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4 **REVIEW PAPER**
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8 **Specific Cognitive Deficits in ADHD: A Diagnostic Concern in Differential Diagnosis**
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23 Running head: Diagnosis of ADHD
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4 **Abstract**
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6 We present a critical account of existing tools used to diagnose children with Attention
7 Deficit Hyperactivity Disorder and to make a case for the assessment of cognitive
8 impairments as a part of diagnostic system. Surveys have shown that clinicians rely
9 almost entirely upon subjective reports or their own clinical judgment when arriving at
10 diagnostic decisions relating to this prevalent disorder. While information from parents
11 and teachers should always be carefully considered, they are often influenced by a host of
12 emotional and perceptual factors. It increases the possibility for misdiagnosis of a
13 condition like ADHD. Recent experimental literature on ADHD has identified unique
14 underlying cognitive dysfunction, specific to ADHD. Therefore, we propose that there is
15 a need to incorporate information on cognitive mechanisms underlying ADHD and
16 inculcate such information in the diagnostic system, which will provide a more sensitive
17 as well as specific tool in differential diagnosis of ADHD.
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38 Key Words: Attention Deficit Hyperactivity Disorder, Oppositional Defiant Disorder,
39 Differential Diagnosis, Diagnostic System, Specific Cognitive Functions.
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4 **Introduction**
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6 Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common
7 developmental cognitive disorders of childhood. Prevalence rate of ADHD is 3-7% of
8 children in the United States, and often continuing into adulthood (Barkley, 1998).
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10 ADHD is usually characterized by a pattern of increased impulsivity, high levels of motor
11 activity, and attentional problems that impair function in home, school, and social
12 settings (American Psychiatric Association, APA, 1994). Children with ADHD usually
13 have functional impairment across multiple settings including home, school, and peer
14 relationships. ADHD also has been shown to adverse effect on academic performance,
15 vocational success and social-emotional development. The prevalence rate of ADHD has
16 drastically increased. The increase is probably due to changes in diagnostic criteria. It is
17 important to diagnose ADHD correctly otherwise they will not get proper treatment.
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19 Diagnosis of a disorder like ADHD is a complex issue for a clinician because of the high
20 prevalence of co-morbid conditions. Misdiagnosis is likely to happen which may resulted
21 in serious consequences, including school failure, depression, conduct disorder, failed
22 relationships, and substance abuse (APA, 1994). Therefore, proper diagnosis of ADHD
23 children is very important. However, clinicians often cannot diagnose children with
24 ADHD accurately consequently, these patients treated inappropriately in the primary care
25 setting.
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50 There is no laboratory test or set of physiological features that has been identified
51 as an unequivocal marker for ADHD. That is, there is no “gold standard” for diagnosing
52 ADHD. The disorder is behaviorally based; thus, behavioral observations are required to
53 identify and correctly diagnose the disorder. It has been argued that ADHD is not a
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4 distinct diagnostic entity, but that it is a “symptom complex” characterized by multiple
5 possible etiologies and a constellation of pathological behaviors (Weinberg & Brumback,
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9 1992; Weinberg, 1993). The observed behaviors are interpreted subjectively by parents
10 and teachers who describe these observations to clinicians. Clinicians often observe the
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14 child during clinical interviews and psychometric testing. Typically, parent, teacher and
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distinct diagnostic entity, but that it is a “symptom complex” characterized by multiple possible etiologies and a constellation of pathological behaviors (Weinberg & Brumback, 1992; Weinberg, 1993). The observed behaviors are interpreted subjectively by parents and teachers who describe these observations to clinicians. Clinicians often observe the child during clinical interviews and psychometric testing. Typically, parent, teacher and clinical observations are incorporated into a diagnostic decision. However, this subjective interpretation can lead to inter-observer differences, and can make ADHD diagnosis difficult. For example, the prevalence of behaviors related to hyperactivity as rated by a teacher can be higher than that rated by a clinician (Lambert et al., 1973). In contrast, the prevalence of behaviors related to hyperactivity can be lower if these behaviors must be judged to be present by more than one source (e.g., parent and teacher) (Sandberg et al., 1980).

Because there is no gold standard for diagnosing ADHD, it is important to make a distinction between how ADHD is defined and how it is diagnosed. The disorder is currently defined by criteria contained in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV). The DSM-IV defines ADHD according to two behavioral domains: inattention and hyperactivity-impulsivity. Each domain contains nine possible symptoms; a child must have at least six of the nine symptoms to qualify for a diagnosis of ADHD. If the child has at least six symptoms on the inattention domain, s/he qualifies for the “ADHD-Predominantly Inattentive Type” diagnosis. If the child has at least six symptoms on the hyperactivity-impulsivity domain, s/he qualifies for the “ADHD-Predominantly Hyperactive-Impulsive Type” diagnosis. If the child has

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4 at least six symptoms on both inattention and hyperactivity-impulsivity domains, s/he
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7 qualifies for the “ADHD-Combined Type” diagnosis (DSM-IV).
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9 Additional DSM-IV criteria specify that some inattentive or hyperactive-
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11 impulsive symptoms must have been present before the age of seven years, although the
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13 diagnosis can be made at older ages. In addition, the symptoms must be present in at least
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15 two settings (e.g., home and school) and must cause impairment. That is, there must be
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17 evidence of interference with developmentally appropriate social, academic, or
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19 occupational functioning. The symptoms should not occur exclusively during the course
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21 of a pervasive developmental disorder (e.g., autism), schizophrenia, or any other
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23 psychotic disorder. Furthermore, the symptoms should not be better accounted for by
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25 another mental disorder (e.g., mood, anxiety, dissociative or personality disorders)
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27 (DSM-IV).
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33 While ADHD is defined by the DSM-IV criteria, the symptom complex is
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35 diagnosed by a clinician. In the absence of a gold standard, the “reference standard” is the
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37 clinician’s judgment. Ideally, this decision would be based on information gathered from
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39 a number of sources (e.g., parent, teacher, observations of the child), and would be
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41 reached by consensus. That is, a number of qualified clinicians would confer in making
42
43 the appropriate diagnosis. Nevertheless, the clinician’s decision is ultimately a subjective
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45 one, and this introduces a level of variability that is difficult to control particularly while
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47 evaluating a tool used for the diagnosis of ADHD. Moreover, the DSM has undergone
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49 several iterations over the past two decades, suggesting that ADHD is indeed a “symptom
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51 complex” characterized by behaviors that are difficult to agree upon. In addition to DSM
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58 IV criteria, there are some diagnostic tools available to diagnose ADHD.
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4 **Existing Tools for a Diagnosis of ADHD**
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6 According to DuPaul et al. (1991) the approach to diagnosis of ADHD may
7 incorporates (1) parent and teacher interviews; (2) parent and teacher rating scales; (3)
8 direct observations of behavior; and (4) academic record. There are certain objective
9 tools such as continuous performance tests (CPTs) that are available to diagnose ADHD.
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16 *Rating Scales*
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18 Rating scales which are most commonly used to diagnose ADHD are the parent-
19 completed Child Behavior Checklist, the Teacher Report Form (TRF) of the Child
20 Behavior Checklist, the Conners Parent and Teacher Rating Scales, the ADD-H:
21 Comprehensive Teacher Rating Scale (ACTeRS), and the Barkley Home Situations
22 Questionnaire and School Situations Questionnaire. These rating scales yield valuable
23 information about overt symptoms efficiently. However, there are certain limitations in
24 the use of rating scales in getting valid ratings. For example, factors like raters'
25 identification with the ratees is one of the factor which may introduce bias and limit the
26 effectiveness of rating scale. Often the rater is known / related to persons being rated. He
27 may identify with some persons positively and with some persons negatively. Persons
28 identified positively are likely to be rated high despite some unfavorable characteristics
29 whereas persons identified negatively are likely to be rated low despite some favorable
30 and sound characteristics. In both the situations the rating would be a misleading index
31 and would reduce the effectiveness of the rating. Sometime vagueness in the meaning of
32 the trait being rated may affect the rating negatively. For example, some traits or
33 dimensions to be rated are vague and abstract ones. As a consequence, their meaning
34 varies from rater to rater and thus naturally affects the consistency in ratings.
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4 Most of the rating scales require the raters to rate the ratees in any one of different
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6 categories like superior, excellent, very good, or best, good, average, below average.
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9 When a rater rates a ratee as superior, the question arises as to what he standard is against
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11 which a ratee is being classified as superior. Is he being compared with the top 5% or top
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13 10% or, is he being compared with he middle cases? The raters have no uniform standard
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15 before them so that the interpretation of category “superior” may not have an identical
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17 meaning to all. In the absence of a uniform standard, the interpretation of a category
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19 varies from rater to rater. One rater’s “superior” may be another rater’s simply “very
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21 good”. This naturally lowers the consistency of ratings and thereby, their reliability.
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23 Raters’ personal characteristics also tend to influence the ratings. Some raters are
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25 conservative and, therefore, they tend to rate persons almost in the middle. They rarely
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27 rate a person very high or very low. Some raters are tough and, therefore, rarely rate
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29 anybody high. Thus personal experiences of raters are likely to color their judgment and
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31 also their ratings. In such situations the rating done by one rater cannot be compared with
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33 the rating done by another rater. In addition, these subjective and behaviorally biased
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35 ratings do not objectively measure attentional variables, which are impaired in ADHD.
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43 *Continuous Performance Tests (CPTs)*

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45 Continuous Performance Tests (CPTs) are computer-based tests designed to
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47 measure inattention and impulsivity. It provides a quick assessment of current abilities
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49 for sustained attention. A number of CPTs are commercial available to private clinician
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51 for the assessment of children with ADHD: Gordon Diagnostic System (GDS) (Gordon,
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53 1983), Test of Variables of Attention (TOVA) (Greenberg & Waldman, 1993), Conners’
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55 Continuous Performance Task (CCPT) (Conners, 1995), and the Intermediate Visual and
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4 Auditory Continuous Performance Test (IVA) (Sandford, 1995). CPTs involve the
5 presentation of stimuli that include a set number of predetermined targets to which
6 subjects respond. CPTs vary in duration (a few minutes to half an hour), sensory modality
7 (visual or auditory), stimuli (numbers, letters, drawings, and colors), and nature of the
8 task (single target, double target, or sequential recognition). The differences among CPTs
9 are factors to consider when comparing CPT performances. Most common measures
10 assess omission errors, or misses, or commission errors, or false alarm and reaction time.
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21 Two of the primary criticisms of the use of CPTs are discussed here. First is
22 related to its reliability and validity; second, CPTs involve high rates of false negatives,
23 and its limited ability to discriminate between ADHD and other clinical disorders.
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29 The commercially available CPTs fail to report acceptable levels of test-retest
30 reliability. The TOVA, for example, does not even report test-retest reliability, but rather,
31 split-half reliability coefficients (Greenberg, 1996). Split-half reliability may be
32 appropriate for a test that is given to a strong practice effect, but that is hardly true of the
33 TOVA. Test-retest reliability is essential to consider in a test that is likely to be used
34 serially (e.g., to evaluate an ADD patient's response to stimulant medications). The
35 Conners CPT-II reports test-retest reliability, but only on 23 participants, and not on raw
36 scores, but on derived scores (Conners, 2000). The GDS lacks strong validity. It may be
37 useful while conducting a comprehensive evaluation of children suspected of attentional
38 problems. There are a number of important confounds that could affect the score obtained
39 on GDS and other computerized measures. Wherry et al. (1993) investigated the validity
40 of the GDS and the results were fairly poor. These authors stated that "The results failed
41 to demonstrate the discriminant validity of any GDS score regardless of the behavior
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4 rating used." As Barkley and others (Barkley & Grodzinsky, 1994) have noted, in order
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6 for a test to be diagnostically useful, it must be able to not only identify the children with
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8 ADHD (sensitivity), but it must also accurately identify children without ADHD
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10 (specificity).
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14 It is also necessary to investigate the sensitivity and specificity of the diagnostic
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16 measures. In the opinion of one expert panel (Dulcan & Popper, 1991) CPTs (Greenberg
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18 & Waldman, 1993; Barkley, 1990; Conners, 1985; Wigal et al., 1998) are not generally
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20 useful in diagnosis because they suffer from low specificity and sensitivity (Lovejoy &
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22 Rasmussen, 1990; Trommer et al., 1988). They are useful, however, as research tools. It
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24 is possible that CPTs may be useful in measuring some isolated symptoms of ADHD.
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26 Various CPTs have yielded false negative rates from 20 to 37% or higher (Greenberg &
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28 Waldman, 1993; Barkley, 1991), leading researchers to caution that "normal" CPT
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30 performance should not be used as evidence to rule out a diagnosis of ADHD. Rielly et
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32 al. (1999) used the GDS CPT to evaluate and classify children with a preschool history of
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34 language disorders for the presence of ADHD. They used the 5th and 25th percentiles as
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36 thresholds for 11 possible outcomes on three GDS tasks. For total commission errors
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38 from the vigilance portion of the CPT, sensitivity was 60% and specificity was 46% at
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40 the 5th percentile; at the 25th percentile these values were 88% and 23%, respectively
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42 (Table 1). The authors concluded that the GDS may have some clinical utility in ruling
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44 out a diagnosis of ADHD in children with a history of language disorders, but may not be
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46 sufficient to confirm an ADHD diagnosis in the population (Rielly et al., 1999).
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48 Description of the other CPTs and its sensitivity and specificity is presented in Table 1.
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Insert Table 1

In order to evaluate the efficacy of the CPT in the diagnosis of ADHD, it is important to consider if CPTs can help in discriminating ADHD from other co-morbid conditions. Children with ADHD are likely to have conduct disorder (CD), Oppositional Defiant Disorder (ODD) or Learning Disability (LD) (APA, 1994; Loney & Millich, 1982; Epstein et al., 1991). A diagnostic tool not only helps to differentiate ADHD from normal children (non-specific diagnosis), but also among disorders like CD, ODD and LD that tend to co-occur with ADHD (differential diagnosis). A number of studies have been found that CPTs have been inconsistent in differentiating ADHD from other clinical groups (Halperin et al., 1992).

One of the main reason that why CPTs are less able to discriminate ADHD from normal children and children with ODD/CD or LD is that CPT assess on aspect of attention such as sustained attention, which is impaired in ADHD. Indeed impairments, in sustained attention are common to a certain extent to all children with psychiatric disorders (Swaab-Barneveld et al., 2000). Therefore, it is important to asses those cognitive functions which are specifically impaired in ADHD and inculcate this information in the diagnostic system. This will provide a more sensitive as well as specific tool to tap the cognitive impairments in ADHD. Recent experimental literatures on ADHD have identified unique underlying cognitive dysfunction, specific to ADHD, are briefly discussed in the next section. In addition, few recent studies also demonstrate the differences in cognitive profile in ADHD subtypes (ADHD-combined type

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4 (ADHD/CT) and ADHD-inattentive type (ADHD/IT) in terms of disinhibition (Nigg et
5 al., 2002), and alerting and executive attentional network (Booth et al., 2001; Oberlin et
6 al., 2005).
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10 11 **Specific Cognitive Deficits in ADHD** 12

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14 Recent experimental literature reveals that children with ADHD are characterized
15 by specific deficits in the monitoring of attentional resources. These deficits in turn
16 negatively affect the cognitive processes, such as response inhibition, error monitoring,
17 attentional disengagement, (Logan, 1985; Rabbit, 1968; Schachar et al., 2004), decision
18 making processes (Garon, 2006), and emotion regulation (Maedgen, 2000; Walcott,
19 2004).
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29 There is evidence that the core deficit linked with ADHD involves sustained and
30 selective attention that is necessary to perform a given task (Greenham, 1998). These
31 individuals exhibit several deviations from their developmental level, sufficient to create
32 impairments in major life activities. Most of these impairments have been studied using
33 objective measures to demonstrate distinct attentional problems. The ADHD individuals
34 show deficits in subsystems of attention such as alerting, orienting, and executive
35 network. Some of the sustained attention problems among ADHD may also be linked
36 with deficits in alerting mechanisms (Posner & Raichle, 1994), which are critical for
37 normal cognitive functioning. Earlier work using spatial orienting task suggested that
38 ADHD children have difficulty in maintaining an alert state (sustained attention) in the
39 absence of warning signal (Swanson et al., 1991). More recent studies using the
40 Attentional Network Task (ANT) have replicated problems with alerting in ADHD
41 mainly due to the inability to maintain the alert state when no warning signal was used
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4 (Blane & Marrocco, 2004; Booth et al., 2001). Other studies using task similar to ANT
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7 have also shown some evidence of abnormalities in alerting and/or executive control in
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9 ADHD in terms of slowed response times to abrupt visual cues especially when faced
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11 with conflicting spatial cues (Oberlin et al., 2005). It should be noted that impairment in
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13 attention processes also results in abnormal functioning in many higher order cognitive
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15 operations that involve inhibition of a pre-potent response, interference control and
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17 emotion regulation.
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21 A number of studies provide consistent empirical support for the assumption that
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23 individuals with ADHD have a deficit in executive control processes, one of which is
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25 response inhibition (Barkley, 1997; Sergeant et al., 1999). Earlier studies reported that
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27 response inhibition deficits have also been associated with CD (Hurt & Naglieri, 1992;
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29 Oosterlaan et al., 1998). However, most previous studies have failed to control for
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31 comorbid diagnosis and it has been suggested that the association between disinhibition
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33 and CD might be accounted for by the large overlap with ADHD (Pennington & Ozonoff,
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35 1996). On the other hand, it is also possible that the association between disinhibition and
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37 ADHD is caused by the overlap with CD. Finally, Lynam (1998) has argued that it is the
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39 combination of high levels of ADHD symptoms and conduct problems that is associated
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41 with poor inhibitory control, and this comorbid group has also been shown to have the
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43 most serious negative outcomes (Moffitt, 1990). Therefore, Nigg et al. (1998) suggested
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45 that it is very important to take into consideration that, even though children diagnosed
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47 with CD, may not meet the criteria for comorbid ADHD, they may still have considerably
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49 higher levels of ADHD symptoms compared to normal controls. As a consequence, it is
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51 important to treat data dimensionally, not categorically, and control for comorbid
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4 symptoms at a subclinical level (Nigg et al., 1998). Studies which have controlled for
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6 subclinical symptoms, reported that disinhibition is specific to ADHD and not primarily
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8 related to CD (Nigg et al., 1998 & Berlin & Bohlin, 2002). Berlin and Bohlin (2002) have
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10 reported that the correlation between response inhibition and conduct problems was no
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12 longer significant when controlling for hyperactivity, whereas the correlation between
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14 disinhibition and hyperactivity did remain significant when controlling for conduct
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16 problems. These findings indicate that the association between inhibition and conduct
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18 problems was caused by the large overlap between conduct problems and hyperactivity.
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20 It also provides further support for the role of response inhibition in understanding the
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22 mechanisms behind hyperactivity. A meta-analytic study also provides clear evidence for
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24 an inhibitory dysfunction in ADHD, whereas evidence for such a deficit for ODD/CD
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26 was less robust (Oosterlaan et al., 1998). ADHD is normally associated with slower
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28 responses during a stop signal task (Schachar & Logan, 1990) which requires responses
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30 to “go” trials and inhibition of responses during “no go” trials. Earlier, it was suggested
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32 that the ADHD individuals are deficient at monitoring responses during “no go” trials.
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34 However, meta-analytic results have shown potential milder problems during “go”
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36 responses as well, indicating that problems in response organization and arousal may also
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38 play a role in the disorder (Oosterlaan et al., 1998; Sergeant et al., 1999). More
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40 specifically, the impairments in executive control processes manifest as poor post error
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42 slowing and decrement in accuracy when faced with response conflict during a flanker
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44 task. Such deficits in monitoring ongoing behavior during the task were confirmed by the
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46 reduced event-related potential amplitude difference between correct and incorrect trials
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48 compared to normal controls (van Meel, 2007; Wang et al., 2004). Recent fMRI study
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4 indicates a functional anatomical asymmetry of response inhibition between ADHD and
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6 normal children.
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9 Cognitive performance of individuals with ADHD is also characterized by large
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11 moment-to-moment fluctuations in cognitive control reflected by a highly inconsistent
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13 and inaccurate response style. It has been suggested that abnormal error processing
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15 underlies this failure to implement adequate control that provides top-down adjustment of
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17 elementary mental operations (Logan, 1985). ADHD individuals get slowed after fewer
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19 inhibition failures than normal controls and when they slow, they slowed to a lesser
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21 extent. This pattern of performance suggests that ADHD individuals differ from normally
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23 developing individuals in behavioral adjustment to errors. Another study examined error
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25 monitoring as one of the executive control measures being impaired in ADHD using the
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27 event related potential (ERP) methodology. The error-related negativity (ERN) was the
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29 same for ADHD and the control group, the former showed diminished error positivity
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31 (Pe). Based on these findings, the authors concluded that individuals with ADHD are
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33 normal in early error monitoring processes related to error detection as indexed by ERN.
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35 However, they show abnormal response strategy adjustments and are deviant in later
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37 error monitoring processes related to Pe which may also be associated with the
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39 subjective/emotional, conscious evaluation of the error (Leube et al., 2003). This is also
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41 an indication of the abnormal emotional regulation in these individuals. Yet in another
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43 study brain electrical activity was recorded during the stop signal task. Individuals with
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45 ADHD showed abnormal scalp distribution in P3a and reduce ERN in dorsal anterior
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47 cingulate cortex suggesting a global deficit in cognitive control operations in these
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49 individuals (Wiersema et al., 2005). ERP amplitude differences between correct and
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4 incorrect responses were also found to be diminished in ADHD. ADHD individuals also
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6 show larger deficit in control processes necessary for disengagement from one task and
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8 preparation for a subsequent task. It has been suggested that behavioral deficits observed
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10 in ADHD are a result of deficient resource allocation policies. No association has not
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12 been reported between error monitoring and reading disability, ODD/CD, or anxious
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14 behavior or generalized impairment (Schachar et al., 2004).
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19 ADHD individuals are also characterized by the abnormality in reward
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21 responsivity that interferes with decision making. ADHD individuals are characterized by
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23 specific motivational style called “delay aversion” (Ernst et al., 2003). Delay aversion is
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25 the tendency to escape or avoid delay, results in preference for small immediate over
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27 large delayed rewards. This is again an indication of abnormal emotional/motivational
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29 mechanism underlying ADHD. Recent positron emission tomography study suggested
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31 that neural circuits engaged during decision making differ in subjects with ADHD and
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33 healthy comparison subjects. Ventral and dorsolateral prefrontal cortex and the insula
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35 were activated during performance of the decision-making task in both the ADHD and
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37 healthy groups; however, activation in the ADHD group was less extended and did not
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39 involve other regions, such as anterior cingulate and hippocampus that sub serve
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41 emotion/memory processes. This difference may explain observed deficits in motivated
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43 behaviors in ADHD (Wu et al., 2006).
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51 **Computerized Neurocognitive Diagnostic System based on Specific Cognitive**
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53 **Deficits: A Proposal**
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56 Diagnosis of ADHD has been dependent on clinician judgment. The existing tools
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58 available for the diagnosis of ADHD include rating scales (parents/teachers), clinical
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4 observations or CPTs. These tools are not susceptible enough to discriminate ADHD
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6 from other developmental disorder (differential diagnosis) as well as from normals.
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8 Experimental evidence informs about the cognitive mechanisms specific to ADHD. An
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10 objective assessment of cognitive impairments can explain the behavioral symptoms as
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12 well as could help in differential diagnosis. This is particularly important in the context of
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14 ADHD, as comorbidity is highly prevalent in ADHD. Therefore, we propose to develop a
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16 diagnostic system based on a combination of tests which tap specific cognitive deficits in
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18 ADHD in addition to the information about behavioral symptoms collected with other
19
20 tools like rating scales and diagnostic criteria (DSM-IV). Such a diagnostic system will
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22 provide the clinician with objective data based upon the child's actual performance and
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24 will allow for observation in a paradigm likely to elicit inattention and impulsiveness.
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26 The clinical relevance of such a system will not only be limited to diagnosis but will also
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28 help to plan the treatment strategies including cognitive rehabilitation.
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36 The rationale for using a more comprehensive neurocognitive screening battery is
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38 that ADHD is not simply a disorder of sustained attention. ADHD is marked by
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40 impairment in complex functional systems such as response inhibition, error monitoring,
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42 attentional disengagement, and decision making. Neuropsychological literature also
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44 indicates that although many tests show cognitive impairment in ADHD, no one test is
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46 sufficient to make the diagnosis of its own. ADHD patients are a diverse group;
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48 individuals may demonstrate deficits in one test, or in one cognitive domain, but not in
49
50 another. Combinations of tests are more likely to yield useful information than any one
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52 single test (Konver et al., 1998; Doyle et al., 2000; Nigg et al., 2002; Schmitz et al., 2002;
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54 Gupta et al., 2006). CPTs like GDS, TOVA, CCPT, and IVA restrict the scope of the
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4 assessment of other cognitive impairments, such as response inhibition, error monitoring,
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6 and delay aversion that are specific to ADHD.
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9 In addition, standardized, computer based laboratory measures of attention can
10 provide objective data less influenced by factors such as rater bias. Computer based
11 laboratory measures do offer both the researcher and clinician an opportunity to
12 incorporate data derived from a child's actual behavior. It would also be helpful in order
13 to detect attention problems in children who are not overtly hyperactive or impulsive
14 (ADHD predominantly inattentive type) and might fall within the normal range on parent
15 or teacher ratings of behavior.
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25 26 **Empirical support for the above proposal**

27 We carried out a study (Gupta, Kar, & Srinivasan, manuscript under review) in
28 which children with ADHD, ODD, and normal controls were examined on four tasks:
29 Stop-signal task (SST), attentional disengagement task (ADT), attentional network task
30 (ANT) (child version), and delay aversion task (DAT). In the SST required inhibition of a
31 motor response. Stop-signal reaction time (SSRT), mean delay, and post-error slowing
32 (PES) were the measure of this task. ADT required switching the attention from one task
33 to another task (task-switching). All participants performed a task in which they had to
34 respond to two different task rules, requiring to discriminating the value of a number
35 presented on a computer screen and deciding how many numbers were present on the
36 screen. Switch costs (SC; difference of RT between the switch trials and nonswitch trials)
37 were the measure of this task. The child ANT is a complex task that provides a measure
38 of efficiency of the attentional function of alerting, orienting, and executive control
39 (Rueda et al., 2004). The ANT uses differences in reaction time (RT) between different
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4 conditions to measure the efficiency of each function. In the target display arrow of five
5 fish presented either below or above fixation. Each target was preceded by one of four
6 warning cue conditions: a center cue, a double cue, a spatial cue, or no cue. In the center
7 cue condition, an asterisk is presented at the location of the fixation cross. In the double
8 cue condition, an asterisk appears at the locations of the target above and below the
9 fixation cross. Spatial cues involve a single asterisk presented in the position of the
10 upcoming target. Children are instructed to pay attention to the middle fish, and to
11 respond based on whether it is pointing to left or right by pressing the corresponding key.
12
13 In the executive attention children are presented with fish surrounded by congruent and
14 incongruent flankers. Differences in RT between incongruent trials and congruent trials
15 give the score of executive attention. Differences in RT between nocue condition and
16 double cue give the score of alerting function. Differences in RT between center cue and
17 spatial cue give the score of orienting function. Alerting, orienting, and conflict score
18 were the measure of this task. In the delay aversion task participants were required to
19 choose between a small rewards (1 point) delivered after a short delay (1 second) or a
20 large reward (2 points) delivered after a long delay (20 seconds). Thus, the child could
21 choose between a small, immediate reward (SDR) and a large, delayed reward (LDR).
22
23 %LDR and %SDR were the measure of this task.

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25 We obtained the Receiver Operating Characteristic (ROC) for each parameter of
26 each task to calculate the sensitivity and specificity to see which parameters individually
27 classify the participants with their respective group correctly. Effect size of the
28 parameters such as %LDR (or %SDR), SC, SSRT, PES, mean delay, and grand mean
29 was more with the range of (0.49 to 0.66) as compared to other parameters such as
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4 alerting, orienting, and conflict score with the range of 0.033 to 0.004. Therefore, in the
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6 further analysis only these six parameters were combined through multinomial logistic
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8 regression to determine which parameters together can classify the children in their
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10 respective group correctly. Overall percentage of the correct classification of the
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12 individual seven parameters was 64%-72%. These parameters were then combined with
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14 multinomial logistic regression. We have tried all the possible combinations of the
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16 parameters. By combining any of the two parameters overall correct classification was
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18 72%-87 %. By combining three it was 82%-92%, by four it was 89%-95%, by five it was
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20 96%-98%, by six it was 97%-98%, and by seven the overall percentage of the correct
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22 classification was increased to 97%. Together all the six parameters correctly classified
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24 97.8% of the participants, with ADHD children classified correctly 100%, ODD children
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26 100%, and control with 93.3%. This study indicates that cognitive mechanisms
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28 underlying ADHD such as response inhibition, error monitoring, attentional
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30 disengagement, delay aversion were together not only helpful in diagnosis of children
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32 with ADHD rather it also helpful in differential diagnosis. Thus, these cognitive markers
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34 should be incorporate in the diagnostic system, which will provide sensitive and specific
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36 tool to tap the cognitive impairments, which may help in differential diagnosis.
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45 **Conclusion**

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48 Diagnosis of a disorder like ADHD is a complex issue for a clinician because of
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50 the high prevalence of co-morbid conditions. Misdiagnoses is likely to happen which
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52 may in turn affect the treatment. Reasons for misdiagnosis are due to the dependence on
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54 subjective reports based on rating scales, interviews from parents while arriving at a
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56 diagnostic decision. The subjective reports yield valuable information efficiently and
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4 systematically. However, there are some factors, which limit or affect valid ratings such
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6 as “rater bias”. Children with ADHD often show strong associations with disorders such
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8 as anxiety, depression, conduct disorder (CD), Tourette’s syndrome (TS) and
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10 oppositional defiant disorder (ODD) (Angold et al., 1999). Furthermore, ADHD,
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12 particularly the inattentive symptoms, are also associated with reading disability
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14 (Maedgen, 2000). Therefore, differential diagnosis is especially important in ADHD due
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16 to both the frequent co-occurrence of ADHD with other disorders and to the potential for
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18 other symptoms to produce symptoms that overlap with the behavioral criteria for
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20 ADHD. Recent experimental literature has identified cognitive mechanisms underlying
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22 ADHD. Thus, there is need to incorporate information on cognitive mechanisms
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24 underlying ADHD and inculcate such information in the diagnostic system, which will
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26 provide a more sensitive as well as specific tool to tap the cognitive impairments, which
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28 may help in differential diagnosis. Such a diagnostic system will provide the clinician
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30 with objective data based upon the child’s actual performance and will allow for
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32 observation in a paradigm likely to elicit inattention and impulsiveness. Moreover,
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34 multiple sources of information, both subjective and objective need to be incorporated in
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36 the diagnostic procedure to ensure accurate diagnosis of ADHD.
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Table Legends

Table 1. Description of various CPTs and its sensitivity and specificity.

Existing measures	Description	Sensitivity (%)	Specificity (%)
to assess cognitive impairments in ADHD			
Gordon Diagnostic System [9]	GDS is a self-contained portable unit, which administers two attention tasks and a test of impulse control. It consists of three subtests, Delay, Vigilance, and Distractibility	60 at 5 th percentile 88 at 25 th percentile	46 at 5 th percentile 23 at 25 th percentile
Test of Variables of Attention [13]	The TOVA (auditory and visual) was designed for use in diagnosis and monitoring medication effectiveness in children and adults with attention	80 (1 > 1.5 SD ^a) 52 (2 > 1.5 SD) 13 (3 > 1.5 SD) 67 (2 > 1.0 SD)	72 (1 > 1.5 SD ^a) 90 (2 > 1.5 SD) 100 (3 > 1.5 SD) 86 (2 > 1.0 SD)

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4 deficit disorders
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11 Conners' CCPT is a vigilance 50 50
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13 Continuous task in which
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15 Performance Task respondents are asked to
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17 [11] press a button when any
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19 letter but "X" appears
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21 on the screen
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27 Intermediate The IVA is an
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29 Visual and integrated 13-minute
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31 Auditory auditory and visual
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33 Continuous CPT. In addition to the
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35 Performance Test typical demands of
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37 [12, 67] clicking in response to a
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39 designated target, the
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41 IVA requires the test
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43 taker to "shift sets" and
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45 to make discriminatory
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47 responses to mixed
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49 auditory and visual
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51 stimuli
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