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The Diagnostic Utility of Behavioral Checklists in Identifying Children with ADHD and Children with Working Memory Deficits

Authors: TracyPackiam Alloway · SusanE. Gathercole · Joni Holmes · Maurice Place · JulianG. Elliott · Kerry Hilton

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Abstract

The present study investigated whether children with ADHD and those with working memory impairments have a common behavioral profile in the classroom. Three teacher checklists were used: the Conners' teacher rating scale (CTRS), the behavior rating inventory of executive function (BRIEF), and the working memory rating scale. The Conners' continuous performance test (CPT) was also included to determine whether there is a correspondence between performance on this widely used cognitive measure of attention deficits and teacher ratings of classroom behavior. All three behavior scales, but not the CPT, were able to successfully discriminate children with ADHD and those with working memory deficits from typically-developing children. Both the CTRS and the BRIEF discriminated a significant proportion of the children with ADHD from those with working memory deficits, indicating that while both groups exhibit behavioral problems in the classroom, they are characterized by differential attention profiles. The children with ADHD were identified on the basis of oppositional and hyperactive behavior, while those with working memory deficits were more inattentive.

Keywords (separated by '-') ADHD - Attention - Working memory - Continuous performance test - Behavior rating scales

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2 **The Diagnostic Utility of Behavioral Checklists**
3 **in Identifying Children with ADHD and Children**
4 **with Working Memory Deficits**

5 **Tracy Packiam Alloway · Susan E. Gathercole · Joni Holmes ·**
6 **Maurice Place · Julian G. Elliott · Kerry Hilton**

7
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9 **Abstract** The present study investigated whether children with ADHD and those with
10 working memory impairments have a common behavioral profile in the classroom. Three
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12 inventory of executive function (BRIEF), and the working memory rating scale. The
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14 is a correspondence between performance on this widely used cognitive measure of
15 attention deficits and teacher ratings of classroom behavior. All three behavior scales, but
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18 BRIEF discriminated a significant proportion of the children with ADHD from those with
19 working memory deficits, indicating that while both groups exhibit behavioral problems in
20 the classroom, they are characterized by differential attention profiles. The children with
21 ADHD were identified on the basis of oppositional and hyperactive behavior, while those
22 with working memory deficits were more inattentive.

23 **Keywords** ADHD · Attention · Working memory · Continuous performance test ·
24 Behavior rating scales
25

26 **Introduction**

27 The core features leading to a diagnosis of attention-deficit/hyperactivity disorder (ADHD)
28 are significant levels of over-activity, inattention, and impulsiveness [1]. Children with

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29 ADHD are usually seen as having great difficulty remaining seated when required to, and
30 being much more active than their peers. They also find it hard to remember complex
31 instructions, show poor attention to instructions, and find it hard not to interrupt with their
32 comments. These symptoms can vary depending on the situation, which makes the diag-
33 nosis quite challenging at times, but the use of formal rating scales does give some
34 objectivity to the assessment [2]. The ADHD assessment considers biological, psycho-
35 logical, and social factors, because children with ADHD usually show significant social,
36 academic, and psychological difficulties at each stage of their development [3].

37 The worldwide prevalence of ADHD is estimated to be 5% [4], though in the UK
38 research suggests a lower rate of 1–3% [5, 6]. In clinics, far more boys present with the
39 disorder than girls, possibly because girls have lower ratings of externalizing problems
40 than boys [7]. Within community samples, the gender ratio is approximately 3:1 [8]. The
41 presence of ADHD increases the risk of the child having oppositional defiance and conduct
42 disorder considerably [9], and it has a strong tendency to persist into adulthood [10]. There
43 is also a considerable increase in the risk of substance misuse [11], as well as other
44 psychiatric disorders such as anxiety and depression [9].

45 According to Barkley [12], behavioral inhibition is a central impairment in those with
46 ADHD (though see the motivational deficits theory [13]). A key feature of Barkley's model
47 is that inhibition serves as a trigger for secondary effects in various executive functions,
48 including working memory [14, 15]. Working memory is a system of interacting cognitive
49 components that support the storage and mental manipulation of information over brief
50 periods of time [16]. Although working memory shares a neuroanatomical association with
51 the frontal lobes, current evidence suggests that in cognitive terms at least, it is distinct
52 from other executive functions such as inhibition [17]. Individuals with ADHD exhibit
53 substantial working memory deficits, particularly in visuo-spatial tasks [18, 19]. In con-
54 trast, performance in short-term memory tasks, such as forward recall of digits, words, and
55 spatial locations, tends to be within age-expected levels [20].

56 The aim of the present study was to investigate whether behavioral inhibition in those
57 with ADHD would serve as a trigger for working memory problems [21], as evidenced by
58 classroom behavior profiles. This research question has diagnostic utility for educators,
59 who are increasingly involved in the initial detection of children with attention problems.
60 Behavioral rating scales are common instruments used in evaluating attention and exec-
61 utive function problems [22], and teacher questionnaires such as the Conners' teacher
62 rating scale (CTRS) [23] and the behavior rating inventory of executive function (BRIEF)
63 [24] measure a constellation of behaviors typical of this profile [25]. In addition to these
64 scales, we also included the working memory rating scale (WMRS) [26], a validated
65 teacher checklist to identify behaviors associated with working memory impairments, in
66 the present study. The use of different teacher ratings allowed us to examine the rela-
67 tionship between behaviors pertaining to attention and working memory in children with
68 ADHD.

69 One concern about the use of teacher checklists is the degree to which such evaluations
70 are open to a negative halo effect where some behaviors have greater impact upon teacher
71 evaluations than others. For example, disruptive behaviors such as defiance towards a
72 teacher are more likely to result in the child being rated as both hyperactive and inattentive,
73 despite there being an absence of attention problems on their part [27, 28]. In order to
74 provide external validity for the teacher ratings, performance on a direct measure of
75 sustained attention, the Conners' continuous performance test (CPT) [29] was also
76 included in the study. This test, which involves the child monitoring the appearance of an
77 occasional target among more frequent non-target events over a lengthy period of time is



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78 the performance measure that is widely used as part of the clinical assessment for ADHD,
79 with affected children showing elevated levels of incorrect detection of non-target events
80 [30].

81 Of additional interest was whether children with ADHD would have distinguishable
82 classroom behavior profiles those selected specifically on the basis of working memory
83 deficits but not attention problems. The limited capacity of working memory varies widely
84 between individuals, and is closely associated with learning abilities during childhood [31].
85 Recent evidence suggests that children with working memory deficits represent a distinct
86 group from those with ADHD. First, those working memory difficulties have a pervasive
87 deficit that impacts both verbal and visuo-spatial working memory, rather than a selective
88 impairment of either verbal or visuo-spatial difficulties. This pervasive deficit is associated
89 with low learning outcomes [32] and without appropriate intervention, these students lag
90 behind their peers [33].

91 Second, their behavioral profile is distinct from those with a clinical diagnosis of ADHD
92 [32, 34]. Relatively few of the children were judged to exhibit the high levels of hyper-
93 active and impulsive behaviors that are found in the majority of children with a clinical
94 diagnosis of ADHD. Instead, teachers rated these children as highly inattentive, with poor
95 attention spans and high levels of distractibility. They were also commonly described as
96 forgetting what they are currently doing and things they had learned, as well as failing to
97 remember instructions and complete tasks.

98 We tested the following hypotheses in the present study. If behavioral inhibition in
99 children with ADHD impacts working memory functioning beyond a cognitive level, then
100 we would expect them to also exhibit behaviors associated with working memory problems.
101 For the children with low working memory, their behavior profile should be motivated by
102 working memory deficits rather than inhibition difficulties. As a result, they would have a
103 distinct classroom behavior profile from those with ADHD. The present study also allowed
104 us to investigate which teacher rating scales are better at discriminating those with attention
105 and memory problems from typically-developing children, as well as the correspondence
106 between performance on teacher ratings of classroom behavior and the CPT.

107 **Methods**

108 **Participants**

109 The participating schools represent a range of demographics, indexed by the national
110 average of eligibility for free school meals, a poverty (income) index used in the UK. Three
111 groups of children participated in the study. The ADHD group comprised 46 children (40
112 boys; mean age = 9.75 years, SD = 12 months) with a combination of hyperactive-
113 impulsive and inattentive behavior (ADHD-combined). Diagnosis of ADHD subtype was
114 confirmed by a comprehensive clinical diagnostic assessment by pediatric psychiatrists and
115 community pediatricians based in the UK. The assessments were based on scores in the
116 deficit range on the continuous performance test [29] and clinical assessments during
117 interview sessions using the DSM-IV criteria [1] and the CHEDOC. The study only
118 included children who score in the normal range on the Developmental, Diagnostic and
119 Dimensional Interview (3di), a computerized assessment for autistic spectrum disorders
120 [35]. All children were receiving stimulants for ADHD (e.g., methylphenidate).

121 A healthy comparison group and a group of children with low working memory were
122 selected from a sample of ~1,000 children, aged 8–11 years, who were screened on two



123 tests of verbal working memory (listening recall and backwards digit recall subtests of the
124 AWMA [36]. These children were screened as part of a larger study reported in Holmes
125 et al. [18]. Children with standard scores below 86 on both tests (bottom 15th centile) were
126 assigned to the low working memory group, and those with standard scores in the normal
127 range (>90 on both tests) formed a comparison group. Children in both the comparison and
128 low working memory groups were age-matched to within 60 days (± 30 days) of children
129 in the ADHD group. The working memory-impaired (WM-I) group consisted of 25 chil-
130 dren (15 boys; mean age = 9.91 years, SD = 11 months) identified via screening as
131 having standard scores below 86 on both the listening recall and backwards digit recall
132 tests from the automated working memory assessment [36]. The typically developing (TD)
133 children ($n = 20$) consisted of 11 boys (mean age = 9.91 years, SD = 11 months). While
134 there were a greater number of boys than girls in the ADHD group, reflecting the higher
135 rate of diagnosis among boys, this gender bias was not evident in the comparison or low
136 working memory groups.

137 Materials

138 *Continuous Performance Test*

139 The *K* test of the continuous performance test (CPT) [29] was administered to assess the
140 children's performance on a vigilance task. In this version of the CPT, a series of letters
141 appears on the computer screen. The child is required to press the space bar in response to
142 the letter *K*, but must not respond when any other letter appears. In total, 480 stimuli are
143 presented for 250 ms, with an inter-stimulus interval of 1 s. The target stimuli appear on
144 140 of the trials at random intervals. The number of omissions and commissions as counts
145 are reported here.

146 *Teacher Rating Scales*

147 Teachers completed three rating scales for all participating children. The Conners' teacher
148 rating scale-revised, short form (CRS-R) [23] is designed to identify attentional failures
149 and ADHD on the basis of classroom behaviors. In this test, teachers are asked to rate the
150 extent to which the child has had problem behaviors in school over the past month that are
151 described in 28 brief statements on the form. The response choices for each described
152 behavior are: not true at all, just a little true, pretty much true, and very much true.
153 Responses are scored as sums of values on four subscales—oppositional (e.g., spiteful or
154 vindictive), cognitive problems/inattention (e.g., forgets things s/he has already learned),
155 hyperactivity (e.g., is always "on the go" or acts as if driven by a motor), and ADHD index
156 (e.g., restless, always up and on the go). The ADHD Index is based on the best set of items
157 for identifying children at risk of a diagnosis of ADHD. *T*-scores (with a population mean
158 of 50 and SD of 10) are calculated for each of the four subscales. Test-retest reliability
159 coefficients for subscale scores reported for a sample of 50 children with a mean age of
160 11 years were as follows: oppositional (.62), cognitive problems/inattention (.73), hyper-
161 activity (.85), and ADHD Index (.72).

162 The behavior rating inventory of executive function (BRIEF) [24] assesses problem
163 behaviors associated with executive function in school. The form consists of 86 brief
164 descriptions of behavior problems, the frequency of which teachers are asked to rate as
165 occurring either never, sometimes, or often. Responses are aggregated to form eight
166 subscales. The inhibit scale measures the ability to control impulses, and to stop own



167 behavior at the proper time. The shift scale assesses the ability to move freely from one
168 situation, activity, or aspect of a problem to another as the situation demands; it also taps
169 behaviors relating to transition, and to the ability to solve problems in a flexible manner.
170 The emotional control scale relates to the ability to modulate emotional responses
171 appropriately. The initiate scale measures the ability to begin a task or activity, and to
172 generate ideas independently. The working memory scale assesses the ability to hold
173 information in mind for the purpose of completing an activity. The plan/organize scale
174 assesses abilities to anticipate future events, set goals, develop appropriate steps ahead of
175 time, carry out tasks in a systematic manner, and to understand and communicate main
176 idea. The organization of materials scale relates to abilities to maintain relevant parts of the
177 environment in an orderly manner. The monitor scale relates to abilities to check work,
178 assess performance, and to keep track of own and others' efforts. Examples of test items
179 from each subscale are shown in the Appendix. *T*-scores are calculated for each measure.
180 Test-retest correlations for individual subscale score reported for a sample of 41 children
181 were: inhibit (.91), shift (.83), emotional control (.92), initiate (.87), working memory
182 (.87), plan/organize (.88), organization of materials (.83), and monitor (.87).

183 The Working Memory Rating Scale (WMRS) [26] consists of 20 descriptions of
184 behaviors characteristic of children with working memory deficits. Examples include: 'The
185 child raised his hand but when called upon, he had forgotten his response'; 'She lost her
186 place in a task with multiple steps'; and 'The child had difficulty remaining on task'.
187 Teachers rate how typical each behavior was of a particular child, using a four-point scale
188 ranging from (0) *not typical at all* to (1) *occasionally* to (2) *fairly typical* to (3) *very*
189 *typical*. Cronbach's alpha across the normative sample was .978, establishing internal
190 reliability of the scale [37].

191 Procedure

192 All were tested on a one-to-one basis as part of the main study and no child/parent declined
193 participation. All children with ADHD were taken off their medication 24 h prior to testing
194 and the CPT was administered as part of a larger cognitive test battery [18].

195 Results

196 Group Profiles

197 For all three behavior scales, *T*-scores, with a population mean of 50 and SD of 10, were
198 calculated (Table 1). As a guide, scores of 55 or below do not represent a cause for
199 concern, while scores above 60 can be viewed in terms of increasing risk of impairment
200 (see Conners, 2001). On the CTRS, mean scores in the ADHD group were elevated for the
201 all four subscales. In contrast, only the score in the cognitive problems/inattention score
202 ($M = 64$) was high for the WM-impaired group. On the BRIEF, mean scores on all
203 subscales were more than 1 SD above the mean (>60) for the ADHD group. The WM-
204 impaired group scored within age-expected levels for most of the subscales; exceptions
205 include the working memory, initiate, and monitor subscales ($M_s = 64, 61, \text{ and } 63,$
206 respectively). In the WMRS, the mean scores for the ADHD and WM-impaired groups
207 were above expected levels ($M_s = 60 \text{ and } 58, \text{ respectively}$). The TD group scored within
208 the expected range on all measures.



Table 1 Descriptive statistics for CPT and behavior measures as a function of group

Measures	Groups										Pairwise comparisons									
	ADHD					WM-impaired					TD		Group comparison		ADHD and TD		WM-I and TD		ADHD and WM-I	
	n	M	SD	n	M	SD	n	M	SD	n	M	SD	p	η_p^2	p	d	p	d	p	d
CPT: omissions	46	36.39	28.33	25	30.68	25.11	20	36.45	24.19	6.66	0.01	0.99	0.00	0.77	0.23	0.69	0.21			
CPT: commissions	46	87.96	78.40	25	78.88	75.71	20	77.35	76.72	0.83	0.01	0.88	0.14	0.98	0.02	0.90	0.12			
CTRS																				
Oppositional	46	64.63	14.73	25	56.48	13.17	20	49.95	9.75	0.00	0.17	0.00	1.18	0.32	0.56	0.05	0.58			
Cognitive problems/inattention	46	61.39	11.66	25	63.96	11.47	20	45.40	4.59	0.00	0.32	0.00	1.80	0.00	2.13	0.98	0.22			
Hyperactivity	46	61.98	12.13	25	54.12	12.26	20	45.90	4.00	0.00	0.26	0.00	1.78	0.04	0.90	0.02	0.65			
ADHD index	46	63.07	14.50	25	57.84	13.73	20	46.40	6.60	0.00	0.21	0.00	1.48	0.01	1.06	0.33	0.37			
BRIEF																				
Inhibit	46	70.26	16.05	25	58.88	18.07	20	46.58	6.24	0.00	0.29	0.00	1.36	0.02	0.81	0.00	0.65			
Shift	46	65.43	15.95	25	55.44	13.63	20	49.26	6.33	0.00	0.20	0.00	1.04	0.32	0.55	0.01	0.64			
Emotional control	46	70.48	19.72	25	59.00	19.74	20	50.16	9.35	0.00	0.18	0.00	1.05	0.22	0.54	0.03	0.57			
Behavior regulation index	46	71.77	16.83	25	58.56	18.16	20	48.35	7.20	0.00	0.27	0.00	1.81	0.10	0.74	0.01	0.76			
Working memory	46	68.00	15.34	25	63.52	17.15	20	48.47	7.40	0.00	0.22	0.00	1.24	0.00	0.98	0.43	0.29			
Plan/organize	46	66.50	12.47	25	57.92	12.91	20	47.11	7.97	0.00	0.29	0.00	1.39	0.02	0.90	0.01	0.66			
Initiate	46	65.28	11.89	25	61.16	15.99	20	46.63	7.75	0.00	0.26	0.00	1.39	0.00	1.00	0.38	0.31			
Organization of materials	46	61.59	13.31	25	56.64	16.85	20	47.79	6.68	0.00	0.15	0.00	1.04	0.07	0.64	0.30	0.34			
Monitor	46	69.83	12.13	25	62.88	19.42	20	47.00	8.80	0.00	0.29	0.00	1.49	0.00	0.93	0.12	0.45			
Metacognition index	46	68.09	13.21	25	60.92	16.18	20	47.55	7.96	0.00	0.29	0.00	1.88	0.00	1.05	0.08	0.49			
Global executive index	46	70.70	14.78	25	62.04	18.90	20	49.85	12.89	0.00	0.22	0.00	1.50	0.04	0.75	0.09	0.51			
WMRS	31	60.13	9.36	17	57.71	11.97	10	44.40	4.17	0.00	0.22	0.00	2.17	0.00	1.49	0.66	0.23			

Note: Behavior measures are represented as *T*-scores are shown in the table (*M* = 50, *SD* = 10); not all WMRS forms were returned



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209 A series of MANOVAs were performed on the *T*-scores for the subscales of the CTRS
 210 and the BRIEF. The probability value associated with Hotelling's *t*-test and Cohen's *d*
 211 effect size values are reported in Table 1. On the CTRS, the ADHD group had significantly
 212 higher scores (i.e., worse performance) in all subscales compared with the TD group, and
 213 in the oppositional and hyperactivity subscales compared to the WM-impaired group. The
 214 WM-impaired group also had significantly higher scores in all subscales compared to the
 215 TD group. In the BRIEF, the ADHD group was rated more highly in all subscales com-
 216 pared to the TD group, and in the inhibit, shift, emotional control, and plan/organize
 217 subscales compared to the WM-impaired group. The ratings for the WM-impaired group
 218 differed significantly from the TD group in all subscales, except for the shift and emotional
 219 control subscales. In the WMRS, both the ADHD and WM-impaired groups were rated
 220 significantly higher than the TD group. A MANOVA was also performed on the omission
 221 or commission errors in the CPT and the probability value associated with Hotelling's *t*-
 222 test and Cohen's *d* effect size values are reported in Table 1.

223 In order to compare the severity of behavioral profiles across the groups, *T*-scores were
 224 banded according to categories as identified by the BRIEF to allow for direct comparison
 225 between the behavioral measures (Table 2). As there is no discrete point at which typical
 226 and atypical performance can be unequivocally distinguished, cumulative proportions over
 227 a range of values that represent different degrees of severity of low performance are

Table 2 Cumulative proportions of children obtaining *T*-scores for the behavioral measures in each band as a function of age group and subscale

Measure	ADHD				WM-impaired				Control						
	<i>n</i>	<46	<56	<66	>65	<i>n</i>	<46	<56	<66	>65	<i>n</i>	<46	<56	<66	>65
CTRS															
Oppositional	46	.17	.35	.48	.52	25	.28	.60	.76	.24	20	.45	.85	.90	.10
Cognitive problems/ inattention	46	.13	.33	.59	.41	25	.08	.20	.52	.48	20	.65	.95	1.0	0
Hyperactive	46	.09	.33	.67	.33	25	.20	.72	.80	.20	20	.60	.90	1.0	0
ADHD index	46	.11	.30	.57	.43	25	.12	.56	.76	.24	20	.65	.95	.95	.05
BRIEF															
Inhibit	46	.04	.16	.33	.67	25	.28	.64	.68	.32	20	.67	.86	.95	.05
Shift	46	.08	.33	.56	.44	25	.28	.68	.80	.20	20	.38	.86	.95	.05
Emotional control	46	.08	.27	.41	.59	25	.28	.68	.80	.36	20	.38	.81	.86	.14
Behavior regulation index	46	.06	.19	.38	.62	25	.20	.64	.72	.58	20	.55	.85	.95	.05
Initiate	46	.04	.22	.47	.53	25	.16	.44	.60	.72	20	.62	.91	.95	.05
Working memory	46	.08	.22	.38	.62	25	.16	.40	.56	.79	20	.48	.81	1.0	0
Plan/organize	46	.06	.20	.43	.57	25	.12	.64	.76	.24	20	.67	.86	.95	.05
Organization of materials	46	.09	.40	.57	.43	25	.20	.60	.76	.24	20	.50	.85	1.0	0
Monitor	46	0	.14	.33	.67	25	.08	.56	.64	.36	20	.48	.81	.95	.05
Metacognition index	46	.04	.21	.43	.57	25	.12	.52	.68	.32	20	.60	.85	.95	.05
Global executive composite	46	.04	.15	.39	.61	25	.08	.15	.39	.61	20	.55	.85	.90	.10
Working memory rating scale	30	.13	.29	.74	.26	17	.24	.53	.71	.29	10	.60	1.0	0	0



228 presented. For scores that are moderately atypical (>65), more than half the ADHD group
229 achieved this level in the oppositional subscale of the CTRS; and all subscales of the
230 BRIEF (except for the shift and organization of materials subscales).

231 In contrast, almost half of the WM-impaired group (48%) obtained high ratings on the
232 cognitive problems/inattention subscale, which included the following behaviors: greater
233 academic difficulties compared to their peers, difficulty organising and completing tasks,
234 and trouble concentrating on activities that require mental effort. Fewer children (20%)
235 showed signs of restlessness and fidgetiness that are characteristic of hyperactive behavior.
236 There was a similar pattern for the BRIEF subscales: over 50% of the WM-impaired group
237 had *T*-scores greater than 65 in the behavior regulation index, and the initiate and working
238 memory subscales. The latter two are related to the child's ability to plan and effectively
239 manage information in working memory. This finding indicates that children with working
240 memory deficits struggled with classroom activities that relate to working memory such as
241 organizing large amounts of information and monitoring work to avoid errors. However,
242 they did not exhibit the difficulties in controlling behavior or emotion that characterized
243 the children with ADHD.

244 Correlations

245 Correlations coefficients among the CPT scores and behavior measures for the ADHD
246 group are displayed in the lower triangle in Table 3; and those for the WM-impaired group
247 are shown in the upper triangle. For the ADHD group, only the CPT omission rates were
248 significantly associated with some of the BRIEF subscales (initiate, working memory, plan/
249 organize, monitor, metacognition index, and global executive composite) and the WMRS
250 (*r*s ranged from .35 to .43). CPT scores were not significantly linked with the behavior
251 regulation index subscales or the CTRS. The intercorrelations between the CTRS and
252 the BRIEF subscales were moderate to high, with *r*s ranging from .38 to .74; with the
253 exception of the cognitive problems/inattention subscale and the shift subscale from the
254 BRIEF. The CTRS and the BRIEF subscales related to attention and working memory
255 skills (working memory, plan/organize, and monitor subscales) were significantly related
256 to the WMRS ratings, with *r*s ranging from .42 to .81.

257 For the WM-impaired group, the correlations between the CPT scores and behavioral
258 measures indicate that only the commissions error rates were significantly associated with
259 the shift subscale from the BRIEF ($r = .47$). The CTRS subscales were significantly
260 associated with all the BRIEF subscales, with the exception of the oppositional subscale
261 and the Shift and Initiate BRIEF subscales (*r*s ranged from .72 to .94). Both the CTRS and
262 the BRIEF were significantly linked to the WMRS, with the exception of the Oppositional
263 subscale (*r*s ranged from .63 to .92). The moderate to high coefficients suggest good
264 concurrent validity between the different teacher checklists purportedly measuring atten-
265 tion and working memory in the classroom.

266 Group Membership

267 In order to determine which behavior ratings uniquely differentiated the groups, dis-
268 criminant function analyses were conducted for CPT scores and indices from each
269 behavior measure (Table 4). Looking first at data for the ADHD and WM-impaired groups
270 compared with the TD group, CPT omission and commission scores were not an effective
271 discriminator of either ADHD or working memory impairment. In contrast, all three
272 behavior scales were able to successfully discriminate the ADHD and WM-impaired



Table 3 Correlations between the CPT and behavior measures for the ADHD-combined group in lower triangle; and for the WM-impaired group in upper triangle

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CPT: omissions	–	–.01	–.20	–.02	–.26	–.26	–.24	–.10	–.26	–.23	–.24	–.21	–.01	–.24	–.25	–.19	–.24	.01
CPT: commissions	.01	–	–.04	.16	.19	.26	.10	.47	.07	.20	.29	.20	.16	.20	.23	.12	.33	.41
CTRS: oppositional	–.09	.07	–	.23	.59	.49	.61	.39	.70	.63	.36	.48	.63	.53	.52	.55	.53	.11
CTRS: cognitive problems/inattention	–.07	–.11	.45	–	.57	.64	.60	.49	.34	.52	.85	.74	.68	.62	.73	.76	.73	.83
CTRS: hyperactivity	–.09	.21	.70	.52	–	.91	.93	.79	.84	.92	.77	.86	.85	.88	.90	.90	.96	.73
CTRS: ADHD index	–.08	.19	.56	.50	.76	–	.87	.75	.71	.84	.79	.85	.83	.78	.86	.85	.94	.81
BRIEF-inhibit	–.14	.14	.69	.47	.71	.63	–	.80	.87	.97	.73	.88	.86	.90	.84	.90	.92	.70
BRIEF-shift	–.26	.12	.58	.26	.38	.43	.57	–	.74	.89	.60	.73	.83	.73	.66	.69	.83	.63
BRIEF-emotional control	–.05	.11	.72	.37	.58	.52	.79	.80	–	.94	.52	.69	.77	.71	.67	.72	.75	.43
BRIEF-behavioral regulation index	–.20	.14	.74	.38	.63	.63	.56	.87	.86	.95	–	.67	.83	.88	.84	.79	.83	.90
BRIEF-initiate	–.39	–.22	.55	.65	.46	.47	.63	.57	.55	.65	–	.88	.72	.77	.85	.88	.87	.90
BRIEF-working memory	–.38	–.08	.52	.67	.63	.63	.75	.53	.58	.69	.85	–	.81	.89	.90	.97	.91	.93
BRIEF-plan/organize	–.43	–.12	.55	.55	.59	.51	.65	.61	.59	.68	.85	.82	–	.79	.76	.84	.87	.76
BRIEF-organization of materials	–.25	–.09	.50	.60	.62	.59	.67	.44	.57	.61	.66	.77	.71	–	.84	.92	.89	.75
BRIEF-monitor	–.38	.04	.58	.58	.62	.54	.80	.56	.70	.75	.69	.82	.75	.76	–	.94	.91	.79
BRIEF-metacognition index	–.41	–.12	.58	.66	.63	.58	.78	.60	.66	.75	.89	.94	.92	.85	.89	–	.92	.92
BRIEF-global executive composite	–.35	0	.70	.60	.69	.62	.88	.75	.82	.90	.85	.89	.87	.77	.89	.95	–	.82
Working memory rating scale	–.36	–.11	.53	.74	.61	.42	.64	.32	.51	.56	.81	.74	.77	.47	.75	.76	.72	–

Note: For the ADHD group, coefficients between .35 and .37 are significant at the .05 level and >.37 are significant at the .01 level; for the WM-impaired group, coefficients between .48 and .51 are significant at the .05 level and >.51 are significant at the .01 level

Table 4 Classification by discriminant function analysis for CPT and behavior measures

Variable entered	Correctly classified as			Correctly classified as			Correctly classified as		
	WL (df)	ADHD	TD group	WL (df)	WM-I	TD group	WL (df)	ADHD	WM-I
CPT	.99 (2)	19 (41%)	13 (65%)	.99 (2)	17 (68%)	8 (40%)	.99 (2)	23 (50%)	16 (64%)
CTRS ADHD index ^a	.73 (1)*	33 (72%)	19 (95%)	.79 (1)*	12 (48%)	17 (85%)	.90 (2)*	29 (63%)	20 (80%)
BRIEF: all 3 indices ^b	.57 (3)*	36 (78%)	18 (90%)	.78 (3)*	13 (52%)	16 (84%)	.87 (2)*	31 (67%)	19 (76%)
WMRS	.55 (1)*	22 (82%)	10 (100%)	.69 (1)*	11 (65%)	9 (90%)	.98 (1)	17 (63%)	9 (53%)

Note: WL = Wilks Lambda; * $p < .03$

For comparisons between the ADHD and WM-I groups

^a Oppositional and hyperactive subscales only

^b Behavior regulation index and plan/organize subscale only



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273 groups from the TD group. The CTRS ADHD index was sufficient to correctly assign
274 group membership for 72% of the ADHD and 48% of the WM-impaired groups. This
275 figure rose to 78% for the ADHD group for the BRIEF indices, and to 82 and 65% ADHD
276 and WM-impaired groups, respectively for the WMRS. This outcome establishes that all
277 behavior measures could successfully discriminate these groups from TD group, with the
278 WMRS correctly classifying identifying the greatest proportion.

279 In order to evaluate the extent to which the behavior measures may differentiate the
280 ADHD group from the WM-impaired group, only the oppositional and hyperactive sub-
281 scales from the CTRS and the behavior regulation index and plan/organize subscale from
282 the BRIEF were included as the groups differed significantly on these scores. Both the
283 CTRS and the BRIEF identified a significant proportion of the children correctly: 63 and
284 67%, respectively for the ADHD group; and 80 and 76%, respectively for the WM-
285 impaired group. However, the WMRS did not discriminate significantly between these
286 groups, which suggest that both groups displayed behaviors associated with working
287 memory because both groups have working memory problems.

288 Discussion

289 The aim of the present study was to investigate whether behavioral inhibition in those with
290 ADHD would serve as a trigger for working memory problems, as evidenced by classroom
291 behavior profiles. Teacher ratings in the present study had good diagnostic validity, with
292 high levels of classification accuracy of the three groups. While all three behavior scales
293 were able to successfully discriminate the ADHD and WM-impaired groups from the TD
294 group, the WMRS identified the greatest proportion in each group, although it was not able
295 to discriminate between children in the ADHD and WM-impaired groups. This suggests
296 that both these atypical groups display common classroom behaviors associated with
297 working memory difficulties. Both the CTRS and the BRIEF discriminated a significant
298 proportion of the ADHD from the WM-impaired group, indicating that while both groups
299 exhibit behavioral problems in the classroom, they are characterized by differential
300 attention profiles. The children with ADHD were rated more highly in oppositional and
301 hyperactive behaviors (CTRS), as well as with inhibiting, shifting and controlling emotions
302 (BRIEF), while the WM-impaired children were best characterized by behaviors related to
303 working memory difficulties, including planning and organizing information.

304 The nature of the relationship between the CTRS, BRIEF, and WMRS teacher ratings is
305 also of interest in the present study. While the close association between these three
306 checklists provides support for the concurrent validity of these measures, the pattern of
307 correlations suggests that they each measure distinct behavioral components. For example,
308 the CTRS assesses oppositional and hyperactive behaviors not included in the other two
309 rating scales, while the BRIEF evaluates shifting, planning, and organizing skills. Given
310 that the ADHD-combined subtype encompasses heterogeneous behavioral manifestations,
311 it seems useful to administer more than one teacher checklist in order to detect attention
312 problems in the classroom.

313 On the CPT test, the children with ADHD made significantly more errors of commission
314 than either the control children or the WM-impaired group. However, CPT scores were not
315 significantly associated with the CTRS ratings, nor were they able to successfully dis-
316 criminate the ADHD and WM-impaired groups from the TD group. It is not uncommon for
317 children to score in the clinical range on some teacher checklists, yet perform successfully
318 on the CPT [25]. Despite the positive predictive power of the CPT to measure sustained



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319 attention, low correlations between these scores and behavior ratings by teachers have been
320 reported before [38]. While omission scores are linked to attention in the classroom,
321 between 30–50% of clinically-diagnosed children with ADHD are not detected by CPT
322 performance [39]. The CPT also appears to lack diagnostic specificity to ADHD relative to
323 other clinical conditions [40]. One possible explanation is that the CPT measures vigilance,
324 rather than attention per se. There are other confounding factors as the CPT requires rapid
325 identification of letters and is highly associated with phonological awareness, identifying
326 those with reading disorders that may not have a clinical diagnosis of ADHD [41]. The
327 present findings suggest that while the CPT can be informative, it may be best to include
328 other complementary assessments of attention.

329 There are limitations to this study that should be addressed in future research. The study
330 would benefit by larger-scale research recruiting the inattentive subtype. This is of particular
331 value in the UK as the inattentive subtype is seldom represented in clinical services. These
332 children do not exhibit troublesome behaviors in the classroom so are not referred through
333 the usual route. One possibility is that children with working memory deficits are in fact those
334 with the inattentive subtype as their behavioral characteristics appear to be very similar.
335 Further research comparing these two groups would clarify this issue. The sample size was
336 admittedly uneven. While reported effect sizes indicate a modest difference across groups,
337 replication with a larger sample would provide a better test of potential differences in
338 behavioral profiles. The gender bias in the present study is in line with reported higher male
339 to female ratios, usually 4–1 [42]. Previous research on the male-female ratio in clinical
340 referrals of ADHD highlights more boys identified for the hyperactive/impulsive subtype,
341 while more females are categorized as the inattentive subtype [43]. It would be of interest to
342 explore whether teachers detect such gender biases in classroom behavior.

343 The present findings have important implications given the link between attention and
344 working memory. Pupils with ADHD are more likely to achieve lower grades at school
345 than their peers although it is inattentiveness, rather than impulsivity, that is problematic in
346 this respect [44]. This pattern is also evident in those who exhibit ADHD symptoms but
347 have not received a formal diagnosis of the disorder [45]. Working memory problems
348 negatively impact performance in classroom activities such as remembering lengthy
349 instructions, keeping track of their place in multi-level tasks, and coping with the simul-
350 taneous processing and storage demands frequently imposed in structured learning
351 activities [46, 47].

352 Summary

353 Behavioral inhibition in children with ADHD appears to impact working memory func-
354 tioning in the classroom as well. Working memory deficits are implicated in ADHD,
355 although may not be necessary for ADHD nor specific to it. Children with low working
356 memory have a distinct classroom behavior profile from those with ADHD as they do not
357 exhibit behaviors associated with hyperactivity or impulsivity. As both problems with
358 memory and attention are linked with learning, checklists that successfully identify chil-
359 dren with problems in these areas are useful for clinical and educational practitioners.

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