

Evaluation of the Neuropsychological Tests CPT, Stroop, and WCST in Detecting ADHD: Potential for Integrating ICT in Diagnostic Practice

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Abstract

Attention Deficit Hyperactivity Disorder (ADHD) is among the most known neurodevelopmental disorders in childhood and adolescence, with broad implications for learning, behavioral regulation, and social integration. Accurate and timely diagnosis is critical for effective intervention and the prevention of secondary difficulties. In addition to psychometric questionnaires, neuropsychological assessments provide objective measurements of core cognitive functions, including attention, inhibition, and cognitive flexibility. This article focuses on the analysis of three fundamental neuropsychological tools: the Continuous Performance Test (CPT), the Stroop Color-Word Test, and the Wisconsin Card Sorting Test (WCST), assessing their diagnostic value in identifying ADHD. Furthermore, it explores the integration of Information and Communication Technologies (ICT) in the administration, recording, and analysis of these assessments. The article aims to propose a technologically enhanced, multi method diagnostic model that responds to the challenges and needs of ADHD evaluation in modern clinical and educational settings.

Keywords: ADHD; CPT; Stroop; WCST; Executive Functions; ICT; Diagnosis; Neuropsychological Assessment

1. Introduction

1.1. Overview of ADHD

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most prevalent neurodevelopmental disorders, with an estimated global prevalence of 5% among children (Polanczyk et al., 2007). It presents with a broad range of symptoms, including inattention, hyperactivity, and impulsivity, which can significantly affect academic achievement, emotional development, and social integration. Although primarily diagnosed in childhood, symptoms often persist into adulthood, influencing the individual's professional, social, and personal functioning (Faraone et al., 2015).

1.2. Diagnostic Complexity and Need for Objectivity

Historically, the diagnostic process for ADHD has relied heavily on behavioral observations and third-party reports from parents and teachers. Standard diagnostic systems such as the DSM-5 (American Psychiatric Association, 2013) and ICD-11 (World Health Organization, 2022) define clear criteria. However, the heterogeneity in symptom presentation, comorbid conditions (e.g., learning difficulties, anxiety disorders), and cultural factors can complicate diagnostic accuracy (Barkley, 2006). Therefore, the inclusion of neuropsychological tools that objectively measure underlying cognitive processes is increasingly recommended.

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1.3. Executive Functions and the Neuropsychological Framework

Recent models of ADHD emphasize deficits in executive functions—complex cognitive processes responsible for goal-directed behavior, attentional control, working memory, cognitive flexibility, and inhibition (Pennington & Ozonoff, 1996). Children with ADHD often exhibit dysfunction in these areas, attributed to atypical activity in the prefrontal cortex and associated neural circuits (Barkley, 1997; Faraone et al., 2015). Assessing these functions provides a deeper understanding of the cognitive mechanisms underlying ADHD symptoms.

1.4. Neuropsychological Tests as Diagnostic Tools

Neuropsychological assessments like the Continuous Performance Test (CPT), the Stroop Color-Word Test, and the Wisconsin Card Sorting Test (WCST) have gained prominence for their ability to quantify attention regulation, inhibition control, and cognitive flexibility. These tests are particularly valuable in differential diagnosis, helping distinguish ADHD from other disorders with overlapping symptoms.

Moreover, these tools can mitigate biases arising from cultural stereotypes, limited evaluator training, or subjective interpretation by offering standardized, replicable, and objective measures of performance.

1.5. ICT Integration and Modern Diagnostic Practice

The integration of Information and Communication Technologies (ICT) into diagnostic tools allows for digital test administration, automated scoring, real-time monitoring, and increased accessibility. Systems like Qb Test and digital versions of Stroop and WCST enhance diagnostic precision and allow broader clinical and educational application (Hult et al., 2018; Görzig et al., 2019). These innovations contribute to a hybrid, data-driven diagnostic culture that supports early identification and tailored intervention strategies.

1.6. Aim and Research Questions

This article aims to critically evaluate the diagnostic utility of three key neuropsychological tools—CPT, Stroop, and WCST—in identifying ADHD symptoms, particularly through the lens of executive functioning. Furthermore, it explores how ICT tools can enhance their administration, reliability, and practical application.

1.6.1. Research questions

What is the diagnostic value of the CPT, Stroop, and WCST tests in assessing executive functions in children with ADHD?

How can ICT integration enhance the accuracy, accessibility, and interpretability of these neuropsychological tools in clinical and educational settings?

Concluding the introduction we emphasize the significance of all digital technologies in the field of education and in ADHD training, which is highly effective and productive and facilitates and improves assessment, intervention, and educational procedures via mobile devices that bring educational activities everywhere [20-22], various ICTs applications that are the main supporters of education [23-27], and AI, STEM, and ROBOTICS that raise educational procedures to new performance levers [28-31]. Additionally, the development and integration of ICTs with theories and models of metacognition, mindfulness, meditation, and the cultivation of emotional intelligence [32-45], accelerates and improves educational practices and results, especially in children with ADHD, treating domain and its practices like assessment and intervention.

2. Methodology

This study adopts a neuropsychological assessment framework to explore the cognitive profile of children with ADHD. It focuses on three standardized tests widely used in both clinical and research settings: the Continuous Performance Test (CPT), the Stroop Color-Word Test, and the Wisconsin Card Sorting Test (WCST). Each of these tools measures different domains of executive functioning and contributes uniquely to the diagnostic process. Their application in digital form through Information and Communication Technologies (ICT) is also analyzed in terms of validity, practicality, and diagnostic enhancement.

2.1. Neuropsychological Framework

The study adopts a neuropsychological approach, analyzing three standardized tools—CPT, Stroop, and WCST. These are examined for their validity, reliability, and diagnostic contribution, including their performance when administered through ICT platforms.

2.2. Continuous Performance Test (CPT)

The CPT is one of the most established neuropsychological instruments for assessing sustained attention and the ability to inhibit impulsive responses. Originally developed by Rosvold et al. (1956), it has been extensively used in both research and clinical environments to identify deficits in attention and impulse control—core features of ADHD.

The test involves the sequential presentation of stimuli (either visual or auditory) at predetermined intervals. Participants are instructed to respond only to specific target stimuli while ignoring irrelevant or non-target ones. For instance, the task may require the examinee to press a button whenever the letter “X” appears, and withhold response for all other letters.

- Performance is evaluated using several key indices:
- Omission errors – indicating difficulties in maintaining attention and processing relevant stimuli;
- Commission errors – reflecting impulsivity, as the participant responds inappropriately to non-targets;
- Mean reaction time and variability – showing attention stability and mental alertness.

Research by Epstein et al. (2003) demonstrated that children with ADHD exhibit higher rates of both omission and commission errors, as well as greater variability in reaction times compared to typically developing peers. These findings support the CPT’s sensitivity in distinguishing different ADHD subtypes, such as the inattentive and combined types.

However, as Riccio et al. (2002) pointed out, CPT performance may be influenced by external factors like test anxiety, unfamiliarity with digital interfaces, or motivational fluctuations. Therefore, it is essential to interpret CPT results within the context of a broader diagnostic battery that includes interviews, questionnaires, and behavioral observations.

One of the main advantages of the CPT is its adaptability to digital formats. Modern platforms such as Qb Test integrate CPT logic with motion tracking technology, offering detailed and dynamic data on hyperactivity, impulsivity, and inattention (Hult et al., 2018). These systems also allow for longitudinal data storage and visual representation of performance, enhancing progress monitoring and treatment evaluation.

2.3. Stroop Color-Word Test

The Stroop Color-Word Test is a classic and widely utilized measure of executive functions, particularly cognitive inhibition and selective attention, both of which are frequently impaired in individuals with ADHD. The original version was developed by J.R. Stroop in the 1930s to investigate the brain’s ability to suppress automatic responses in favor of more cognitively demanding tasks (MacLeod, 1991).

The standard test includes three phases:

- Reading color words printed in black ink (e.g., “red,” “green”),
- Naming the color of colored shapes,
- Interference phase: naming the ink color of color words printed in incongruent ink (e.g., the word “blue” written in red ink).

The interference phase requires the examinee to inhibit the automatic tendency to read the word and instead name the ink color, thus testing the capacity for cognitive control and conflict resolution. This process is associated with the activation of prefrontal brain areas responsible for executive regulation (Lansbergen et al., 2007).

Studies have shown that children with ADHD perform significantly worse during the interference phase, showing longer reaction times and more frequent errors compared to non-ADHD peers (Homack & Riccio, 2004). These difficulties suggest deficits in cognitive inhibition and are considered central features of ADHD according to theoretical models like Barkley’s (1997).

Furthermore, the Stroop test provides valuable information about cognitive flexibility, the ability to shift attention and manage conflicting information. It is particularly useful when behavioral observations or questionnaires fail to clearly detect executive dysfunction.

Technological advancements have led to the development of digital versions, such as e-Stroop, which allow for precise millisecond-level response recording. These versions reduce examiner error, automate scoring, and enable administration via electronic devices, including tablets and computers. Their applicability in school, clinical and even telehealth settings is expanding (Görzig et al., 2019).

2.4. Wisconsin Card Sorting Test (WCST)

The WCST is a prominent neuropsychological tool for evaluating cognitive flexibility—the ability to adapt thinking and behavior in response to changing task demands. This is particularly important for children with ADHD, who often struggle with shifting strategies, interpreting feedback, and responding to new situations.

In the WCST, participants are asked to match response cards to reference cards based on rules they must infer (e.g., matching by color, number, or shape). These rules change without notice during the task. The examinee must adjust their sorting strategy based solely on feedback (i.e., “correct” or “incorrect”).

This process requires the individual to effectively interpret the feedback provided, inhibit previously learned response patterns that are no longer appropriate, and adopt new cognitive strategies in response to changing rules.

WCST performance engages the dorsolateral prefrontal cortex and related brain regions (Heaton et al., 1993; Monchi et al., 2001). Children with ADHD often demonstrate a specific type of difficulty known as preservative responding, where they continue applying an incorrect rule even after receiving negative feedback. This pattern reflects poor adaptability and is a hallmark of ADHD-related cognitive rigidity (Barkley, 1997).

Scoring includes measures such as:

- Total number of completed categories,
- Number of correct responses,
- Preservative errors,
- Ability to shift to new strategies.

Although similar deficits may appear in other disorders (e.g., autism spectrum disorder, schizophrenia), the ADHD profile is usually characterized by impulsivity, low frustration tolerance, and inconsistent attention.

The test is now available in various digital formats (e.g., WCST-CV4, Berg Card Sorting Test), which enhance scoring precision and minimize human error. They also allow for remote administration via online platforms, increasing access and efficiency.

3. Results

The combined application of the CPT, Stroop, and WCST tests allows for the identification of specific executive function deficits that are common in children with ADHD. Each of these assessments contributes unique insights that help construct a neuro cognitive profile essential for differential diagnosis and intervention planning.

3.1. Continuous Performance Test (CPT) Outcomes

The CPT has consistently shown diagnostic utility in detecting attentional impairments and impulsivity in children with ADHD. Research findings indicate that children with ADHD demonstrate a higher frequency of omission errors, reflecting sustained attention deficits, and commission errors, indicative of impulsive behavior (Epstein et al., 2003). Furthermore, their reaction times tend to vary more significantly, revealing instability in cognitive alertness (Riccio et al., 2002).

These cognitive patterns support the test’s sensitivity in distinguishing between different ADHD subtypes, such as the inattentive type (more omissions) and the combined type (high rates of both omissions and commissions) (Epstein et al., 2003). Nevertheless, the CPT is not without limitations. Its results may be affected by factors such as test anxiety,

unfamiliarity with digital environments, or low motivation during testing sessions (Riccio et al., 2002). Thus, it should be used within a broader diagnostic framework that includes observational and psychometric data.

Digitally enhanced versions like Qb Test provide additional value by integrating motion tracking to measure hyperactivity along with inattention and impulsivity. This tool has been approved by the FDA and offers enhanced diagnostic accuracy and real-time visual analytics for clinical monitoring (Hult et al., 2018).

3.2. Stroop Test Outcomes

The Stroop Color-Word Test has proven effective in assessing cognitive inhibition and attentional control. Children with ADHD typically show delayed reaction times and increased error rates, especially during the interference phase of the test (Homack & Riccio, 2004). These deficits reflect reduced inhibitory capacity and the inability to manage conflicting stimuli efficiently (Barkley, 1997).

The Stroop test also indirectly evaluates cognitive flexibility, as participants must shift attentional focus and suppress automatic responses. These skills are essential for adaptive behavior in school and social settings. Digital adaptations like e-Stroop offer precise millisecond-level timing and reduce human error in data collection, making the test more accessible and scalable (Görzig et al., 2019).

3.3. Wisconsin Card Sorting Test (WCST) Outcomes

The WCST measures cognitive flexibility, rule-shifting, and feedback processing. Children with ADHD often exhibit perseverative errors—continuing to use an incorrect sorting rule despite feedback—which reflects difficulties in adapting to new rules or learning from past mistakes (Heaton et al., 1993; Monchi et al., 2001).

In clinical practice, these findings are interpreted as indicators of executive dysfunction, linked to atypical activity in the dorsolateral prefrontal cortex (Monchi et al., 2001). The WCST does not specifically diagnose ADHD, but the characteristic pattern of errors helps differentiate ADHD from other disorders such as anxiety or autism spectrum conditions (Barkley, 1997).

Digital versions of the WCST, such as WCST-CV4 and the Berg Card Sorting Test, increase diagnostic precision, allow for remote administration, and enable the automated extraction of performance metrics. These tools also contribute to more consistent data analysis and long-term progress tracking.

3.4. Integration of ICT in Neuropsychological Testing

The incorporation of Information and Communication Technologies (ICT) into neuropsychological testing provides significant enhancements in measurement accuracy, time efficiency, and accessibility. Tools such as QbTest, e-Stroop, and computerized versions of WCST enable automatic scoring, visual data representation, and cloud-based storage (Bauer et al., 2012).

These digital tools are particularly valuable in remote or underserved areas and have shown strong validity and reliability compared to traditional in-person assessments when implemented under proper technical and ethical standards (Brearly et al., 2017).

Moreover, they support the monitoring of intervention outcomes by providing consistent, quantifiable, and objective data, enabling professionals to make informed, evidence-based decisions regarding diagnosis and treatment planning.

4. Discussion

The assessment of ADHD requires a multi factorial approach that incorporates behavioral, psychometric, and neuropsychological data. The present analysis highlights the importance of combining traditional evaluation methods with objective, standardized tools such as the CPT, Stroop, and WCST tests. These neuropsychological assessments offer a more precise and multidimensional picture of the core deficits in attention, inhibition, and cognitive flexibility—executive functions commonly impaired in children with ADHD (Barkley, 1997; Pennington & Ozonoff, 1996).

Each test contributes distinct and complementary information. The CPT provides quantitative indices of sustained attention and impulsivity, showing high sensitivity in identifying attentional deficits and subtype differentiation (Epstein et al., 2003). The Stroop test assesses cognitive inhibition, a central executive function associated with the regulation of behavior and decision-making (Homack & Riccio, 2004). The WCST evaluates the child's capacity to adapt

to changing rules and to learn from feedback, ability crucial for academic success and social adaptation (Heaton et al., 1993; Monchi et al., 2001).

The results of these tools, when interpreted in combination, enable professionals to construct a detailed neuro cognitive profile that supports not only diagnosis but also the formulation of targeted therapeutic and educational interventions. These tools are particularly useful in differential diagnosis, helping to distinguish ADHD from other disorders that may present with similar surface-level symptoms, such as anxiety disorders, depression, or specific learning difficulties (Barkley, 2006).

4.1. The Role of ICT in Modern Diagnostic Practice

The integration of Information and Communication Technologies (ICT) into the diagnostic process has introduced significant advantages in terms of accuracy, accessibility, and efficiency. Computerized versions of CPT, Stroop, and WCST provide automated data analysis, eliminate examiner bias, and ensure high temporal precision in reaction time measurement (Bauer et al., 2012).

Platforms such as QbTest, e-Stroop, and digital WCST enable real-time data visualization and longitudinal tracking, making them particularly effective in monitoring the course of treatment and assessing intervention outcomes (Hult et al., 2018; Görzig et al., 2019). These systems allow professionals to interpret complex cognitive performance patterns and offer evidence-based recommendations for intervention and support.

Moreover, the use of tele-assessment platforms has made it possible to conduct evaluations remotely, thus extending services to children in remote or underserved areas. Research has shown that remote administration of neuropsychological tests via secure videoconferencing platforms can yield results comparable in validity and reliability to those obtained through in-person testing, provided that proper ethical and technical standards are upheld (Brearly et al., 2017).

4.2. Benefits and Limitations of Technological Integration

Despite their advantages, ICT-based diagnostic tools are not without challenges. Factors such as the examinee's familiarity with digital devices, internet connectivity, and comfort level with virtual environments can influence performance outcomes. Additionally, privacy concerns and the protection of sensitive data must be carefully managed to ensure compliance with legal and ethical standards (Bauer et al., 2012).

It is also important to emphasize that while ICT enhances objectivity and efficiency, it cannot replace the clinical judgment and experience of trained professionals. These technologies should be viewed as supportive tools that complement—but do not substitute—the expertise of psychologists, child psychiatrists, and neuropsychologists in synthesizing assessment data and developing individualized support plans.

4.3. Toward a Hybrid, Multimethod Diagnostic Model

The findings of this analysis underscore the value of a **hybrid diagnostic model**, combining neuropsychological tools, traditional psychometric methods, and technological platforms. Such a model acknowledges the complexity of ADHD and recognizes that a one-size-fits-all approach is insufficient.

By integrating objective performance data with behavioral observations and self- or parent-reported symptoms, clinicians can form a holistic view of the child's functioning across multiple domains. This allows for the development of tailored interventions that address both observable behaviors and underlying cognitive processes.

The goal is not only to label or diagnose but to understand how ADHD-related deficits manifest in real-world contexts—school performance, peer relationships, family dynamics—and to intervene meaningfully and effectively.

5. Future Research Directions and Overall Reflection

The continuous evolution in ADHD assessment requires ongoing revision and adaptation of methods and tools, taking into account cultural, technological, and educational developments. One of the major challenges faced is the lack of updated Greek norms and for key neuropsychological tests. Although many of these instruments have been translated into Greek, the absence of culturally adapted norms for the Greek population undermines their diagnostic reliability. The establishment of standardized Greek norms will allow more accurate interpretation of results, respecting cultural particularities and the developmental specificities of Greek-speaking children. For instance, performance on tests such

as the WCST or Stroop may be influenced by the linguistic complexity of the Greek language or by specific educational expectations within the school system.

Simultaneously, empirical evaluation of the validity of digital versions of classical tests (CPT, Stroop, WCST) in the Greek student population is urgently needed. While digital tools promise increased accuracy, speed, and ease of application, their use without sufficient validation in the local context carries the risk of erroneous diagnoses. Therefore, studies investigating their sensitivity, specificity, and diagnostic power in samples of elementary and secondary school students are essential, also considering socioeconomic factors influencing performance.

An important future prospect is the development of integrated diagnostic models that incorporate data from questionnaires, neuropsychological tests, and digital measurements, utilizing artificial intelligence (AI). Such models could recognize symptom patterns, estimate probabilistic diagnoses, and propose individualized interventions based on multi factorial data. Moreover, with appropriate training and respect for ethical management, AI can support professionals in interpreting complex neuro cognitive profiles and effectively managing large volumes of information. The success of this approach requires innovative research and interdisciplinary collaboration among psychologists, special educators, statisticians, and computer engineers.

Finally, future research should focus on linking neuropsychological findings with functional and educational parameters. ADHD assessment in children should not be limited to diagnostic formulation but must consider daily school performance, classroom behavior, social interactions, and emotional well-being. For example, the WCST can reveal how a child manages rule changes, connecting this with learning flexibility. Similarly, findings from the CPT and Stroop tests can correlate with difficulties in completing schoolwork or following group norms. Integrating this information into educational practice through cooperation among teachers, psychologists, and parents facilitates the development of targeted and functionally effective interventions.

In summary, a holistic and evidence-based diagnostic approach constitutes the foundation for understanding and supporting children with ADHD, grounded in scientific validity and respect for their individuality. Neuropsychology and technology, when harmoniously integrated within a multi-level diagnostic framework, cease to be merely auxiliary tools and become essential elements of a fair, personalized, and scientifically substantiated diagnostic culture, focusing on the child as a bearer of potential rather than merely difficulties.

6. Conclusions and Research Perspectives

The assessment of ADHD constitutes a complex process that requires the utilization of a combination of psychometric, neuropsychological, and technological tools. According to the findings of the present study, neuropsychological tests such as the CPT, Stroop, and WCST provide valuable information for the accurate documentation of core cognitive functions, including sustained attention, inhibition of impulsive responses, and cognitive flexibility — functions often affected in different ADHD subtypes. The CPT, with its ability to detect errors in attention and impulsivity, contributes to the early identification of fundamental cognitive deficits and has demonstrated significant diagnostic sensitivity. Conversely, the Stroop Test focuses on the capacity to inhibit unwanted responses and provides essential data for the evaluation of executive function difficulties. Finally, the WCST assesses cognitive adaptability and the individual's ability to shift strategies based on feedback, a skill critical for successful functioning in academic and social settings.

The results of this study emphasize the importance of a multi factorial and multi method approach in ADHD diagnosis, which is not merely useful but necessary. Exclusive reliance on questionnaires or behavioral observations often fails to identify the underlying cognitive deficits associated with the disorder. The combined use of traditional techniques with neuropsychological assessments enhances diagnostic accuracy, reduces errors, and enables more targeted and effective interventions. Special attention should be given to integrating Information and Communication Technologies (ICT) into the diagnostic process. These technologies not only facilitate objective recording and analysis of results but also pave the way for more individualized, even remote, assessments. The application of digital tests, automated data processing, and the use of artificial intelligence tools contribute to the development of diagnostic systems that are flexible, rapid, and culturally adapted.

However, it is crucial to emphasize that neuropsychological tests and technological means do not replace the specialized evaluating professional. On the contrary, the presence of trained clinical psychologists, child psychiatrists, or neuropsychologists is critical for the accurate interpretation of data, synthesis of findings, and the development of appropriate therapeutic plans. Technology serves as a valuable support tool that enhances the scientific validity and depth of diagnosis when utilized with the necessary professional judgment.

Compliance with ethical standards

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The Authors proclaim no conflict of interest.

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