPT outcome measures. The WMT can be considered as a benchmark for the detection of feigned cognitive impairment (Stevens & Licha, 2019). The associations of its validity indications with the MOXO-d-CPT outcome measures, therefore, provide strong support for the external validity of these measures as embedded validity indicators (notably, the impulsivity index and combined scale). Taken together, Study 1 findings were promising, supporting the utility of the MOXO-d-CPT and most of its indices for the detection of feigned ADHD.

Study 2 utilized archival data, provided by the MOXO-d-CPT's publishers, of ADHD patients and healthy controls to validate the findings of Study 1. As in Study 1, simulators and ADHD patients significantly differed in all MOXO-d-CPT indices, as well as the combined scale. Importantly, we assessed the discriminative capacity of the measures and the findings were compared with those found in Study 1. By integrating the findings, a tentative interpretation of the clinical utility of the measures can be presented. In the following, these interpretations are presented from the most to the least promising measures for the detection of feigned ADHD[2]: (a) *Combined scale*: The scale showed outstanding discriminative capacity in both studies. Correspondingly, it was possible to reach cutoffs with specificity >90% and sensitivity >50% using the scale, suggesting its suitability as a validity indicator (see Table 6). The scale showed a relatively large decrease in discriminative capacity between the studies (AUC Δ= 0.053) compared to most indices (i.e., attention, timeliness, and hyperactivity). This suggests that further research is advisable before clinical implementation. (b) *Attention index*: The scale showed outstanding discriminative capacity in both studies (e.g., it reached 61.70% sensitivity while maintaining specificity >90% in Study 1) and was relatively insensitive to changes in the samples. ROC curve analyses suggested that its predictive power was lower than that of the combined scale. However, an inspection of cutoffs reveals very similar indices of classification accuracy (i.e., sensitivity and specificity) for the two measures, at least in Study 2. Its use for the detection of feigned ADHD can, therefore, be recommended with relative confidence. (c) *Hyperactivity index*: The index's discriminative capacity was relatively insensitive to changes in the samples. However, cutoffs for this index with specificity >90% were associated with low sensitivity (i.e., a max sensitivity of 31.91% in Study 2). This suggests that, while poor performance in this index can be used to infer that the examinee is feigning cognitive impairments, the opposite cannot be concluded with confidence (i.e., that examinees scoring above the cutoff are not feigning cognitive impairments; see Boone, 2013). (d) *Impulsivity index*: As in the hyperactivity index, this index's cutoffs were associated with low sensitivity levels (i.e., a max sensitivity of 25.53% in Study 2). This index also showed instability in discriminative capacity between the studies (AUC Δ= 0.073), further eroding our confidence in its clinical utility for the detection of feigned ADHD and stressing the need for further research of the index. (e) *Timeliness index*: The scale showed poor discriminative capacity in both studies and, therefore, seems less suitable for the detection of feigned ADHD.

Two specific issues should be noted at this point. First, a conservative approach was utilized in interpreting the findings. Specifically, it is conceivable that at least some of the ADHD patients that were *included* in the archival data were feigning cognitive impairments when originally assessed. All facilities that contributed to the archival database noted the use of procedures aimed at detecting feigned ADHD. There was, however, large variability in the procedures and no objective data (e.g., performance in PVTs) was provided. Contamination of data is, therefore, conceivable and would result in lower specificity levels in Study 2 (i.e., *underestimating* differences between simulators and ADHD patients and, therefore, the true specificity of the cutoffs). If so, the discriminative capacities of the measures may actually be higher than noted by us.

Second, the more pertinent comparison in the context of ADHD assessments is that between simulators and ADHD patients. We, therefore, elaborated upon these comparisons. The finding using healthy controls is, however, also of interest and will be briefly reviewed at this point: (a) Simulators performed significantly worse on all MOXO-d-CPT indices than controls (either assessed in Study 1 or derived from archival data in Study 2). (b) ROC curve analyses pointed toward outstanding discriminative capacities of all measures, except the timeliness index. The discriminative capacity of the timeliness index, though still excellent, was lower than the other indices in both studies (AUC range: 0.823 to 0.851). Overall, these findings corresponded to those based on the comparisons of simulators and ADHD patients and further stressed the lower utility of the timeliness index for the detection of feigned ADHD. The source of this diminished discriminative capacity is of interest. This index assesses hits (i.e., pressing the key in response to a target stimulus), during target display. It, therefore, measures correct responses *only* if performed with good timing, differing from the attention index (i.e., the latter measures correct responses *independently* of their timing). This unique characteristic makes the timeliness

index particularly appealing for the detection of ADHD associated cognitive impairments. Correspondingly, timeliness was the only MOXO-d-CPT index in which the ADHD patients significantly differed from healthy controls in Study 1 (differences approached significance in Study 2; p=.058). These findings correspond with the excellent discrimination capacity of the index among children in most (Berger & Goldzweig, 2010; Berger et al., 2013; Berger, Slobodin, & Cassuto, 2017; Slobodin, Cassuto, & Berger, 2018), though not all studies (A. R. Borkowska, 2016). Data regarding the MOXO-d-CPT profile of adults diagnosed with ADHD is, however, still limited. The attention and hyperactivity indices, rather than timeliness, differentiated between ADHD patients and controls in the only two studies of adults that we are aware of (Grossman et al., 2015; Jacoby & Lavidor, 2018). At present, however, it seems somewhat premature to attempt and reconciling these differences, and more research is clearly needed. In this regard, it is worth noting that the ADHD patients in the current study were university undergraduate students. As these were highly functioning ADHD patients, fewer cognitive impairments compared to the overall ADHD patient population can be expected.

The last point (i.e., concerning the discriminative capacity of the timeliness index) raises additional questions, both specific and general, regarding the utility of the MOXO-d-CPT for the detection of feigned ADHD. First, can conclusions be reached concerning the *differential* utility of the MOXO-d-CPT indices to detect feigned ADHD? Initially, we speculated that adults attempting to feign ADHD will present exaggerated impulsive-hyperactive symptoms (e.g., by intentionally performing commission errors and, thereby, lowering both impulsivity and hyperactivity indices of the MOXO-d-CPT) compared to genuine adult ADHD patients. This was based on findings of developmental studies that suggested a larger *decline* in hyperactivity-impulsivity symptoms than inattentiveness as ADHD patients mature (Biederman, Mick, & Faraone, 2000; Holbrook et al., 2016), though this is likely an over-simplification (e.g., patient subgroups may differ in developmental trajectories; (Larsson, Dilshad, Lichtenstein, & Barker, 2011; Tandon, Tillman, Agrawal, & Luby, 2016). Correspondingly, the impulsivity and hyperactivity indices had the highest discriminative capacity of the four MOXO-d-CPT indices in Study 1. The study's findings, therefore, seem to correspond to these initial speculations.

Further research, however, is needed as the attention index had stronger discriminative capacity than both the impulsivity and hyperactivity indices in Study 2. Furthermore, the findings of Berger et al. (2013) suggest that the developmental patterns do not change for inattentiveness versus hyperactivity-impulsivity symptoms, at least when assessed using the MOXO-d-CPT and up to the age of 11 (see also Berger et al., 2017; A. R. Borkowska, 2016). Second, the findings of the current study point toward the general usefulness of CPTs for the detection of feigned ADHD-related cognitive impairment.

Most earlier studies seem to concur with our conclusion regarding the utility of CPTs for the detection of feigned ADHD (for studies using the Conners' CPT, TOVA, and IVA-CPT, see Leark et al., 2002; Lee et al., 2010; Leppma et al., 2018; Quinn, 2003). Some studies, however, found weaker group differences. For example, those who failed a forced-choice recognition memory PVT had only slightly elevated mean inattention score in the Qb+© CPT than those who passed the PVT (Hirsch & Christiansen, 2018). Similarly, J. A. Suhr et al. (2011) found differences in only two measures of the Conners' CPT-II (see also Sollman et al., 2010). Comparing the findings of the studies, however, is challenging at present. The studies are few, and they differ in selected measures (even when performed using the same CPT) and research designs (i.e., simulation studies vs. studies of clinical populations). Finally, many do not provide sufficient data for comparisons across studies (e.g., ROC curve analyses or cutoffs with associated indices of classification accuracy). All these factors stress the need for further research that will aid in discerning the general utility of CPTs for the detection of feigned ADHD and measures that hold the most promise in achieving this aim.

Strengths, Limitations, and Venues for Future Research

The current study is the first to assess the utility of the MOXO-d-CPT for the detection of feigned ADHD. Additional strengths include (a) inclusion of a clinical patient group (i.e., ADHD patients), thereby increasing the generalizability of our findings; (b) stringent inclusion/exclusion criteria (e.g., prior ADHD diagnosis was reaffirmed by the research team and participants provided data regarding response bias in their previous diagnosis[3]); and (c) validation of the prospective study's findings using archival data. Alongside these strengths, several limitations of the study should be acknowledged. First, a simulation research design was used. This research design has high internal validity, can be easily implemented, and offers a good capacity to manipulate key variables by the researchers (Rogers & Gillard, 2011). It was, therefore, considered appropriate for the aims of the current study. However, simulators may differ from those feigning ADHD in a clinical setting, raising concerns regarding the generalizability of the findings. Relatedly, undergraduate students were included in the prospective stage of the research (Study 1). This is a clinically relevant population for evaluating feigned and genuine ADHD (as noted by Robinson & Rogers, 2017). However, the findings of Study 1 are consequently chiefly representative of *highly functioning* patients. Second, the archival data may have been contaminated with examinees feigning ADHD, though

a conservative approach in interpreting the findings (noted earlier) likely mitigated, at least partially, this limitation. Third, the archival data did not include examinees suspected of feigning ADHD. Consequently, the sensitivity levels that were found in Study 1 could not be validated. Taken together, researchers are advised to include examinees undergoing real-life ADHD assessments in future studies and, thereby, further assess the generalizability of the findings of the current study.

Several additional lines of future research can be suggested. First, researchers (e.g., Erdodi et al., 2018; Sollman et al., 2010) recommend combining data as a means to enhance the ability to detect feigned cognitive impairments. The current study assessed one option for such integration of data (i.e., using logistic regression). Future studies can further explore the myriad possibilities that CPT measures and PVTs offer (e.g., combining performance in the CPT *and* validity indicators derived from the PVT). Second, researchers are encouraged to go beyond assessing the general utility of CPTs and further explore the differential utility of CPT measures for the detection of feigned ADHD (e.g., impulsivity-hyperactivity vs. inattentiveness symptoms, as discussed by us earlier). Third, four participants in Study 1 participated in an undergraduate course on ADHD. While this likely did not confound the findings of the study (i.e., the groups did not differ significantly in the proportion of these students), no other information was available regarding the prior knowledge of ADHD among the participants. As such knowledge may be instrumental in the ability to feign the cognitive impairment associated with the disorder, researchers are encouraged to include a comprehensive prior knowledge questionnaire in future studies (e.g., the Adult Knowledge of Attention Deficit Disorder Scale [AKADDS] used by Edmundson et al., 2017). Finally, it would be of interest to explore the utility of the MOXO-d-CPT in detecting feigned cognitive impairment in neuropsychiatric populations other than ADHD (as done using other CPTs; Erdodi, Lichtenstein, Rai, & Flaro, 2017; Erdodi et al., 2018; Sharland et al., 2018).

Summary

The current study aimed to establish embedded validity indicators for the MOXO-d-CPT. The findings of Study 1 suggested that three MOXO-d-CPT indices (i.e., attention, hyperactivity and impulsivity) and the combined scale (i.e., integrating the indices using logistic regression) show initial promise for the detection of feigned ADHD. Archival data, used in Study 2, pointed toward relative stability (i.e., robustness to variations in samples) of the attention, timeliness, and hyperactivity indices. Considering the findings of the two studies, the combined scale showed the highest potential as a validity indicator, followed by the attention index. The former, despite having outstanding discriminative capacity in both studies, showed evidence of instability between the studies and therefore necessitates further research. Finally, the hyperactivity index also showed potential, though its sensitivity was rather low. Overall, the archival data validated the utility of the MOXO-d-CPT for detecting feigned ADHD and are in general agreement with most studies utilizing other CPTs. Additional studies, however, are needed to decrease the gap that has grown over time between clinical reality (i.e., widespread use of CPTs and prevalent feigning of ADHD) and the limited empirically validated techniques for the detection of feigned ADHD that are at the disposal of the clinician (Bordoff, 2017; Sagar et al., 2017; Tucha et al., 2015). Until then, caution is warranted before the implementation of these indices in daily clinical practice. We believe that the current study, despite its preliminary nature, helps to some extent to bridge this gap.

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Supplemental Material

Supplemental material for this article is available online.

Notes

1. The data were checked after reaching $n = 47$ participants in each group (i.e., the number of ADHD patients in the archival data; see Study 2). We then discarded suspected data (e.g., data of participants who did not comply with the experimental instructions; see "Participants" subsection). Next, we continued recruitment until reaching a final n of 47 participants,

with adequate data in each group (data of one healthy control was randomly discarded to achieve this aim).

2. Note that discriminative capacity in all but one index (i.e., attention) was stronger in Study 1 than Study 2. We, therefore, adopted a conservative approach (i.e., attempting to minimize false positives) by selecting cutoffs based on the latter study for these indices (see Table 5). As for the attention index, we suggest using the findings of Study 1 for selecting cutoffs for further research (Table 3). However, considering the stability of the index between the studies, cutoffs based on Study 2 (Table 5) can also be considered (see "Results" section of Study 2: "Discriminative capacities of the MOXO-d-CPT indices / combined scale and suggested cutoffs for further research").
3. As detailed in the "Procedure" subsection and the "Results" section, participants in the ADHD group (Study 1) provided data regarding their prior diagnosis, including response bias during the assessment. Consequently, data of two participants were excluded from the analyses.

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