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An investigation of cognitive skills and behavior in high ability students

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ABSTRACT

The purpose of this study was to investigate the cognitive and behavioral profiles of high ability students. Performance on measures of verbal and visuo-spatial working memory and general ability (vocabulary and block design) was compared across the following groups: high, average, and low ability students. The behavioral profile of high ability students was also compared with those with a clinical diagnosis of ADHD. The working memory performance was superior in the high ability students compared to the low and average ability groups, though the relationship between working memory and IQ weakens as a function of increasing ability. The findings are discussed in light of Spearman's law of diminishing returns. The behavioral profile of this group indicates similar features in some respects to those with a clinical diagnosis of ADHD, however, underlying explanations may differ and should be taken into consideration in future research on dual needs in high ability students.

1. Introduction

Ability within educational settings is typically assessed using psychometric measures tapping general intelligence. One widely accepted view of general intelligence indicates that it is composed of crystallized intelligence (Gc) and fluid intelligence (Gf; Cattell, 1971; though see Carroll, 1993, for an extension of this theory). Gc involves learning, knowledge and skills; Gf refers to our ability in tests of problem-solving, pattern matching, and reasoning (Flanagan, McGrew, & Ortiz, 1999, for a review). Crystallized intelligence (Gc) is thought to reflect skills acquired through knowledge and experience and is related to verbal ability, language development (Kline, 1998) and academic success (Deary, Strand, Smith, & Fernandes, 2007).

A related cognitive skill is working memory, our ability to process and manipulate information for a brief period (Just & Carpenter, 1992). Working memory capacity is thought to be a fluid cognitive skill (Blair, 2006) that is related to yet dissociable from IQ (Ackerman, Beier, & Boyle, 2005; Conway, Kane, & Engle, 2003). Working memory deficits are often evident in students with reading difficulties (Gathercole, Alloway, Willis, & Adams, 2006), math difficulties (Geary, Hoard, & Hamson, 1999), learning disabilities (Alloway, 2009), and borderline intellectual functioning (i.e., those with below average cognitive ability, defined by IQ standard scores between 71 and 85; Alloway, 2010; van der Molen, 2010). Working memory also plays an important role in academic attainment even when IQ is statistically accounted in typically developing students (Alloway & Alloway, 2010; Cain, Oakhill, & Bryant, 2004). However, there is a limited amount of literature investigating the working memory profile of cognitively gifted children (though see Dark & Benbow, 1994; Hoard, Geary, Byrd-Craven, & Nugent, 2008; Swanson, 2006). Q19

High ability students were of interest in the present study for two reasons. First, the relationship between working memory and IQ scores may not be similar in this population, as they are known to develop atypically (Distin, 2006). Atypical development refers to higher than age expected IQ scores in the present context. One theory relating to high ability and cognitive skills known as Spearman's Law of Diminishing Returns (SLODR) or 'the differentiation hypothesis' (Deary et al., 1996) suggests that as ability increases, certain cognitive skills reach a plateau as other skills, such as metacognitive ability (Gaultney, Bjorkland, & Goldstein, 1996), creativity and application of knowledge, continue to grow. While the law of diminishing returns is evident in the performance of some IQ measures (Deary et al., 1996; Reynolds & Keith, 2007), we don't yet know whether it also influences working memory in a similar way. It may be that individuals with high ability do not have significantly better working memory capacity compared to average ability students. The relationship between working memory and general intelligence may also differ across ability groups. While the association between these two factors in struggling students is strong (e.g., Alloway, Gathercole, Kirkwood, & Elliott, 2009a, 2009b), it may be weaker in high ability students. Q20

The second reason high ability students are of interest is because some of them are termed as 'twice-exceptional', which refers to their exceptional status as well as additional learning difficulties and attention problems (Baum & Olenchak, 2002). "Exceptional" can be used both to refer to gifted students and to students with disabilities (both ends of the spectrum). While a high ability student without a clinical diagnosis of ADHD (though displaying similar behaviors) would not be considered as clinically twice exceptional,

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there is a growing number of reports of high ability students manifesting ADHD-like behaviors: impulsivity, hyperactivity, and inability to sustain attention (Baum, Olenchak, & Owen, 1998; Richards, Encel, & Shute, 2003). Different explanations have been put forward to explain these similar behavior patterns. In the high ability student such behaviors might be the result of frustration from not being sufficiently challenged academically (Cornell, Delcourt, Bland, & Goldberg, 1994; Pfeiffer & Stocking, 2000), while it is likely to be a neurological etiology in the individual with ADHD (Barkley, 1990). However, some researchers suggest that the overlap in behavioral patterns is an overestimation and many high ability students do not struggle emotionally or behaviorally (Mika, 2006; Richards et al., 2003). In order to investigate this issue, we compared the behavioral profile of high ability students with those with a clinical diagnosis of ADHD.

In the present study, the following issues were investigated: i) do working memory skills reach a plateau as a function of ability? And ii) do high ability students and those with ADHD engage in similar behaviors as measured by standardized behavioral rating scales? In order to address these issues, the cognitive and behavioral profile of high ability students were compared with average and low ability students, as well as a cohort of individuals with a clinical diagnosis of ADHD. Working memory was assessed using a standardized battery of well-validated tests where the individual had to simultaneously process and remember verbal and visuo-spatial information (Alloway, 2007; Alloway, Gathercole, & Pickering, 2006). Behavioral symptoms characteristic of ADHD were assessed using the Conners' Teacher Rating Scale-Revised (Conners, 2001), a well-accepted rating scale typically used to assess attention and executive function problems. Previous research has also indicated that students with ADHD also tend to exhibit behaviors characteristic of working memory problems (Alloway, Gathercole, & Elliott, 2010). In order to investigate whether high ability students manifest working memory behaviors alongside ADHD-type behavior, we included the Working Memory Rating Scale (WMRS; Alloway, Gathercole, & Kirkwood, 2008), which highlights behavior patterns associated with working memory deficits.

2. Method

2.1. Participants

Four groups of children participated in the study. The high ability students ($n = 44$; 66% boys; M age = 10.4 years; SD = 19 months) fit two criteria. First, all high ability students were recruited from the National Association for Gifted Children, UK (NAGC) and were in the top 5% ability range, showing certain characteristics (such as above average academic aptitude in school) that are hallmarks of high ability children in line with the UK education policy on identifying high ability (Department for Education and Skills, 2006). Second, all 44 students scored at least one standard deviation above average (>115; $M = 136.0$; $SD = 7.58$) on a vocabulary test which measures Verbal IQ (Wechsler, 1999). High verbal ability scores can be used for defining giftedness (Alexander, Carr, & Schwanenflugel, 1995) and the group performance fell within the moderate to profoundly gifted range (Winner, 1997).

The average ability group ($n = 38$; 61% boys; M age = 9.8 years; $SD = 12$ months) achieved standard scores in the normal range (90–115) in the vocabulary test ($M = 99.79$; $SD = 7.04$). The low ability children ($n = 46$; 50% boys; M age = 9.10 years; $SD = 11$ months) all achieved standard scores of 1 SD below the average (<86) in the vocabulary test ($M = 72.65$; $SD = 9.89$).

The ADHD group ($n = 83$; 86% boys; M age = 9.9 years; $SD = 12$ months) were given a comprehensive clinical diagnostic assessment by pediatric psychiatrists and community pediatricians. The assessments were based on clinical assessments during interview sessions using the DSM-IV criteria (APA, 1994) and scores in the deficit range on the Continuous Performance Test (Conners, 2004). Children with autistic spectrum disorders were excluded. To ensure that assessments were uninfluenced by medication, all ceased taking their medication (i.e., methylphenidate) 24 h prior to testing (see Mehta, Goodyear, & Sahakian, 2004, for the effect of medication in individuals with ADHD in cognitive test performance).

All participants were native English speakers, were recruited from similar demographic backgrounds, and were from mainstream schools. Consent was obtained from schools and parents/guardians, with appropriate opportunities for withdrawal. Each child was tested individually in a quiet area within the school, in their homes, or at the NAGC offices.

2.2. Measures

2.2.1. IQ

Two subtests of the Wechsler Abbreviated Scales of Intelligence (WASI, Wechsler, 1999) were administered. Verbal ability was assessed by the vocabulary subtest and nonverbal ability was measured using Block Design. Test–retest reliability coefficients for both subtests were .87. Standard scores ($M = 100$, $SD = 15$) were recorded.

2.2.2. Working memory

Two working memory measures from the Automated Working Memory Assessment (AWMA; Alloway, 2007) were administered. In the listening recall task, the child verifies a series of sentences by stating 'true' or 'false' and recalls the final word for each sentence in sequence. In the spatial recall task, the child views a picture of two arbitrary shapes where the shape on the right has a red dot on it and identifies whether the shape on the right is the same or opposite of the shape on the left. The shape with the red dot may also be rotated. At the end of each trial, the child recalls the location of each red dot on the shape in sequence by pointing to a picture with three compass points. Test–retest reliability for the listening recall is .88 and for the spatial recall task is .79 (Alloway et al., 2006; test validity is reported in Alloway, Gathercole, Kirkwood, & Elliott, 2008). Standard scores ($M = 100$, $SD = 15$) were recorded.

2.2.3. Behavior

Two behavior checklists were used. The Conner's Teacher Rating Scale- Revised Short Forms (Conners, 2001) was administered and the following subscale scores are reported: Oppositional, Cognitive problems/Inattention, Hyperactivity and ADHD Index. The internal reliabilities for Conners' Teacher Rating Scale range from .77 to .96 on the various subtests. The Working Memory Rating Scale (WMRS; Alloway, Gathercole, & Kirkwood, 2008), which consists of 20 statements of behaviors characteristic of working memory deficits, was also administered. Cronbach's alpha establishing internal reliability was .98 (Alloway et al., 2009a, 2009b). A four-point Likert scale is used and T-scores were recorded for both behavior checklists ($M = 50$, $SD = 10$). Q21

3. Results

3.1. Cognitive measures

Descriptive statistics for the cognitive measures for the high, average, low ability, and ADHD students are shown in Table 1. In order to compare the cognitive profiles of the different ability groups, the cumulative proportions of children obtaining standard scores below a cut-off indicative of poor performance are also presented. For the present purposes, values below one standard deviation from the mean (standard scores <86) are viewed as indicative of mild deficit. It is perhaps unsurprising that none of the high ability students achieved below average scores in the working memory tests compared to one-third of the average ability students and two-thirds of the low

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Table 1
Descriptive statistics of cognitive skills and behavioral profile for the different groups.

		High	n = 44	%*	Avg	n = 38	%*	Low	n = 46	%*	ADHD	n = 83	%*	Group			High-avg	High-low	High-ADHD	ADHD-Avg	ADHD-Low
		M	*SD*	<1*SD*	*M*	*SD*	<1*SD*	*M*	*SD*	<1*SD*	*M*	*SD*	<1*SD*	*F*	*p*	η^2_p	*p*	*p*	*p*	*p*	*p*
Q3,Q4	Verbal WM	125.73	16.31	0	93.42	14.76	37(20)	84.39	17.54	63(18)	90.65	17.70	45(14)	8.17	.000	.11	.000	.000	.000	.99	.99
Q5,Q26	VS-WM	128.00	12.15	0	92.13	18.29	37(20)	81.65	17.82	67(18)	82.82	16.13	64(14)	15.21	.000	.18	.000	.000	.000	.19	.99
Q6	Verbal ability	136.00	7.57	0	99.79	7.04	0	72.65	9.89	100	82.57	15.87	60(14)	81.75	.000	.54	.000	.000	.000	.000	.000
Q7,Q8	Nonverbal ability	131.86	12.04	0	102.21	12.28	5(9)	91.15	12.82	33(18)	96.59	14.49	22(12)	12.41	.000	.15	.000	.000	.000	.19	.16
	Conners's Teacher	High	n = 21	>1*SD*	Avg	n = 15	>1*SD*	Low	n = 28	>1*SD*	ADHD	n = 59	>1*SD*								
Q9,Q10	Opp.	60.76	14.05	33(27)	51.67	11.56	20(17)	55.00	13.37	21(16)	65.08	15.36	58(14)	5.32	.002	.12	.37	.99	.99	.009	.02
Q11,Q12	Cog. Prob	49.38	5.48	5(12)	49.80	10.14	13(14)	60.64	13.17	54(19)	60.80	11.52	51(14)	8.78	.000	.18	.99	.003	.000	.005	.99
Q13,Q14	Hyp.	62.62	15.56	43(28)	48.13	6.59	7(11)	52.39	11.78	14(13)	62.24	11.92	52(14)	8.72	.000	.18	.003	.03	.99	.001	.003
Q15,Q16	ADHD-I	64.76	16.65	52(28)	47.80	8.02	13(14)	56.79	13.25	25(17)	63.59	12.67	64(14)	7.25	.000	.16	.001	.22	.99	.001	.15
Q17,Q18	WMRS	50.15	8.27	15(20)	42.83	2.99	0	55.69	12.0	36(18)	60.28	9.38	52(14)	7.67	.000	.27	.61	.51	.004	.001	.80

Note: WM = working memory; VS-WM = Visuo-spatial working memory; Opp. = oppositional; Cog. Prob. = cognitiveproblems/inattention; Hyp. = hyperactivity; ADHD-I = ADHD-Index; WMRS = Working Memory Rating Scale.
Confidence intervals (at a confidence level of 99%) are reported in parentheses.

ability students. Approximately half of the ADHD students performed below age-expected levels in the working memory tests.

In order to account for the possibility that cognitive skills in one area may be mediating performance in another, the following analyses were conducted. First, a MANCOVA was performed on the standard scores of the two working memory tests (listening recall and spatial recall) co-varying nonverbal ability (block design). The overall group term associated with Hotelling's *T*-test was significant ($F=8.88$, $p<.001$; $\eta 2p=.12$). Post-hoc pairwise comparisons found significant differences in the following ($p<.001$, Bonferroni adjustment for multiple comparisons, see Table 1). The high ability group performed significantly better than all three groups in both verbal and visuo-spatial working memory tasks. No other pairwise comparisons were significant.

An ANCOVA was performed on the standard scores of nonverbal ability (block design) while co-varying the working memory measures. The overall group term associated with Hotelling's *T*-test was significant ($F=12.41$, $p<.001$; $\eta 2p=.15$). In the post-hoc pairwise comparisons ($p<.001$, Bonferroni adjustment for multiple comparisons), the high ability group performed significantly better than all three groups. No other pairwise comparisons were significant. A similar pattern was found in scores of verbal ability (vocabulary), though this was to be expected as scores on this test were used as a criterion for identifying ability levels.

Also of interest was whether the relationship between working memory and intelligence differed as a function of ability (see Tables 2 and 3). The strength of the relationship between these factors seems to weaken as a function of ability. For example, in the low ability group the relationship between verbal working memory and verbal ability is .37, compared to .01 in the high ability group; between verbal working memory and nonverbal ability, it is .53 and .30 for the low and high ability groups respectively (see Table 3).

3.2. Behavior ratings

Descriptive statistics for the behavioral measures are provided in Table 1. The Conners' Teacher Rating Scale and WMRS are scored as *T* values ($M=50$; $SD=10$). Higher scores are indicative of behavior problems. For scores that are markedly atypical (>1 *SD* from the mean) on the Oppositional scale, 33% of the high ability student achieved this level. A larger proportion obtained high scores on the Hyperactivity scale (43%), and over half (52%) also obtained ADHD index scores indicating a high risk for a diagnosis of ADHD. In contrast, only a small proportion exhibited behaviors associated with Cognitive Problems and inattentiveness, or working memory problems (5% and 15% respectively).

The relationship between the behavior rating scales as a function of group was also explored. The correlational analyses yielded the following values for the association between the Conners' Teacher Rating Scale and the WMRS: high ability $r=.77$; average ability $r=.13$; low ability $r=.83$; ADHD $r=.45$.

A MANOVA was performed on the *T* scores of the four subtests of the Conners' Teacher Rating Scale. The overall group term associated with Hotelling's *T*-test was significant ($F=12.0$, $p<.001$; $\eta 2p=.17$). Post-hoc pairwise comparisons found significant differences in the following ($p<.001$, Bonferroni adjustment for multiple comparisons, see Table 1). For the Oppositional subscale, the ADHD group had higher scores than the average and low ability groups, but not the high ability group. For the Cognitive Problems/Inattentive subscale, the ADHD had higher scores than the high and average ability groups;

Table 2
Correlations between the cognitive measures.

	Verbal WM	Visuo-spatial WM	Verbal ability	Nonverbal ability
Verbal WM	1	.55**	.36*	.31
Visuo-spatial WM	.64**	1	.22	.54*
Verbal ability	.37*	.44**	1	.06
Nonverbal ability	.53**	.52**	.49**	1

Note: The low ability group is displayed in the bottom half and average ability in the top half.
* $p<.05$.
** $p<.01$.

Table 3
Correlations between the cognitive measures.

	Verbal WM	Visuo-spatial WM	Verbal ability	Nonverbal ability
Verbal WM	1	.50**	.47**	.35**
Visuo-spatial WM	.43**	1	.45**	.42**
Verbal ability	.01	.24	1	.50**
Nonverbal ability	.30*	.29	.45**	1

Note: The high ability group displayed in the bottom half and ADHD group in the top half.
* $p<.05$.
** $p<.01$.

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and the low ability group had higher scores than the high ability group. For the Hyperactive subscale, both the high ability and the ADHD groups had higher scores than the average and low ability groups. For the ADHD-Index, both the high ability and the ADHD groups exhibited more problem behaviors than the average and low ability groups. This pattern of findings suggests that both the high ability and ADHD groups exhibit Oppositional and Hyperactive behaviors more frequently than average and low ability students.

An ANOVA was performed on the *T* scores of the WMRS. The overall group term associated with Hotelling's *T*-test was significant ($F=7.67$, $p<.001$; $\eta 2p=.27$). In the post-hoc pairwise comparisons ($p<.001$, Bonferroni adjustment for multiple comparisons), the ADHD group exhibited more behaviors associated with working memory deficits than the high and average ability groups. No other pairwise comparisons were significant.

4. Discussion

Gifted or high ability students often outperform their peers on measures of cognitive skills. However, it was not clear whether they would also demonstrate a marked advantage in working memory tasks. The high ability group outperformed the average and low ability students in both working memory tasks, even after nonverbal ability was statistically accounted. They also performed better than the ADHD students, though this may be unsurprising given the substantial evidence that working memory is significantly impaired in those with ADHD (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005), with suggestions that deficits in this area are a key feature of the disorder (Barkley, 1997; Holmes, Gathercole, Place, Alloway, & Elliott, 2010). In the present study, nonverbal ability skills also differed as a function of ability, after working memory was statistically accounted. This pattern of findings suggests that working memory skills and general ability are dissociable (see Alloway & Alloway, 2010; Cain et al., 2004; Gathercole et al., 2006).

Do the superior working memory skills reflect enhanced capacity or better strategy use? The present data do not allow us to distinguish between these two explanations. There is evidence that high ability students develop better strategies and apply them better in learning situations (Gaultney et al., 1996; Shore, 2000). This flexibility in their strategy use can reduce the memory demand and thus boost recall scores. However, other research indicates that they have a memory advantage that cannot readily be explained by strategy use alone
Q22 (Harnishfeger & Bjorklund, 1994) and some high ability students may indeed have superior processing and recall skills compared to their typically developing peers (Johnson, Im-Bolter, & Pascual-Leone, 2003).

The correlational analyses shed further light on the nature of the relationship between working memory and general ability. The relationship between the two factors was stronger in the low ability group compared to the high ability students. This finding is not inconsistent with the view that IQ or *g* functions like a central processor (Anderson, 1992). In low ability groups, this central processor has to work harder on all cognitive tasks, which may explain why there was a stronger relationship between working memory and IQ tasks. In contrast, with high ability students, the central processor does not have to work as hard and so working memory is not as constrained by performance in IQ tests (see Reynolds & Keith, 2007).

With respect to the behavioral profile, there was an overlap in the types of behaviors high ability students and those with ADHD exhibited. In particular, both groups demonstrated oppositional and hyperactive behaviors. One issue is how to reconcile the high proportion of behavior problems in the present study with fewer frequencies
Q23 reported in other studies (e.g., Richardson et al., 2003). A possibility is that age is a factor: adolescents and teenagers may have learned to manage their behavior appropriately, while younger children, such as those in the present study, might still struggle to curb their over-excitability and boredom, which teachers may interpret as hyperactive and oppositional behavior, respectively.

Multiple explanations have been put forward to account for behavioral problems in high ability students, ranging from a misinterpretation of over-excitability as hyperactivity, to boredom in waiting for peers to catch up, to a disparity between their intellectual function and their social environment (see Hartnett, Nelson, & Rinn, 2004). Furthermore, there is evidence that this cohort does not excel at cognitive measures of inhibition (Johnson et al., 2003), which may in turn impact their ability to inhibit inappropriate behaviors. While it is beyond the scope of the present study to distinguish between these explanations, they suggest that the underlying explanations to account for behavior in high ability individuals may be complex and a multi-dimensional model that accounts for social, educational, and cognitive factors may provide a way forward.

There are several implications for the current findings. First, it suggests that alternative assessments of cognitive skills, like working memory, might yield accurate estimations of ability. Some suggest that the reliance on IQ scores to identify high ability children can be problematic due to discrepancies in performance between verbal and nonverbal tests (Sweetland, Reina, & Tatti, 2006). Furthermore, IQ tests are sensitive to socioeconomic factors such as maternal education level (Groth, 1975), caregivers' attitude towards education (Reynolds, Willson, & Ramsey, 1999), and cultural differences (Brody & Flor, 1998), which may result in an under-representation Q24
of children from lower socioeconomic backgrounds in gifted programs (Borland, 2009). In contrast, working memory appears to be relatively impervious to such factors like maternal education (Alloway et al., 2005) and income levels (Engel, Santos, & Gathercole, 2008). Working memory skills also seem to be a robust predictor of academic attainment, even when IQ is statistically accounted for (Alloway, 2009; Alloway & Alloway, 2010). Thus, standardized working memory assessments can provide a suitable alternative for classification of ability levels.

Another implication of the present research is how behavior problems in high ability students are identified. Behaviors characteristic of working memory deficits and inattentivity were rare in the high ability group. In contrast, they were more likely to display hyperactive and oppositional behavior. However caution needs to be exerted as this may be a function of age in the present study. Furthermore, less than half exhibited these problem behaviors and there are reports that students who are sufficiently challenged do not exhibit these behavior patterns (Morrison, 2001). Thus, the teacher ratings scales that are typically used to identify ADHD-like behaviors, while suitable for initial screening, may not be sensitive enough to account for a multi-dimensional model of behavioral difficulties in high ability students.

The present study was limited in the use of two measures each of working memory and IQ. While these tests have been found to be excellent indicators of their respective cognitive skills with good internal validity (see Alloway et al., 2009a, 2009b; Wechsler, 1999), Q25
future research could include additional measures to provide a more comprehensive assessment of the different cognitive components. Nonetheless, the present study provides a good starting point to further our understanding of the cognitive and behavioral profiles of high ability students.

In summary, the present study offered a first step in comparing cognitive and behavioral profiles across students with a range of ability levels, as well as in those with a clinical diagnosis of ADHD. Working memory performance was superior in the high ability students compared to the low and average ability groups. Further research is needed to determine whether this increased capacity is due to enhanced capacity or better strategy use. The behavioral profile of this group indicates similar features in some respects to those with a clinical diagnosis of ADHD, however, underlying explanations may differ and should be taken into consideration in future research on dual needs in high ability students.

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