

**Original Article**



# A Comprehensive Review of Attention Detection Tools in Medical Research: Focusing on ADHD Detection and Treatment

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## Abstract:

Attention is a fundamental cognitive process crucial for accurate job performance and significantly impacts various medical conditions. Attention disorders, particularly attention deficit hyperactivity disorder (ADHD), are prevalent neurodevelopmental disorders that typically manifest in childhood and may persist into adulthood. Current treatment options for ADHD encompass pharmacological, non-pharmacological, and comprehensive approaches. However, challenges such as diagnostic complexity and medication side effects present significant obstacles to effective management. Therefore, enhancing the precision of ADHD diagnosis is essential. This review synthesizes existing knowledge on attention detection tools, focusing on their operational mechanisms and applications in diagnosing and treating ADHD. The aim is to provide a comprehensive overview of these tools, clarify their uses, and suggest future directions for innovation in advanced attention detection methods. To achieve this, the review employs a multi-faceted approach that includes literature review, theoretical analysis, empirical research, and case studies. This integrative methodology seeks to establish a robust framework for understanding and improving diagnostic and therapeutic effectiveness. Attention detection tools have extensive applications in the medical field, particularly in diagnosing and managing attention disorders. Evidence suggests that integrating multiple detection methods can significantly enhance diagnostic accuracy and therapeutic efficacy, especially in the context of ADHD. This review highlights the potential of these tools to refine clinical practices and improve patient outcomes, underscoring the necessity for ongoing innovation in this area.

**Keywords:** attention detection tools; ADHD treatment; CPT; Child Psychiatry

## 1. Introduction

Attention stands as a sophisticated evolutionary mechanism, pivotal for the regulation of information processing and the orchestration of

our responses to the environment [1]. Historically, the concept of attention was first pondered by philosophers, who recognized it as a cornerstone

for maintaining cognitive order and coherence [2]. This philosophical groundwork laid the foundation for a deeper understanding of attention as a gateway, allowing stimuli to transition from the realm of the unconscious to the conscious awareness [3]. Attention is a pivotal cognitive faculty, the impairment of which can precipitate a spectrum of disorders. Among these, ADHD stands out as one of the most prevalent and influential. Characterized by its onset in childhood, ADHD is a neurodevelopmental condition that significantly impacts a substantial portion of the pediatric population [4]. Epidemiological studies in the United States suggest that ADHD affects 2% to 18% of children between the ages of 6 and 17. The disorder is typified by a triad of symptoms: inattention, impulsivity, and hyperactivity, which manifest with considerable heterogeneity among individuals. The nosology of ADHD has evolved to recognize three distinct subtypes: predominantly hyperactive-impulsive, predominantly inattentive, and a combined type that encapsulates features of the former two [5]. The progression of ADHD is marked by a complex trajectory, with a significant proportion of affected children experiencing a chronic course that extends into adulthood [6]. This persistence is associated with a profound burden across various life domains [7-9].

ADHD is increasingly recognized as a psychiatric disorder with high heterogeneity and a propensity for comorbidity with other psychiatric conditions [10]. The Multimodal Treatment of ADHD (MTA) trial highlighted the presence of one or more co-occurring conditions in nearly 40% of participants [11], encompassing a range of disorders from oppositional defiant disorder to learning difficulties [12, 13]. The discourse surrounding ADHD has broadened to consider it not merely as a neurodevelopmental disorder but also as a persistent and complex condition with long-reaching implications for adult life quality [14]. Early diagnosis is thus paramount, with studies suggesting that timely intervention can lead to neuroanatomical and functional normalization in adults who have overcome ADHD [15-17].

The management of ADHD has been the focus of numerous randomized controlled trials (RCTs) over the past two decades, primarily sponsored by

pharmaceutical companies to substantiate the efficacy and safety of both stimulant and non-stimulant medications [18]. However, concerns regarding the side effects and long-term impacts of these medications persist, largely due to the nuances of ADHD diagnosis. Diagnosing ADHD typically involves a comprehensive clinical assessment by a psychiatrist or pediatrician, who evaluates the presence of five or more symptoms against the DSM-5 criteria [19]. Yet, the scarcity of trained specialists and the time-intensive nature of these assessments often result in delayed diagnoses [20]. The global shortage of psychiatrists is stark, with ratios as low as 11:100,000 in the United Kingdom and Australia [21]. The accuracy of ADHD diagnosis is also a subject of scrutiny, with pooled area under the curve (AUC) values indicating variability in diagnostic reliability [22]. Computerized neuropsychological tests have emerged as valuable adjuncts to clinical assessments, offering objective measures to aid in diagnosis [23]. Continuous performance tests (CPTs), for instance, have been instrumental in identifying sustained attention deficits characteristic of ADHD [24]. Despite the integration of computer technology in ADHD diagnosis, the specificity of such tools remains a topic of debate. High response time variability has been identified as a robust marker in affected children [25], yet the precise role of attention detection tools in diagnosis is not fully elucidated.

This review aims to synthesize the current landscape of attention detection tools and evaluate their efficacy in enhancing ADHD diagnosis accuracy. We explore the potential of integrating diverse tools to improve diagnostic precision and discuss the future trajectory of attention detection tools, including the incorporation of virtual reality, advancements in digital health algorithms, and the development of personalized medical strategies.

## 1. Attention Detection Tools

### 2.1 Schulte Grid Test

This section delves into the application and assessment techniques of the Schulte grid test, a widely recognized tool for gauging attentional capabilities. The test employs a  $5 \times 5$  grid, populated with numbers or letters in a randomized pattern. Participants are directed to concentrate on

the grid's center and utilize their peripheral vision to detect all the numbers or letters without eye movement. This method has been extensively utilized in attention training programs for both adults and children, as evidenced by the works of Liu & Li (2014, 2016) and Yao (2015). In an innovative study, a two-tone Schulte grid was introduced, designed to emulate the unpredictability of real-life scenarios [26]. The study utilized a standard 5×5 grid layout to generate 240 digital images, half in pure black and the other half in a black-red combination. Each image was uniquely numbered from 001 to 120, with each grid cell featuring a distinct random number ranging from 1 to 25. The black-red images were crafted by modifying the black images, altering the color of numbers in odd positions to red. This color differentiation served to accentuate specific numbers, which presented

an identical set of numbers in both formats (Fig.1).

Employing E-Prime 2.0 software, researchers assembled the 240 images, which were then displayed in a randomized sequence on a computer monitor. Participants were presented with a subset of these images, which could potentially overlap with those seen by others, but were intentionally varied to ensure a diverse sampling. The study's protocol required participants, including children, to sequentially identify the numbers 1, 2, and 3, or directly spot the number 5 using the Schulte grid. The time required to accomplish these tasks served as an indicator of attentional performance. The research's focus extended to a detailed analysis of eye movement trajectories and event-related potentials (ERPs), providing a comprehensive examination of attentional processes.

(a)					(b)				
4	17	21	8	11	4	17	21	8	11
10	2	20	13	25	10	2	20	13	25
3	7	19	24	12	3	7	19	24	12
1	6	18	14	23	1	6	18	14	23
16	22	15	5	9	16	22	15	5	9

**Figure 1. Pure black grid 001 and black-red grid 001.(a) Subjects identified either numbers 1, 2, and 3 in sequence or the number 5 directly using the Schulte grid with pure black digits.(b) Subjects identified either numbers 1, 2, and 3 in sequence or the number 5 directly using the Schulte grid with pure black digits.**

Recently, a Chinese research team has employed the Schulte grid test to assess the clinical symptoms and cognitive functions of patients with ADHD [27]. Recognized for its simplicity, scientific rigor, and efficacy, the Schulte grid test serves as a valuable tool for attention training. Extensive training with this tool has been confirmed to significantly enhance children's attentional capabilities, with attention being the focal point of the intervention. The study in question explored the combined application of the Schulte grid test and Methylphenidate hydrochloride sustained-release tablets for the

treatment of ADHD. The findings demonstrated that the integration of the Schulte grid test with pharmacological intervention can enhance the therapeutic outcomes beyond those achieved with medication alone (Table1). This synergistic effect is primarily attributed to the ability of Methylphenidate hydrochloride sustained-release tablets to effectively ameliorate the imbalances in brain regulatory functions and cognitive abilities in children. The medication works by inhibiting detrimental brainwave patterns, thereby reducing the adverse impact on the cranial nerves. Based on these research outcomes, the Schulte grid test has

been established as a pivotal component in both the diagnosis and treatment of ADHD, offering a

complementary approach to traditional pharmacological therapies.

**Table1**

**(a) The therapeutic effect of methylphenidate hydrochloride sustained-release tablets in the treatment of ADHD**

Group	Significant effective	Effective	None effective	Total effective
Control	15 (28.30%)	30 (56.60%)	8 (15.09%)	45 (84.91%)
Experiment	20 (37.74%)	32 (60.38%)	1 (1.89%)	52 (98.11%)

**(b) The therapeutic effect of methylphenidate hydrochloride sustained-release tablets combined with Schulte's formula in the treatment of ADHD**

Group	Significant effective	Effective	None effective	Total effective
Control	25 (47.17%)	15 (24.53%)	13 (124.53%)	40 (75.47%)
Experiment	32 (60.38%)	17 (32.08%)	4 (7.55%)	49 (92.45%)

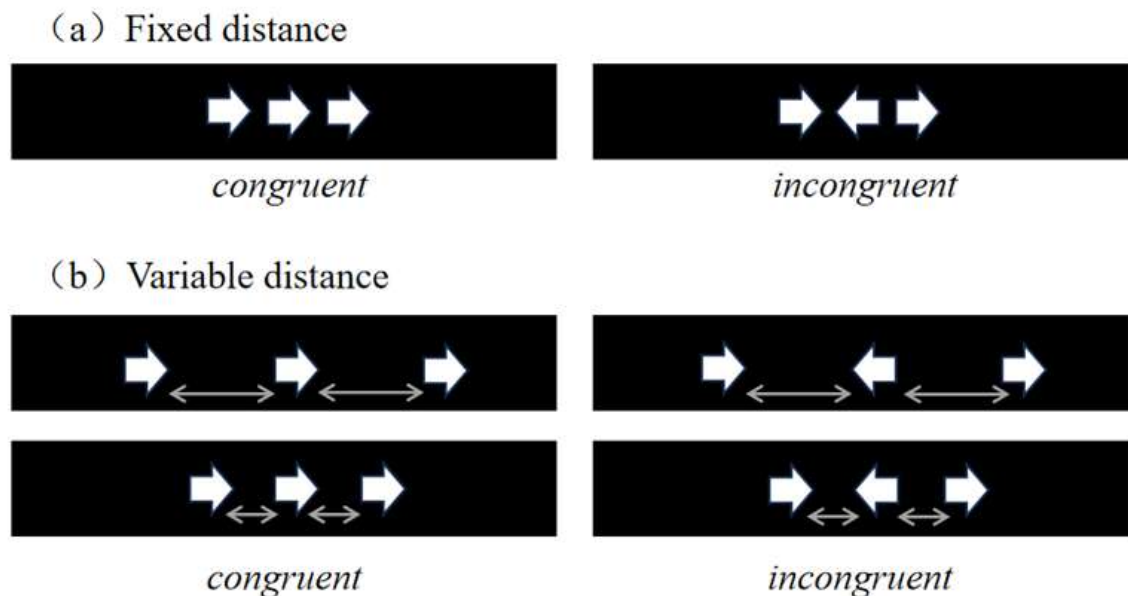
## 2.2 Flanker Task

This section explores the application and assessment methodologies of the Flanker task, a paradigm established by Eriksen & Eriksen (1974) and widely recognized for its efficacy in measuring attentional control. The task involves the identification of a target stimulus amidst distracting flankers, which can impede the processing of the target. With over 8000 citations, the Flanker task has profoundly influenced our comprehension of the dynamics of visual attention, as evidenced by subsequent studies [28-30]. The task's straightforward nature—requiring participants to discern the direction of a central arrow amid surrounding arrows—combined with its consistent elicitation of the flanker effect, has rendered it a favored tool in both educational settings and experimental design. Its popularity is further bolstered by its inclusion in standard experimental software packages, as well as online platforms like PsyToolkit [31], OpenSesame [32], PsychoPy [33], and Gorilla [34].

A recent study investigated the performance of female college students, both with and without ADHD, on the Flanker task [35]. The task was adapted to use numerical stimuli ranging from 2 to 9, with each stimulus comprising three horizontally aligned digits: two flanking digits identical to each other and a central target digit distinct from the flankers (e.g., 272). Participants, positioned 50-60 cm from the screen, were tasked with judging the parity of the central digit by

pressing corresponding keys on a standard keyboard. The mapping of keys to parity was counterbalanced across participants to control for lateral bias. Each trial commenced with a 400 ms presentation of a fixation cross, followed by a 600 ms interval of blank screen, and then a 160 ms presentation of the stimulus against a black background in white. Incorrect responses were met with 1,000 ms of visual and auditory feedback. Subsequent trials initiated 100 ms after the participant's response. The study revealed that individuals with ADHD demonstrated heightened focus but reduced adaptability to shifting task demands, underscoring the Flanker task's potential utility in ADHD diagnosis.

However, the classical Flanker task is not without limitations. Its primary focus on measuring inhibitory control may not fully capture the spatial aspects of attention distribution. Additionally, it relies predominantly on a single measure of the flanker effect. An alternative, the Spatial Flanker Task (SFT), offers enhanced advantages by incorporating variable distance flanker stimuli and providing a broader array of performance metrics (Fig.2). Comparative research has attested to the online SFT's reliability, equating it to its laboratory counterpart across all metrics and demonstrating robust test-retest reliability for key indicators such as mean flanker effect and reaction times for incongruent trials [36]. This suggests that the SFT may offer enhanced precision in the diagnosis and treatment of ADHD in future applications.



**Figure 2. Examples of arrow-flanker stimuli with a fixed distance between the target and the flankers (a) and with a variable distance (b)**

### 2.3 CPTs

CPTs have gained significant prominence in the evaluation of attentional processes. Initially conceived as an instrument for detecting brain injuries, the CPTs' utility has expanded considerably since their inception by Rosvold *et al.* (1956) [37]. These tests have become a staple in the assessment of attentional functioning and treatment efficacy, particularly among individuals with schizophrenia [38]. More recently, CPTs have also been pivotal in diagnosing ADHD across the age spectrum, from children to adults [39].

The contemporary landscape of CPTs is characterized by an increasing diversity, propelled by advancements in technology and the introduction of various test types. The following section will provide an in-depth discussion of several prominent CPTs, including the Test of Variables Attention (TOVA), Go/No-Go Switch Task (GDS), Conners' Continuous Performance Test (CCPT), Integrated Visual and Auditory Continuous Performance Test plus (IVA+CPT) and the Quantitative Brain Test (Qb Test) (Table2). These assessments have become integral components in the diagnostic and therapeutic arsenal for attention-related disorders.

**Table2. List of sensitivity and specificity of different CPTs.**

Software name	Sensitive	Specificity	Remark
TOVA [40]	85.7%	70.0%	-
GDS [41]	49-59%	81-87%	-
CCPT [42]	67%	73%	-
IVA+CPT [43]	72.9%	70.9%	-
QbTest	Not provide	Not provide	FDA approved for use as an aid to evaluation and treatment monitoring
Mixed use e.g. CCPT+ DIVA [44]	90.0%	81.3%	-

#### 2.3.1 TOVA

TOVA is a sophisticated CPT that serves as a vital adjunct in the diagnosis of ADHD and in gauging responses to treatment. It has been meticulously studied and standardized for use across both

pediatric and adult populations. The TOVA provides a unique perspective on ADHD, complementing traditional diagnostic measures, and has been shown to correlate with other ADHD assessments [45, 46]. With its sensitive reaction time metrics and high sensitivity to performance

changes indicative of therapeutic effects, the TOVA has been extensively normed [47].

As described by The TOVA Company, the TOVA is a culture- and language-independent test, eliminating the need for left/right discrimination or sequencing. It utilizes a highly accurate microswitch to record responses to visual or auditory stimuli with a precision of  $\pm 1$  ms. The test evaluates response time variability, speed, impulsivity (commissions), and focus/vigilance (omissions), comparing these metrics against a large, age- and gender-matched normative sample, as well as a sample of individuals diagnosed with ADHD. This comparison yields an immediately available, comprehensive report. Research has demonstrated the absence of a practice effect in the TOVA, ensuring that results reflect genuine changes in attentional performance [48]. With a reported sensitivity of 85.7% and specificity of 70.0% [40], the TOVA stands out as a promising diagnostic instrument for ADHD.

### 2.3.2 GDS

GDS is a cognitive test that assesses an individual's response inhibition and selective attention [49-53]. In this task, participants are presented with a sequence of stimuli and are required to respond quickly to a specific target stimulus (the "Go" signal), while refraining from responding to non-target stimuli (the "No-Go" signal). The test measures the ability to suppress a pre-potent response, which is crucial for impulse control and decision-making. GDS is often used to study various cognitive functions, including attention, decision-making, and impulse control. It is also used in clinical settings to assess cognitive deficits associated with certain conditions, such as ADHD, Parkinson's disease, and other neurological disorders.

A research about the use of an infrared motion tracking system to monitor and record movement intensity in children during a modified GDS designed the GDS as follows [54]. In the research's version of the GDS, a white block appeared within a white frame on a black background. A block appearing at the top of the frame signaled the "go condition," while a block at the bottom signaled the "no-go condition." Children were instructed to click the mouse during "go conditions" and to refrain from clicking during "no-go conditions." Each stimulus

was presented for 500 ms, with a 1000 ms inter-trial interval. Participants had to confirm they could see the screen clearly before starting and needed to complete at least five trials with  $>90\%$  accuracy for their data to be included. The task consisted of two runs, each with 28 blocks (totaling 56 blocks and 9 trials per block). The first run had a Go/No-Go ratio of 2:7, and the second run had a ratio of 7:2. The entire task took approximately 12.6 minutes, with 252 Go trials and 252 No-Go trials. Performance measures of interest included: omission errors (failure to respond during "Go" trials); commission errors (responses during "No-Go" trials); accuracy (correct responses across "Go" and "No-Go" trials); multiple response errors (multiple responses after stimulus presentation during "Go" trials); reaction time (time taken to respond during "Go" trials); and reaction time variability (standard deviation of reaction time). The GDS's sensitivity (49-59%) and specificity (81-87%), as reported by Mayes *et al.* [41], underscore its potential in ADHD diagnosis when integrated with other assessment tools.

### 2.3.3 CCPT

CCPT can be used to create clinically homogeneous groups, which may assist clinicians in understanding an individual's difficulties and implementing targeted treatments [55]. Norms for the CCPT are established using data from both a non-referred community population and clinic-referred cases with an ADHD diagnosis, resulting in T-scores. An overall index score exceeding 11 is used as a cut-off to indicate potential attention problems [56].

According to a research on whether the CCPT can be helpful in ADHD diagnosis, the process of CCPT is as follows. Patients were required to refrain from stimulant use for at least 24 hours prior to the assessment. During the task, participants were instructed to press the space bar on the computer whenever any letter other than 'X' appeared on the screen. The task lasted 14 minutes and was divided into six consecutive time blocks, each consisting of three sub-blocks. Each sub-block had a different interstimulus interval (ISI) of 1, 2, or 4 seconds. The CPT II generates 12 multiple dependent measures, detailed in Table 1. These measures are presented as T-scores, which compare a subject's responses to those of a normative group of the same sex and age. A T-

score of 50 represents the average of the comparison group, with each 10-point increment reflecting one standard deviation from the mean [55].

Additionally, CCPT can assess neuropsychological performance in areas such as cognitive flexibility, inhibition, and attention, demonstrating a sensitivity of 67% and a specificity of 70.9% [42]. However, there are still some limitations when CCPT aids the ADHD diagnose, such as its low association with linguistic capability [56].

#### 2.3.4 IVA+CPT

IVA+CPT is a neuropsychological assessment tool that evaluates attention and impulse control, particularly in children. This computerized test utilizes both visual and auditory stimuli to provide a comprehensive measure of an individual's ability to sustain attention and inhibit responses to non-target stimuli [39].

In a clinical trial examining the utility of quantitative electroencephalography and the IVA+CPT as auxiliary tools for diagnosing ADHD, participants were instructed to click a button when they saw or heard the number '1'. Conversely, they were instructed not to click when presented with the number '2'. The test lasted approximately 20 minutes and was conducted in a quiet environment, with the tester present in the room. Prior to the assessment, participants received detailed explanations and completed sample tests to ensure they understood the test's content. According to the study, the accuracy of IVA+CPT in distinguishing ADHD from normal controls can reach to 82.1%. Additionally, the research reported a sensitivity of 72.9% and a specificity of 70.9% [43], further validating the IVA+CPT as an effective assessment tool for ADHD.

#### 2.3.5 QbTest

QbTest, developed by Qbtech Ltd, is a state-of-the-art diagnostic tool for assessing and monitoring ADHD in individuals aged 6 to 60 years. This innovative technology combines a CPT with an infrared motion-tracking system, allowing for objective measurement of the three core symptoms of ADHD: inattention, impulsivity, and hyperactivity. The QbTest evaluates these three symptom domains and generates summary scores based on deviations

from normative data sets, which are adjusted for age and gender. Each domain score is calculated from 17 parameters, including five related to activity (time active, distance traveled, score area, number of micro-events, and motion simplicity) and 12 associated with the CPT (reaction time, score outliers, reaction time variation, normalized variation, omission errors, commission errors, normalized commission errors, anticipatory responses, multiple responses, D-Prime modified, longest passivity, and total error rate) [57].

There are two versions of the QbTest: a 15-minute version for children aged 6 to 11 years and a 20-minute version for adolescents aged 12 to 17 years. The results are further enhanced by behavioral observations that may influence test performance. Notably, the QbTest has received approval from the US Food and Drug Administration (FDA) as a supplementary tool for standard clinical assessment and treatment monitoring. To date, it is the only test cleared for both assessment and treatment of ADHD [39].

#### 2.4 Mixed use of multiple attention testing tools

Recent research has increasingly questioned the clinical utility of CPTs in diagnosing adult ADHD [58-63]. Notable examples of these tests include CCPT, TOVA, GDS and IVA+CPT. Studies suggest that relying solely on these tests for attention detection may compromise diagnostic validity and classification accuracy. However, when integrated into a comprehensive assessment framework, these tools can be more effective, as they each assess different aspects of attention. For instance, metrics such as the number of false responses in the CCPT can provide valuable insights into treatment efficacy and experimental outcomes. Consequently, in contexts where diagnostic accuracy is critical, it is advisable to employ multiple attention assessment tools in conjunction rather than in isolation. This multifaceted approach ensures a more nuanced evaluation of attention-related issues, potentially enhancing diagnostic precision and informing more effective intervention strategies [64]. A research utilized a mixed-methods approach with both the CCPT and the DIVA. The results indicated significant improvements in both sensitivity and specificity, with sensitivity reaching 90.0% and specificity at 81.3% [44].

#### 2.5 A new detection tool: BOKE CPT+

### 2.5.1 A introduction of BOKE CPT+

The BOKE CPT+ is a computerized continuous performance test developed for the assessment of ADHD in children aged 6 to 12, offering a significant advancement over traditional CPT paradigms. The test has a duration of 12.5 minutes and is accessible via a PAD platform, requiring no additional hardware, though optional accessories such as a button switch and earphones are available. It utilizes both visual and auditory stimuli, including distractors, and is suitable for use by both professionals and non-specialists.

The test design incorporates a target-non-target paradigm, using stimuli like a cat picture or noise as non-targets, and a fish picture as the target. The task is structured to optimize clinical efficiency while aligning with the cognitive development characteristics of children. It includes progressively challenging levels, with variations in both visual and auditory stimuli, ensuring a balance of efficiency and effectiveness in the assessment process.

The test is organized into several blocks, each containing sub-blocks with varying frequencies and types of stimuli—visual, auditory, or a combination of both. The sequence of these blocks is designed to gradually increase the difficulty, thereby challenging the child's attention over time.

### 2.5.2 Clinical Validity Evaluation of BOKE CPT+in ADHD Diagnosis: A Pilot Study

A key innovation of the BOKE CPT+ is its use of visual fixation points, arranged to combine both order and randomness. This design provides better control over variables compared to entirely random stimuli. Additionally, the system supports expandability, allowing the integration of eye movement parameters for further refinement of the assessment.

The clinical validity of the BOKE CPT+ for diagnosing Attention-Deficit/Hyperactivity Disorder (ADHD) in children and adolescents was evaluated in a pilot study conducted by BOKE Medical Technology at Xinhua Hospital, affiliated with Shanghai Jiao Tong University School of Medicine. The goal of the study was to assess the clinical validity of BOKE CPT+ based on diagnoses made by clinical specialists in accordance with the DSM-5 criteria (the gold standard).

The study involved 45 participants in the ADHD group and 49 in the control group. Binary logistic regression analysis, using the Forward LR method, was conducted, accounting for participants' sex, age, and four primary indices (Omission, Commission, Reaction Time, and Reaction Time Variability) across all blocks. The analysis also considered the first and second halves of sub-blocks, with frequent (TNT=3.5:1) and infrequent (TNT=1:3.5) target stimulation sub-blocks, reflecting the participants' performance on the BOKE CPT+. Internal validation was employed to assess the model's efficiency.

The results showed that Receiver Operating Characteristic (ROC) curves were plotted to evaluate the model's efficiency in detecting ADHD. The area under the curve (AUC) was found to be 0.96. The cut-off point, determined by the maximum Youden index, was used for ADHD detection, with internal validation revealing a sensitivity of 86.67%, specificity of 91.84%, and accuracy of 89.36%.

## 2. Discussion

ADHD is a prevalent mental health condition that notably impacts school-aged children, posing challenges in their learning processes and daily functioning. This neurodevelopmental disorder, characterized by its onset in childhood and potential persistence into adulthood, significantly affects a substantial portion of the pediatric population, with epidemiological studies in the United States suggesting that ADHD affects 2% to 18% of children between the ages of 6 and 17. Prompt identification of ADHD is of paramount importance, as early intervention has been proven to enhance neuroanatomical and functional outcomes. Nevertheless, the intricacies of diagnosis and the shortage of trained specialists pose formidable challenges to effective management. Furthermore, the accuracy of ADHD diagnosis is under scrutiny due to reported variations in diagnostic reliability. Consequently, it is imperative to employ reliable and objective diagnostic tools.

In total, this review introduces eight different attention detection tools and different attention detection tools have different characteristics: The Schulte grid test is a highly regarded method for training attention due to its simplicity, rigorous

scientific foundation, and proven effectiveness. The sensitive reaction time metrics and its high degree of sensitivity to changes in performance render TOVA a promising diagnostic tool for ADHD. And some studies have consistently validated the efficacy of IVA+CPT as a valuable tool for assessing ADHD [43]. Our review does not aim to definitively rank attention detection tools based on their effectiveness and accuracy for ADHD diagnosis. After all, the specific circumstances of patients are multifaceted, and different tools inherently possess unique strengths and weaknesses that cater to various aspects of the diagnostic process. We suggest physicians who intend to utilize attention detection tools for ADHD diagnosis to have a clear understanding of their respective strengths and limitations. A dynamic integration of multiple attention detection tools can enhance the accuracy of the diagnosis.

Given the continuing and increasing use of attention detection tools like CPTs to aid clinical practice in ADHD, we focused on synthesizing the current landscape of these tools and evaluating their efficacy in enhancing ADHD diagnosis accuracy. CPTs, such as TOVA and GDS, have emerged as valuable adjuncts to traditional clinical assessments, offering objective measures to aid in diagnosis. These tools have been meticulously studied and standardized for use across both pediatric and adult populations, providing a unique perspective on ADHD that complements traditional diagnostic measures.

Some evidence reported the CPT could not differentiate ADHD from non-ADHD in a clinic-referred sample [56], which suggests these tools have limited utility in clinical practice. Given the variation in causes and behavioural consequences of ADHD, we know the clinician's judgment is currently the most widely accepted method of assessment and there is no single test used to diagnose the disorder [39]. So in clinical practice, combining the doctor's judgment with the results of multiple attention detection tools can lead to a more accurate diagnosis of ADHD. One study [57] combined a CPT with a QbTest to aid assessment and found the tool improved the clinician's ability to accurately diagnose ADHD. But given the possibility of misdiagnosis of ADHD by CPTs and doctors, computerized neuropsychological tests have emerged as

invaluable supplementary tools in clinical assessments, providing objective metrics to facilitate diagnosis. Some research [4] suggests that artificial intelligence (AI) techniques, namely machine learning (ML) and deep learning (DL), can be used to diagnose ADHD faster and more cost-effectively, thereby reducing the workload of clinicians. If CPTs can be effectively combined with virtual reality technology and complex computer vision algorithms in the future, their utilization in the field of healthcare can be greatly improved. When combined with computer algorithms, these tools can precisely locate and analyze critical elements, ultimately improving the accuracy and convenience of the ADHD diagnosis process. Now there is a computerized continuous performance test (BOKE CPT+) which works maturely. In terms of time, accuracy, operation difficulty and so on, it has been completely superior to the traditional CPTs. Mature algorithms should be developed continually, the future development direction of these detection methods will focus on how to combine algorithms and how to develop efficient and precise algorithms.

The seamless integration of clinical practice with AI-assisted diagnosis for ADHD resonates profoundly with the vision of Wise Information Technology of Medicine (WITMED), a pioneering medical service paradigm that encapsulates the very essence of modern healthcare innovation. By automating routine tasks, enhancing diagnostic accuracy, and streamlining workflows, WITMED significantly boosts the efficiency of healthcare delivery, enabling medical professionals to focus on what truly matters—providing compassionate care and personalized treatment plans. In the context of ADHD diagnosis, the integration of AI-assisted tools within clinical practice represents a significant leap forward. By leveraging AI's ability to process vast amounts of patient data, including behavioral patterns, cognitive assessments, and genetic information, clinicians can gain deeper insights into the complex mechanisms underlying ADHD. This, in turn, enables them to tailor treatments more precisely, taking into account individual differences and the unique needs of each patient. In essence, the marriage of clinical practice and AI-assisted diagnosis for ADHD within the WITMED framework underscores the potential of

technology to transform healthcare. By leveraging the power of intelligent technologies, WITMED strives to create a future where medical services are not only efficient and effective but also deeply empathetic, ensuring that every patient receives the care they deserve, tailored to their unique needs and circumstances.

The clinical utility of these attention detection tools to aid assessment requires further investigation, especially about the sensitivity and specificity when diagnose ADHD. Using multiple attention detection tools can be more comprehensive evaluation of individual attention, and initial evidence suggests this may improve the clinical utility of these tools.

### 3. Conclusions

This comprehensive review systematically surveyed the landscape of ADHD diagnostic tools, with a particular emphasis on studies employing machine learning and deep learning AI techniques for diagnostic purposes. Our analysis revealed a notable predisposition towards hospital-based modalities, such as MRI and EEG, in the existing literature. These modalities dominated the research landscape, while other potential diagnostic methods were scarcely explored. A significant finding was the scarcity of publicly available datasets for the majority of these modalities, with MRI being the exception. The utilization of data from wearable devices, such as ECG and accelerometers, was limited to a handful of studies, and no studies were found to incorporate PPG signals for ADHD diagnosis. Given these observations, we advocate for future research to prioritize the creation of more publicly accessible datasets for non-traditional modalities in ADHD assessment. Additionally, there is a clear need for the development of AI models that can effectively utilize data from wearable devices for the diagnosis and ongoing monitoring of ADHD. Enhancing the interpretability of these AI models should also be a focus of future studies, to foster greater trust and adoption in healthcare settings. The potential for a robust, cloud-based AI system that integrates various ADHD diagnostic tools is immense. With further advancements in AI research, such a system could become a reality, offering an invaluable clinical decision support tool for healthcare professionals managing ADHD.

### Ethics declarations

#### Funding

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#### Competing Interests

The authors have no competing interests to disclose.

#### Ethical Approval

This study was approved by Xinhua Hospital affiliated to Shanghai Jiao Tong University School of Medicine.

#### Informed Consent

All participants provided informed consent (parents) and assent (children).

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