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Associations of executive and functional outcomes with full-score intellectual quotient among ADHD adults

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Abstract

Associations between executive and functional impairment, intelligence, and attention deficit hyperactivity disorder (ADHD) have been scarcely investigated among adult populations and lead to inconsistent results. This study tested the impact of intellectual level on executive and functional impairment in a clinical sample of adults diagnosed with ADHD. Participants were recruited in a specialized center for the diagnosis and treatment of ADHD (n=66, mean age=27.9 ± 10.8). Measures included intellectual quotient (IQ, Wechsler Adult Intelligence Scale) categorized as ≤110 or >110, the continuous performance test (CPT3^{TM}), grade retention, educational attainment, and having an activity (job or studies). Participants with a higher IQ had significantly better functional outcomes than participants with a standard IQ: higher educational attainment, lower grade retention, and often having an activity. Participants with higher IQ performed significantly better on all CPT variables assessing executive functioning. Intelligence seemed to work as a protective factor for executive and functional outcomes in a clinical population of ADHD adults and might reduce long-lasting detrimental consequences in life.

Keywords: ADHD; executive function; high IQ; functional impairment.

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1. Introduction

Attention deficit hyperactivity disorder (ADHD) is a neuro-developmental disorder characterized by attentional deficits, increased impulsivity, and hyperactivity that starts in childhood (APA, 2013). Even if it usually starts in childhood, there is an increasing evidence that this disorder is chronic and persists in adulthood (Sibley et al., 2016). ADHD features evolve over time, with more hyperactivity symptoms in childhood, and more inattentive symptoms in adulthood (Döpfner et al., 2015; Vergunst et al., 2018). ADHD has become an important public health concern in recent years because it is associated with severe long-lasting detrimental consequences in several areas of life (Asherson et al., 2016; Franke et al., 2018).

ADHD can occur among people with different levels of intelligence, even if in adulthood ADHD individuals often have a lower level of intellectual functioning relative to non-ADHD subjects (Bridgett and Walker, 2006; Frazier et al., 2004), especially in presence of comorbid disorders (Roy et al., 2017). Intelligence quotient (IQ) and ADHD are independently associated with educational and occupational attainment (Cheng and Furnham, 2012; Deary et al., 2007; Halmøy et al., 2009). IQ and ADHD also interact: a low IQ in childhood is associated with worse developmental courses of ADHD symptomatology and related impairment across adolescence and adulthood (Cheung et al., 2015; Ramos-Olazagasti et al., 2018; Roy et al., 2017; Vergunst et al., 2018). Therefore, a high IQ may protect against functional impairment among individuals with ADHD (Park et al., 2011). Indeed, ADHD is characterized by developmental delays in the acquisition of executive functions such as those involved in inhibition (Barkley, 1997) and a worse neuropsychological performance (LeRoy et al., 2019). On the contrary, college students with and without ADHD have a similar intellectual functioning, meaning that students with ADHD might represent a small subgroup of ADHD individuals with a high functioning (Weyandt et al., 2017).

However, associations between executive and functional impairment, IQ, and ADHD have been scarcely investigated among adult populations (Milioni et al., 2017) and lead to inconsistent results. Some studies reported that ADHD adults with high IQ had an increased executive functioning impairment in comparison with controls from the general population (Antshel et al., 2010; Brown et al., 2009). On the contrary, another study reported no clear neuropsychological deficits in specific subgroups of patients (Thorell et al., 2017). Working memory deficits have been more extensively studied and are moderately related to ADHD (Alderson et al., 2013; Brydges et al., 2017), but Milioni et al. (2017) found almost no difference between ADHD adults with high IQ and normal controls on executive functioning, and no significant differences between ADHD adults with standard and high IQ. Regarding functional impairment, very few studies compared ADHD adults with standard and high IQ with respect to academic and occupational attainment. Noh et al. (2018) concluded that a higher level of IQ predicted better societal outcomes among male outpatients diagnosed with ADHD (i.e., being eligible to military service or not and being employed; there was no significant association with highly-skilled employment). Thus, further evidence is needed to understand how high IQ may compensate ADHD symptomatology in respect to executive and functional impairment in adulthood. Indeed, having a high IQ may lead to high-functioning ADHD. High-functioning ADHD individuals compensate deficits (e.g., efforts to control distractibility, studying/working extra hard) and take advantages of resources (e.g., high motivation, creativity) (Lesch, 2018).

Therefore, the aim of this study was to investigate the impact of intellectual level on executive and functional impairment among adults diagnosed with ADHD. We compared functional outcomes (educational and occupational attainment) and executive functioning (using a neuropsychological test measuring sustained and selective attention) among ADHD adults with a standard IQ (≤110) and a high IQ (>110).

2. Methods

2.1 Participants and procedures

Data were collected from 2015 through 2018 among 66 adult outpatients with an ADHD diagnosis. They were recruited in a specialized center for the diagnosis and treatment of ADHD at the Geneva University Hospitals, Switzerland. All patients underwent an initial clinical evaluation of ADHD. IQ assessment was offered to patients who were suspected to have a low or a high IQ based on the first clinical evaluation. For this study, we focused on patients having a complete assessment of IQ. ADHD participants were divided in two groups, based on the Wechsler Adult Intelligence Scale – fourth edition (Wechsler, 2008), with IQ≤110 and IQ>110 (respectively *n*=34 and *n*=32), as previously done (Milioni et al., 2017).

After the first clinical evaluation, all participants were invited to a second appointment. They signed the consent form, and then they were administered a semi-structured ADHD interview. In the same appointment or one-two weeks after, they also completed the continuous performance test (CPT) and a complete IQ assessment. They were asked to refrain from using psychostimulant medication 24 hours before the CPT, as it may alters CPT outcomes (Epstein et al., 2005). No response rate was available, but almost all patients accepted to undergo tests and assessments proposed for diagnosis and medical care.

The inclusion criteria were 1) to be diagnosed with ADHD, 2) to be suspected to have a standard or high IQ, and 3) to provide informed consent to participate in the study. Participants with severe comorbid mental health disorders were excluded (e.g., personality disorders, psychosis, and substance use disorders). In addition, we excluded one participant who had the hyperactive presentation with few symptoms of inattention. The study was approved by the Ethics Committee of the Geneva University Hospitals.

2.2 Measures

ADHD adult evaluation. ADHD was assessed using a semi-structured clinical interview according to DSM-5 criteria. The Diagnostic interview for ADHD in adults (DIVA) was used in 2015 and 2016 (Kooij and Francken, 2010), and the ADHD evaluation for adults (ACE+) in 2017 and 2018 (Young, 2016). The DIVA was adapted to reflect DSM-5 criteria. The same symptoms and cut-offs were used in both scales. Participants were classified in two subtypes or presentations: inattentive presentation and combined presentation. There was only one participant with the hyperactive presentation, and the number of inattentive symptoms was close to the threshold of the combined presentation (4 out of 5 required), he was included in the group "combined presentation". We also computed the score of ADHD symptoms to provide an estimate of ADHD severity. We summed up all symptoms: inattention symptoms in childhood (9 symptoms) and adulthood (9 symptoms) and hyperactivity/impulsivity symptoms in childhood (9 symptoms) and adulthood (9 symptoms) (range: 0-36).

IQ. Intelligence was assessed with the Wechsler Adult Intelligence Scale – fourth edition (WAIS-IV) (Wechsler, 2008). It included four major components of intelligence: verbal comprehension index (composite score of vocabulary, similarities, and information), perceptual reasoning index (composite score of picture completion, block design, and matrix reasoning), working memory index (composite score of arithmetic and digit span), and processing speed index (composite score of digit symbol-coding and symbol search). We also used the broad score: the full-scale IQ (including the four components described above).

Executive functioning. To assess attention-related problems, we used the Conners CPT 3 ™ (Fasmer et al., 2016). In this computer-assisted task, participants responded when any letter (target) except the letter X (non-target) appeared on the monitor. The task was composed of six blocks of three sub-blocks with 20 trials for a total duration of 14 minutes. As the CPT provides a large variety of scores, we selected those commonly related to ADHD's features (Baggio et al., 2019):

- Detectability: ability to discriminate between non-targets and targets;
- Omission: non-response to targets;
- Commission: response to non-targets;
- Hit reaction time standard deviation: consistency of response speed for the entire test;
- Variability: consistency of response speed within sub-blocks.

Scores were standardized (mean=50, standard deviation=10, upper limit=90, and lower limit=0). Higher scores indicate worse performance, with atypical scores being higher than 60.

Functional outcomes. To assess functional impairment, the following variables were assessed: grade retention (yes/no), level of education (secondary or vocational school versus high school diploma or tertiary education), and having an activity (job or studies, yes/no).

Socio-demographic variables. We recorded age and gender.

2.3 Analytical strategy

Sample size calculation. We computed two sample sizes estimations. We first used a two-sample means test using the scores of the CPT to estimate the sample size for executive outcomes. With alpha=5%, power=80%, allocation ratio=1, mean first group=50 (normal score), and mean second group=60 (atypical score), and standard deviation=10 (Fasmer et al., 2016), we needed *n*=34 (17 participants in each group). Then, we used a two-sample proportions test using previous data on college graduation among ADHD patients to estimate the sample size for functional outcomes (Katusic et al., 2011). With alpha=5%, power=80%, allocation ratio=1, proportion in the ADHD group with standard IQ=0.116, and proportion in the ADHD group with high IQ=0.441, we needed *n*=58 (29 participants in each group).

Statistical analyses. We first computed descriptive statistics (percentages and means). We also performed pairwise comparisons between IQ subscales in both groups using paired t-tests. Then, we tested associations between groups (IQ≤110 and IQ>110) using logistic regressions (binary outcomes: gender, level of education, grade retention, and activity) and linear regression (continuous outcomes: age, CPT variables, IQ indices). We computed unadjusted and adjusted models for outcomes of interest, controlling for age, gender, and ADHD presentation. Effect sizes (adjusted R^2 and pseudo R^2) are reported. We also controlled for ADHD severity, but results were similar and as there were 5 missing values on ADHD scores, this variable is not controlled for in the final models. We also performed a sensitivity analysis using the full-scale IQ, which yielded similar results. Stata 15 was used for all statistical analyses, including sample size calculations (StataCorp, 2017).

3. Results

Demographic statistics and ADHD symptomatology are reported in Table 1. Participants were on average 27.9 ± 10.8 years old and 54.6% were males. A total of 50.0% had the inattentive ADHD presentation. On average, the participants had 22.8 ADHD symptoms. Nine participants were diagnosed in childhood. A total of 29% were on medication psychostimulants, anti-depressants, and benzodiazepine. There were no differences between participants with standard and higher IQ on these variables. IQ ranged between 66 and 110 for the group≤110 and 112 and 146 for the group>110. A total of 9.1% of participants received disability benefits.

The average scores of IQ are reported in Table 2. Overall, participants with standard IQ had significant lower scores for all subscales (p<.001). The patterns between indices were similar in the two groups. In both groups, scores were significantly lower for working memory index in comparison with verbal comprehension index (*p*<.001) and with perceptual reasoning index for the standard-IQ group (higher-IQ group: *p*=.059). In both groups, scores were also significantly lower for processing speed index in comparison with verbal comprehension (*p*<.001) and for perceptual reasoning index in comparison with verbal comprehension index (IQ≤110: *p*=.022, IQ>110: *p*<.001). Processing speed index were not significantly different from perceptual reasoning index and working memory index in both groups.

3.1 Executive outcomes

All CPT variables were significantly associated with the level of IQ, in both unadjusted and adjusted models (see Table 3). Effect sizes ranged between 10.4% and 16.2% in the unadjusted models.

3.2 Functional outcomes

Functional outcomes were significantly associated with the level of IQ (≤110 and >110) in the unadjusted and adjusted models (see Table 3). Participants with a higher IQ had a higher educational attainment (adjusted odd ratio [*aOR*]=4.81, *p*=.025), had less grade retentions (*aOR*=4.41, *p*=.022), and had more often an activity (*aOR*=3.24, *p*=.032) than participants with a standard IQ. Effect sizes ranged between 4.3% and 8.4% in the unadjusted models.

4. Discussion

This study investigated executive and functional outcomes in a clinical sample of ADHD adults with different levels of IQ.

For executive outcomes, our findings showed that all CPT variables were significantly associated with IQ groups, defined as high (>110) or standard (≤110). Higher-IQ participants performed significantly better, suggesting higher sustained attention and inhibition control levels in comparison with standard-IQ participants. It replicated previous findings among ADHD children showing that those with a high IQ performed better than those with a standard IQ (Park et al., 2011). However, among adults, Milioni et al. (2017) failed to identify significant executive functioning differences between ADHD adults with standard and high IQ. Thus, ADHD adults with high IQ had a reduced impairment of executive functioning. Further studies should investigate how IQ interact with executive functioning deficits: Are there less severe executive functioning deficits among high-IQ ADHD adults? Or do these adults compensate for their deficits?

Besides, our results confirmed that IQ was a confounder for neuropsychological tests among ADHD patients (Barkley, 2019). However, clinicians and researchers should be aware that the CPT does not allow to identify correctly ADHD (Baggio et al., 2019; Barkley, 2019) and thus should not be used to detect ADHD, even among standard-IQ ADHD adults. Notably, both groups displayed normal ranges of CPT scores (<60).

For functioning impairment, ADHD adults with higher IQ were less likely to report having repeated grades, more likely to have a tertiary level of education, and more likely to have an activity in comparison with ADHD adults with standard IQ. To our knowledge, only one study has already investigated how adult IQ influences social functioning in adulthood (Noh et al., 2018). The authors concluded that high IQ predicted better outcomes in life, however they focused on a restricted sample (young men in the context of military service) and outcomes. Our study thus confirmed that high IQ predicted a better functioning, especially for academic attainment (Antshel et al., 2010; Milioni et al., 2017). In spite of these significant differences, higher-IQ participants still had underachievement, because there were large proportions of participants having low-level outcomes: 62.5% did not reach tertiary education and 37.5% had no activity. This suggests underachievement, as they do not meet their potential (Lee and

Olenchak, 2015). Indeed, in the Geneva's general population, on average, 2.6% of children repeat a grade (Richard and Rogner, 2012). The Swiss rate of unemployment was 4.6% in 2018, meaning that 95.4% of individuals had an activity (OFS, 2019b). A total of 19% of the whole Swiss population has been unemployed for a period of five years (2014-2018), but individuals mostly stayed unemployed for a very short time period. Among adults (25-64 years old), 43% had a tertiary level of education in 2017 (OFS, 2019a). Therefore, ADHD participants of our study had a lower level of achievement for all these outcomes and it was also true for higher-IQ ADHD participants.

Our results also showed that ADHD symptomatology was not different among participants with standard and higher IQ. There were similar proportions of inattentive and combined/hyperactive presentations in both groups and ADHD severity measured with the number of symptoms did not differ significantly. This finding stood out from previous findings reporting a worse developmental course of ADHD symptomatology among ADHD children with lower IQ (Cheung et al., 2015; Ramos-Olazagasti et al., 2018; Vergunst et al., 2018). It might be because high-IQ adults consult in more severe cases in comparison with standard-IQ adults. Further studies among non-clinical populations should investigate this question to elucidate ADHD symptomatology and course according to intelligence. However, these non-significant differences between IQ groups in ADHD symptomatology strengthened our findings: If high-IQ participants had better functional and executive outcomes, it was not because of a less severe symptomatology.

Another interesting finding was that patterns of IQ indices were similar in both high and standard IQ groups: They all had lower levels of working memory and processing speed ability in comparison with verbal comprehension and perceptual reasoning indices. Even if higher IQ participants had higher levels on each index, the deficits were similar in both groups and corresponded to those already described in the literature in the whole ADHD population

(Theiling and Petermann, 2016). Thus, higher-IQ ADHD adults also had typical ADHD deficits.

This study had some shortcomings. First, we focused on a clinical population, which was not representative of the whole ADHD population. We missed untreated and undiagnosed ADHD individuals. Studies using population-based samples are needed to see how intelligence and ADHD impact executive and functional outcomes. Second, as we used data collected after the initial evaluation, we missed several relevant variables assessing academic and occupational attainment. Further studies need to investigate more extensively these outcomes (e.g., level of qualification, salary, periods of unemployment) as well as quality of life. Third, we used a threshold of IQ>110 to define higher intelligence. Even if this threshold has been used in previous studies (Milioni et al., 2017), other thresholds have also been used (e.g., >120, Katusic et al., 2011). The threshold of 110 was also used in our study because of the modest sample size. However, the sensitivity analysis using the full IQ scale provided similar results, showing that our findings were not influenced by the threshold used to define higher intelligence. Nonetheless, future studies should include a larger number of participants to be able to identify the association between high IQ (e.g., >130) and executive/functional outcomes. Therefore, our results should be considered as preliminary ones, nonetheless highlighting that higher IQ – even >110 – seemed to result in better functioning. Another shortcoming was that we did not know which ADHD presentation participants had in childhood and information on early ADHD treatment were not included. Further longitudinal studies should include a larger range of factors to better capture the effect of IQ on executive and functional outcomes during the life course. Finally, the IQ measure is not “culture free”, so it might be somewhat colinear with educational attainment. These results should therefore be interpreted cautiously.

To conclude, intelligence seemed to work as a protective factor for executive and functional outcomes in a clinical population of ADHD adults and might reduce long-lasting detrimental consequences in life. This confirmed and extended previous findings on children populations.

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Table 1. Socio-demographic characteristics of the sample

	Overall (n=66)	IQ ≤ 110 (n=34)	IQ > 110 (n=32)	Unadjusted models
Gender[1]				
Male (ref.)	54.6 (36)	50.0 (17)	59.4 (19)	OR=1.46, p=.445
Female	45.4 (30)	50.0 (17)	40.6 (13)	
Age[2]	27.9 (10.8)	27.7 (10.6)	28.1 (11.3)	b=0.42, p=.877
ADHD presentation[1]				
Inattentive (ref.)	50.0 (33)	47.1 (16)	53.1 (17)	OR=0.78, p=.623
Combined/hyperactive	50.018 (33)	52.9 (19)	46.9 (15)	
ADHD severity score (n=61)[2]				
Inattention adulthood	6.4 (2.5)	6.5 (2.7)	6.3 (2.3)	b=-0.19, p=.762
Hyperactivity adulthood	4.8 (2.7)	5.1 (2.5)	4.4 (2.9)	b=-0.71, p=.311
Inattention childhood	6.5 (2.5)	6.5 (2.6)	6.4 (2.4)	b=-0.15, p=.814
Hyperactivity childhood	5.2 (3.1)	5.3 (3.0)	5.1 (3.2)	b=-0.18, p=.819
Total	22.8 (8.1)	23.4 (8.1)	22.1 (8.3)	b=-1.24, p=.556

IQ: intellectual quotient, ADHD: attention deficit hyperactivity disorder.

[1] Percentages and n are given, unadjusted models: logistic regressions.

[2] Means and standard deviations are given, unadjusted models: linear regression.

Table 2. Intellectual quotient (IQ) and index in the two groups

	IQ ≤ 110		IQ > 110		
	Mean	SD	Mean	SD	p-value[e]
Total IQ	95.1	11.9	124.2	8.5	<.001
Verbal comprehension index	103.4[a]	14.8	128.2[a]	9.3	<.001
Perceptual reasonning index	96.3[b]	11.9	117.4[b,c]	10.7	<.001
Working memory index	90.7[c,d]	13.8	112.8[c]	10.6	<.001
Processing speed index	91.7[b,d]	13.0	114.7[c]	12.1	<.001

IQ: intellectual quotient, SD : standard deviation.

[a,b,c,d] Different letters correspond to significant differences at the .05 level between pairs of subscales using paired t-tests within each group (column comparisons).

[e] Comparisons between groups using t-tests (row comparisons).

Table 3. Associations between IQ groups, functional, and executive outcomes

Outcomes	Overall (n=66)	IQ ≤ 110 (n=34)	IQ > 110 (n=32)	Unadjusted models			Adjusted models[3]		
				Estimate	p	Effect size	Estimate	p	Effect size
Level of education[1]									
Secondary/vocational school (ref.)	75.8 (50)	88.2 (30)	62.5 (20)	4.50	.020	0.084	4.81	.025	0.180
High school diploma/university	24.2 (16)	11.8 (4)	37.5 (12)						
Grade retention[1]									
Yes (ref.)	25.8 (17)	38.2 (13)	12.5 (4)	4.33	.022	0.079	4.41	.022	0.081
No	74.2 (49)	61.8 (21)	87.5 (28)						
Activity[1]									
No (ref.)	50.0 (33)	61.8 (21)	37.5 (12)	2.69	.051	0.043	3.24	.032	0.110
Yes	50.0 (33)	38.2 (13)	62.5 (20)						
Continuous performance test[2]									
Detectability	52.6 (11.1)	56.9 (10.7)	47.6 (9.5)	-9.34	.001	0.162	-9.09	.001	0.230
Omissions	49.3 (9.1)	52.1 (10.9)	46.0 (4.7)	-6.28	.007	0.104	-6.21	.006	0.160
Commissions	55.4 (11.0)	59.1 (10.1)	50.9 (10.5)	-8.07	.004	0.121	-7.91	.004	0.145
Hit reaction time standard deviation	49.6 (10.5)	53.0 (11.7)	45.6 (7.0)	-7.59	.004	0.116	-7.33	.007	0.093
Variability	49.6 (9.7)	52.7 (11.3)	45.9 (5.4)	-7.01	.004	0.117	-6.96	.006	0.082

IQ: intellectual quotient.

[1] Percentages and n are given, models: logistic regressions with odd-ratios (estimate) and pseudo R^2 (effect size).

[2] Means and standard deviations are given, models: linear regression with b (estimate) and adjusted R^2 (effect size).

[3] Adjusted models controlled for age, gender, and type of attention deficit hyperactivity.