Article

Comparison of Two Measures of Working Memory Impairments in 220 Adolescents and Adults With ADHD

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Abstract

Objective: This study tests the hypotheses that (a) adolescents and adults with ADHD score lower on two normed measures of verbal working memory, relative to their overall verbal abilities, than the general population and (b) a specific story memory test is a more sensitive and relevant measure of working memory impairment than a numerically based test. **Method:** Scores on normed story memory and numerical memory tests of 220 adolescents and adults with ADHD were corrected for the individual's verbal abilities and compared with each other and national norms. **Results:** Participants with ADHD scored significantly below their verbal ability measure on both verbal and numerically based memory tests in comparison with national norms. Scores on verbal memory test were lower than scores for numerically based memory tests. **Conclusion:** This story memory test is a more sensitive measure of working memory impairments in adolescents and adults with ADHD than measures based on recall of numerical data. *(J. of Att. Dis. XXXX; XX(X) XX-XX)*

Keywords
ADHD, WMS-III, WAIS-IV, working memory, logical memory

Introduction

"Often forgetful in daily activities" is one of the nine inattention criterion symptoms of ADHD in *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM-5*; American Psychiatric Association [APA], 2013). Though they may have excellent longer term recall of facts and events, individuals with ADHD often report short-term working memory (WM) deficits in daily activities. They often forget things in the here-and-now: what others have just said to them, where they have put something, what they were about to do, what they have just finished reading, and so on (Brown, 2005, 2013).

WM is widely recognized as a significant aspect of the impairments associated with ADHD. Martinussen, Hayden, Hogg-Johnson, and Tannock (2005) analyzed 26 studies demonstrating that children with ADHD exhibited deficits in multiple aspects of WM. A subsequent meta-analysis by Kasper, Alderson, and Hudec (2012) of 45 studies found that children with ADHD exhibit statistically significant, large magnitude WM deficits relative to their typically developing peers.

Alderson, Kasper, Hudec, and Patros (2013), reported a meta-analysis of 38 studies of WM in adults with ADHD. Findings indicated that WM deficits observed in children with ADHD tend to persist in adults with ADHD. Their results showed moderate magnitude between-group effect sizes in both phonological and visuospatial WM domains.

Among studies of WM included in these meta-analyses, almost all assessed WM with tasks requiring recall and/or manipulation of short or longer arrays of simple numerical or visuospatial data with or without reordering. None assessed recall of more complex orally presented narrative text that would resemble listening tasks in classrooms, meetings, or conversation in conventional social interactions of daily life.

One commonly used measure of WM impairment is the WM Index (WMI) of the Wechsler Adult Intelligence Scale–Fourth Edition (WAIS-IV). That measure combines digit span (forward and backward) with verbally presented mental arithmetic for its WMI. These tasks both based upon recall and manipulation of numerical data have been demonstrated effective in assessing some aspects of WM. In patients with ADHD, the WMI has been shown to be significantly impaired in adults with ADHD (The Psychological Corporation, 1997; Theiling & Petermann, 2014), in children (Fried, Chan, et al.,

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2016) and in children and adults with high IQ diagnosed with ADHD (Brown, Reichel, & Quinlan, 2009, 2011). Yet numerical measures are quite different from many daily tasks where one is expected to recall more lengthy and complex verbal information heard only once.

One of the most common complaints from people with ADHD is their chronic difficulty keeping in mind verbal content—what they have just read or heard. This study tests the hypothesis that a brief, normed story memory test derived from the Wechsler Memory Scale–Third Edition (WMS-III) is a more sensitive measure of WM impairments in adolescents and adults with ADHD than is the WAIS-IV (Wechsler, 2008a) WMI, which is based on recall and manipulation of numerical data. This study also compares the difficulty of ADHD patients in demonstrating WM skills relative to a normative sample of comparable age in the general population.

Quinlan and Brown (2003) reported a study of verbal memory impairment in adults with ADHD. They corrected each individual's score for story memory using that individual's score for verbal ability from the WAIS. They found that adults with ADHD tended to have significant impairments relative to their verbal comprehension ability when asked to recall two brief stories immediately after hearing each one.

This present study compares two measures of WM impairments in a sample of 220 adolescents and adults with ADHD. One is the WMI of the WAIS-IV, a numerical measure which combines recall of spans of digits forward and backward with a measure of mental arithmetic using orally administered problems. We compared the WMI from the WAIS-IV with the Logical Memory subtest (story recall) from the WMS-III, a fully verbal measure of prose narrative.

The aims of this study were to test the hypotheses that (a) adolescents and adults with ADHD score lower on two normed measures of WM relative to the general population and (b) this specific story memory test is a more sensitive and relevant measure of WM impairment than a widely used test of WM based upon numerical data.

Methods

Participants

This study reviewed charts of 610 adolescents and adults aged 16 to 53 years who sought evaluation for possible attention problems in a specialty clinic for ADHD and related disorders which specializes in high IQ patients. Most paid private practice fees with or without insurance; those with limited finances were seen for reduced fees or pro bono.

Assessment Measures

Each patient received a comprehensive clinical evaluation from an experienced clinical psychologist. That evaluation included a comprehensive, semi-structured clinical interview with patient and a collateral using the Brown ADD Diagnostic Form (Brown, 1996), the normed Brown ADD rating scale, the story memory subtest of the WMS-III, review of ADHD symptoms stipulated in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; APA, 1994) diagnostic criteria, and screening for possible comorbid disorders. No participant was on any medication for ADHD at the time of the evaluation, and none was suffering from any speech or language disorder. Data from the chart of each patient who fully met *DSM-IV* diagnostic criteria for ADHD and also received a full WAIS-IV administered without any medication were included in this study. A total of 220 participants met criteria; all were included. All data of this study were derived from the charts of these patients.

We used the WMI of the WAIS-IV as the measure to assess WM for numerical data. This was obtained using the standard protocol for administration and scoring of the WAIS-IV.

We had assessed auditory verbal memory during initial evaluation of each patient using the two brief stories in the Logical Memory subtest (story memory) of the WMS-III, each read aloud to the participant only once. Immediately after each story was read aloud by the examiner, the patient was asked to retell it to the examiner, as close to verbatim as possible. Responses were scored using the published protocol for that test. The standardized score obtained from the WMS-III norms was then converted to an IQ-like score (M = 100; 1 SD = 15) which we identified as Story Recall Index (SRI).

Verbal abilities are correlated with both auditory verbal memory and WM for numerical data. The WAIS Verbal Comprehension Index (VCI) is correlated .57 with WMS-III auditory verbal recall (Hawkins & Tulsky, 2003) and is correlated .64 with the numerically based WMI of the WAIS-IV (Wechsler, 2008b). To correct for the possible effect of verbal comprehension abilities on the measures assessed, we subtracted each participant's scores for WMI and SRI from that individual's VCI on the WAIS-IV.

To compare possible differences in memory measures between participants with higher versus lower verbal comprehension abilities, we created three ability groups based on the VCI scores. The chart of each participant was placed in one of three groups according to the individual's VCI: average (90-109), high average (110-119), or superior (120+). These groups were created to assess whether level of verbal comprehension competence significantly affected performance on these measures of WM.

To compare group differences in performance on the memory tests, we first calculated the means for the WMI and SRI for each VCI group. We then corrected each group's WMI mean with that group's mean VCI score. Next, we repeated the same procedure with each group's SRI mean and VCI mean. Differences between the means for each of these pairs of measures were compared to determine which of the two measures of WM was more challenging for the

Table 1. Means for Working Memory Index.

	Average (52)[a]	High average (44)	Superior (124)
Group means for VCI–WMI			
VCI	102.4 (5.01)[b]	114.32 (2.86)	133.28 (9.25)
WMI	91.92 (11.30)	94 (8.7)	100.93 (13.74)
	Average	High average	Superior
Paired sample tests			
VCI–WMI	10.48 (11.10)	20.31 (9.34)	32.35 (14.07)
t-test	*df* = 51; *t* = 6.81	*df* = 43; *t* = 14.43	*df* = 123; *t* = 25.61
p	<.001	<.001	<.001

Note. VCI = Verbal Comprehension Index; WMI = Working Memory Index; *df* = degree of freedom.
[a]VCI (*n*).
[b]*M* (*SD*).

Table 2. Means for Story Memory Index.

	Average (52)[a]	High average (44)	Superior (124)
Group means for VCI–SRI			
VCI	102.4 (5.01)[b]	114.32 (2.86)	133.28 (9.25)
SRI	82.60 (12.35)	87.84 (10.96)	92.62 (15.25)
	Average	High average	Superior
Paired sample tests			
VCI–SRI	19.8 (12.91)	26.48 (10.91)	40.66 (15.70)
t-test	*df* = 51; *t* = 11.06	*df* = 43; *t* = 16.09	*df* = 123; *t* = 28.84
p	<.001	<.001	<.001

Note. VCI = Verbal Comprehension Index; SRI = Story Recall Index; *df* = degree of freedom.
[a]VCI (*n*).
[b]*M* (*SD*).

participants in each group. Paired *t* tests were used to test significance of the findings.

To test our hypothesis that those with ADHD have significantly more difficulty with both of these measures of WM than others in the general population and comparable IQ, we compared scores of each of our three ADHD ability groups with the national normative sample for the WAIS-IV and WMS-III (L. G. Weiss, personal communication, July 10, 2015). The *n* for each of the VCI ability subgroups in the normative sample was as follows: VCI average: *n* = 576; VCI high average: *n* = 221; and VCI superior: *n* = 132.

Statistical Analysis

The tests of differences of the proportions of ADHD sample with the those of the normative sample for the WAIS-IV and WMS-III were conducted with chi-square analysis, with the observed values drawn from the ADHD sample and the expected values calculated as the proportion of the normative sample with differences between the VCI and the Logical Memory I and II subtest scores converted to the common scale (*M* = 100, *SD* = 15). The chi-square calculations rounded the expected values, the frequencies of the differences of ≥ 1 *SD* (15) and ≥ 2 *SD* (30) rounded to the nearest integer values. The chi-square values were calculated using Yate's correction for continuity. All of the resulting chi-square values exceeded the value for $p < .001$.

Results

In this sample of 220, 45% were aged 16- to 18 years old and 55% were aged 19- to 53 years old. There were no significant differences between these two age groups on WAIS-IV verbal comprehension abilities or WM abilities. Females constituted 35% of the total sample; there were no significant differences between the scores of males and females.

For the three VCI groups of our ADHD sample, 23% (*n* = 52) were in the average VCI range; 20% (*n* = 44) were in the high average range; 56% (*n* = 124) were in the superior range (120 and up).

The mean VCI for all 220 participants was *M* = 122.19. The mean WMI for the total sample was *M* = 97.41. The SRI mean for the whole sample was *M* = 89.30. Both the WMI (Table 1) and SRI means (Table 2) were significantly

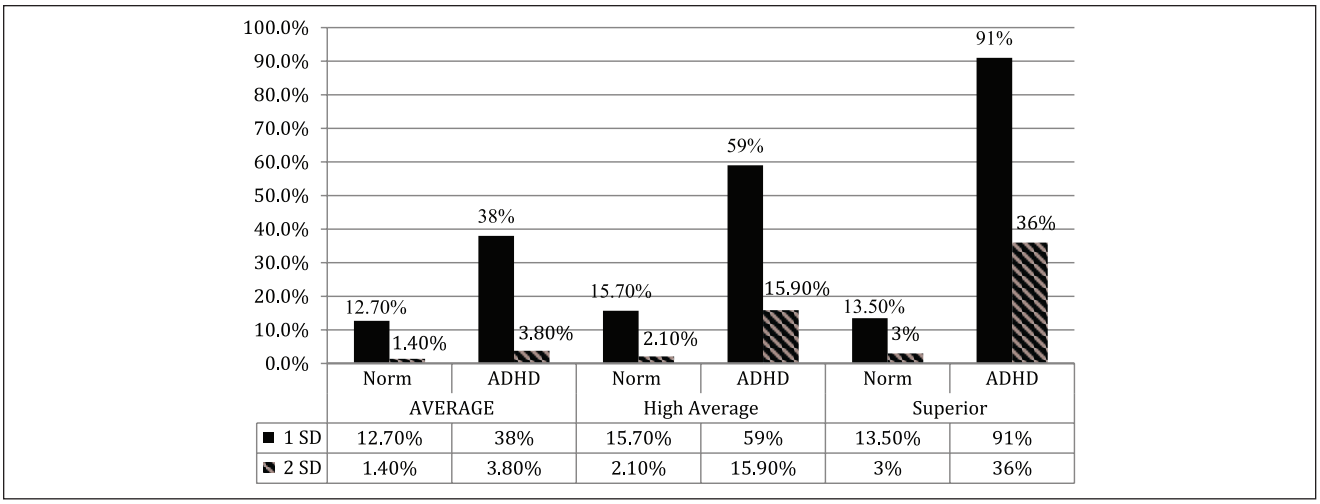

Figure 1. Percentages of ADHD and normative samples with 1 or 2 *SD* of VCI > WMI.
Note. VCI = Verbal Comprehension Index; WMI = Working Memory Index.

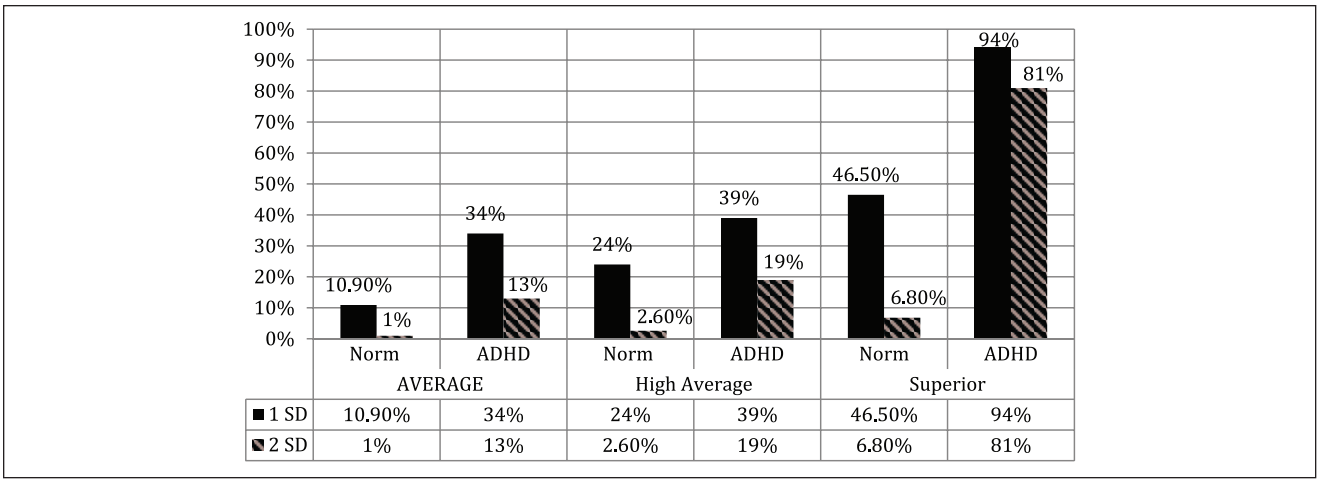

Figure 2. Percentages of ADHD and normative samples with 1 or 2 *SD* of VCI > SRI.
Note. VCI = Verbal Comprehension Index; SRI = Story Recall Index.

lower than VCI means for all three groups. The discrepancies between the means for VCI and both the WMI and the SRI were also significantly lower than comparable means in the normative sample of the general population.

In our sample, every comparison of the SRI scores was also significantly lower, more impaired, than the WMI ($p \leq .001$), indicating that the story recall test was more challenging for participants than was the WMI of the WAIS-IV.

Figure 1 shows the percentage of participants in each of our three ADHD VCI groups whose corrected scores for WMI were 1 or 2 *SD* below their individual VCI compared with the comparable percentages of the normative sample. Figure 2 shows the percentage of each of our ADHD VCI groups whose corrected SRI scores were 1 or 2 *SD* below their VCI compared with the percentages for the normative sample.

Our computation of the overall percentage of participants who scored ≥ 1 *SD* or ≥ 2 *SD* lower than their VCI—SRI showed variability according to IQ group; percentages increased progressively as VCI scores increased, due possibly to regression to the mean. Ranges for ≥ 1 *SD* discrepancy below VCI ranged from 34% to 75%; for ≥ 2 *SD* the range was 13% to 67%. For comparison, the national standardization sample (N = 1,250) for the WMS-III Logical Memory subtest comparable percentages were just 15.4% for ≥ 1 *SD* for and 2.2% for ≥ 2 *SD*.

Discussion

Results from this study support the hypothesis that adolescents and adults with ADHD tend to score significantly

lower on both of these normed verbal and numerical WM tasks, relative to their overall verbal ability, than do most persons of comparable age in the general population.

These data also support our hypothesis that this brief normed story memory test is a more sensitive measure of WM impairments in adolescents and adults with ADHD than is the commonly used WAIS-IV WMI which is based solely on recall and manipulation of numerical data.

Results of this study need to be interpreted in the context of certain limitations. First, our sample of persons with ADHD was comprised of individuals who were seeking assessment and treatment for problems they considered possibly to be related to ADHD. Our results may not apply to individuals with ADHD who are not seeking treatment, who may be functioning well enough in daily life that they feel no need to seek assessment or treatment.

Another limitation of our sample is that it is heavily skewed with high IQ individuals. Our clinic is known as having a special, though not exclusive, focus on individuals with ADHD and related problems who have high IQ. This problem is compensated for by separation of our sample into the three separate groups according to their overall verbal comprehension abilities as measured by the WAIS-IV. Results reported here show that the magnitude of discrepancy between SRI scores and VCI scores is significantly higher in the two groups with above average verbal comprehension abilities. Yet the discrepancy found in the group with average verbal comprehension abilities was also statistically significant.

One advantage to the story task used in this study is that it offers more ecological validity than do tests of WM that involve only recall and cognitive manipulation of numerical or visuospatial information. This is simply to say that the task of attending to and recalling these brief stories administered orally without opportunity to see the words or to hear them more than once resembles activities common in daily life more than does attending to and manipulating increasingly long sequences of numbers, letters, or images of objects. Story recall is more similar to listening to a teacher presenting a lesson or to keeping track of conversation in a meeting or other types of social interaction.

Brown (2005, 2006, 2013) and Barkley (1997, 2011; Barkley, Murphy, & Fischer, 2008) have suggested that standard neuropsychological "tests of executive function" are not adequate measures of executive functions impaired in ADHD. They argue that such tests administered in office or laboratory settings lack ecological validity because such measures involve overly simplified tasks such as sorting of cards, tracking designs, or pressing buttons on computer screens, tasks that do not realistically assess the many complex ways in which executive functions of ADHD disrupt multiple activities of daily life across multiple settings.

This story memory task is one neuropsychological test that does have ecological validity; it more realistically resembles multiple tasks occurring commonly in daily life. It can provide a somewhat objective measure to assess an individual's ability to pay attention to a sizable, but manageable, chunk of verbal information and to remember what has been heard. This is not so different from many daily life situations where one needs to pay attention to what someone is saying and keep it in mind long enough to understand and recall what has been said, at least for a few minutes.

Another advantage to this story recall task as a measure of WM is that the task can be administered in a brief time, typically within about 10 min. And it can be easily and quickly scored using the protocol published with the WMS. Mental health professionals can obtain the stories, scoring criteria, and age-based norms that are published in the WMS-III (1997). They can learn to administer and score this simple test without much difficulty. In this study, we compared each participant's score on the story memory task with that person's VCI on the WAIS-IV so we could have an objective, standardized measure of verbal ability against which to make a comparison. This is the optimal way to make such comparisons.

However, in our standard clinical practice we administer this story memory test routinely, along with the digit span test, in all initial evaluations for possible ADHD; we then compare the individual's scores with just the published norms from the standardization sample for that person's chronological age. This provides an adequate estimate of how that individual performs on these simple measures relative to the general population of similar age. If a more precise measure is wanted, the abbreviated Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999) can be administered in just a few additional minutes. Most of the patients evaluated in our clinic do not need a full IQ test included in their assessment for possible ADHD. Yet both the patient and the evaluating clinician can benefit from utilizing this brief standardized measure of WM which helps to supplement rating scale and clinical interview data with an objective empirical measure of that person's tendency to be "forgetful in daily activities."

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr. Brown has disclosed that he received research support from Shire and consultation or speaker fees from Janssen and Ironshore. From Yale University Press, Routledge, Wiley, and Pearson he receives royalties for publications. Mr. Kennedy and Dr. Quinlan have no disclosures to report.

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