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Does IQ Influence Association Between Working Memory and ADHD Symptoms in Young Adults?

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Abstract

Objective: This study examined the association between WM and ADHD symptoms in young adults and whether IQ-score influenced this association. **Method:** Data from the 1993 Pelotas (Brazil) Birth Cohort Study were analyzed (N=2,845). Working memory and ADHD symptoms were collected at 22 years. IQ was examined at age 18. Poisson regression with robust variance was used to assess the associations between working memory and ADHD symptoms. We also evaluated whether IQ modified associations between working memory and ADHD symptoms. **Results:** Working memory was negatively associated with Inattention symptoms of ADHD. The association between working memory and hyperactivity-impulsivity symptoms of ADHD varied by IQ. **Conclusions:** This study provides new insights to theories about the relationship between WM and ADHD symptoms as well as the development of interventions aimed at improving the performance of WM in ADHD. *(J. of Att. Dis. 2022; 26(8) 1097-1105)*

Keywords

ADHD, working memory, cognition, longitudinal, young adults

Introduction

ADHD is characterized by a developmentally inadequate and impairing pattern of inattention or, hyperactivity/impulsivity, affecting an estimated 5% of children and 2.5% of adults (American Psychiatric Association, 2013).

Recent evidence supports the view that adult ADHD is not necessarily a continuation of childhood ADHD since a substantial proportion of adults with ADHD lack a history of the disorder in childhood (Agnew-Blais et al., 2016; Caye et al., 2016; Moffitt et al., 2015). In addition, some authors suggest, not only that the onset of ADHD can occur in adulthood, but that childhood onset and adult-onset ADHD may be distinct syndromes (Caye et al., 2016). However, currently, there is insufficient data to clarify the extent to which early and late onset ADHD reflect a different balance of genetic and environmental risks or share the same underlying neuropsychological pathways (Asherson & Agnew-Blais, 2019).

Among the potential neuropsychological pathways is the ability to temporarily maintain and manipulate information necessary for achieving a certain goal, called Working Memory (WM; Baddeley & Hitch, 1994). Several theoretical models propose that deficits in WM play an important role in explaining ADHD symptoms (Barkley et al., 2006; Castellanos & Tannock, 2002; Rapport et al., 2001; Willcutt et al., 2005). In support of this, empirical evidence suggests that children and adolescents with ADHD exhibit poorer WM performance (Ramos et al., 2020).

Adolescence and young adulthood is a time of substantial concomitant refinement of cognitive processes and physical maturation of neural circuitry underlying cognitions, such as WM (Casey et al., 2011; Gathercole et al., 2004). Thus, as observed in certain types of psychopathology that emerge during adolescence and early adulthood, such as affective and anxiety disorders (Paus et al., 2008), these changes could confer a vulnerability to late-onset ADHD symptoms.

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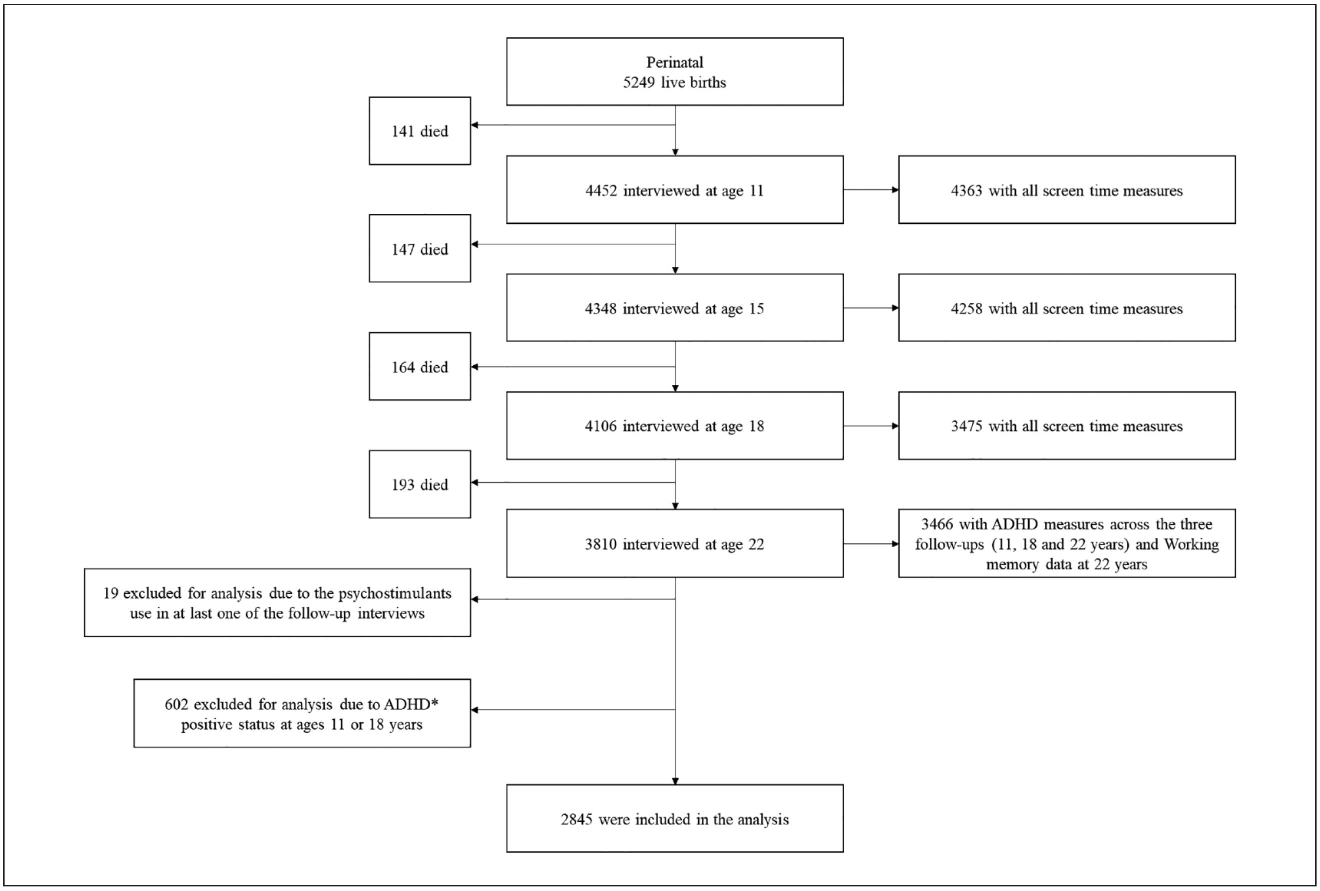

Figure 1. Flow chart of data collected on screen time and attention deficit hyperactivity disorder (ADHD) in the 1993 Pelotas Birth Cohort Study.
*ADHD at 11 years: scores on the SDQ hyperactivity scale (parent report) equal or higher to 8 points and associated with impairment, defined by at least 1 point in the impact supplement. ADHD at 18 years: DSM-5 criteria.

Previous studies have found that those with late-onset ADHD may show a slightly lower intelligence quotient (IQ) than those who never had the disorder, but have significantly higher IQ than those with childhood ADHD (both in childhood and in adulthood) (Agnew-Blais et al., 2016; Cooper et al., 2018). Since several researchers have demonstrated that the relationship between performance on tasks of WM and intelligence is in the range of 0.55 and above (Ackerman et al., 2002; Conway et al., 2003), it is possible that the cognitive correlates of ADHD in highly intelligent individuals are only observed when compared to highly intelligent controls, yet not when compared to average intelligent controls. However, to date, no studies have evaluated the moderating role of IQ in the association between WM and ADHD in early adulthood.

Examining WM and IQ in young adults not only helps clarify the nature of late-onset ADHD, but also provides an additional method for examining the association between cognition and ADHD symptoms. The aim of this study were (1) to examine the association between WM and ADHD symptoms in young adults who had no previous history of ADHD and (2) to test whether IQ-score influences associations between WM and ADHD symptoms. Our hypothesis were (1) poorer working memory performance would be associated with late-onset ADHD symptoms; (2) if poorer working memory performance is associated with late-onset ADHD symptoms, this association would be moderated by the Intelligence Quotient (IQ).

Methods

Design and Sample

Individuals enrolled in this study were participants in the 1993 Pelotas Birth Cohort. All children born in 1993 in the city of Pelotas, Brazil (5,249 individuals), were assessed at multiple time points and followed up until 22 years of age, with a retention rate of 76.3% (Figure 1). The study was approved by the Ethics Committee of the Faculty of Medicine of the Federal University of Pelotas. Before participating in the study, the parental consent of the participants was obtained. More details of the methods have been reported previously (Gonçalves et al., 2018; Victora et al., 2006).

Participants who reported using psychostimulants (e.g., Ritalin) in at least one of the follow-up interviews were excluded from the sample ($N=19$).

Measurements

Attention hyperactivity disorder (ADHD). The assessment at 11 years of age included data on ADHD symptoms using the Brazilian Portuguese Version of the Strengths and Difficulties Questionnaire (SDQ, parent-reported version). The cutoff point of 8 or more points on the SDQ hyperactivity scale was adopted (85.7% sensitivity and 67.4% specificity for the ADHD diagnosis) (Anselmi et al., 2014).

At the 18- and 22-year follow-ups, ADHD was assessed by trained psychologists using specific module for attention deficit hyperactivity disorder modified from the Mini-International Neuropsychiatric Interview (Amorim, 2000). The ADHD assessment was performed with a structured interview according to DSM-5 criteria (Matte et al., 2014). For the present study, we did not require DSM-5 criterion B (age at onset).

At the 18-year follow-up, we initially applied a screening questionnaire using the same structure as the six-question World Health Organization Adult ADHD Self-Report Scale Screener (ASRS) for all subjects (Ustun et al., 2017). ASRS includes six questions about ADHD symptoms with a cutoff point of 4 or more points (97.9% accuracy for the ADHD diagnosis). In order to enhance sensitivity, any subject with 2 or more positive questions among the 6 was considered screening positive, and answered 12 additional questions about the 12 remaining ADHD symptoms. At the 22-year follow-up, ADHD symptoms was treated as a discrete measure.

Working Memory

At the 22-year follow-up, we assessed WM using the Digit Span Backward subtest from the WAIS-III (Wechsler, 1997). This subtest requires the participant to repeat the numbers in the reverse order of that presented by the examiner. In contrast to digits forwards (repetition of digits in the same order presented), which involves only the temporary storage and maintenance of information in mind, digits backward require storage, maintenance and manipulation of information, and thus qualifies as a WM task (Diamond, 2013).

In the present study, a duly-trained psychologist recited a set of digits (at the rate of one digit per second) which the participant repeated in reverse order. The first set of digits consisted of two digits. The set size increased by one digit every two trials. The test stopped when the subject made two consecutive errors at any given set size. The total score was the sum of the item scores; the maximum backwards digit span score was 14 points.

The WAIS-III has been adapted and standardized for the Brazilian population (Nascimento, 2004). In the 20- to 29-year-old participants in the Brazilian standardization sample, the median was 5 points in the digits backwards (De Figueiredo & Do Nascimento, 2007).

Intelligence Quotient (IQ)

We assessed Intelligence Quotient (IQ) using the Wechsler Adult Intelligence Scale, third version (WAIS-III), at 18 years, with the Digit Symbol, Similarities, and Picture Completion subtests. These subtests together are known to correlate between .91 with the Full-scale IQ (Silverstein, 1982). Crude scores for each subtest were converted into weighted scores in accordance with the Brazilian standard (Nascimento, 2004). The test was administered individually by trained psychologists using a standardized procedure in a private and quiet room.

Covariates

We selected covariates according to previous literature on ADHD and WM (Blasiman & Was, 2018; Caye et al., 2016). Birth-related covariates included sex (female and male), skin color (white, black, brown, and others), household income (expressed in Brazilian minimum wages), birth weight (<2,500, 2,500–2,999, 3,000–3,499, and ≥3,500 g) and maternal information—maternal education (0–4, 5–8, 9–11, and ≥12 years), alcohol consumption (no/yes), and smoking during pregnancy (no/yes). Birth weight was measured by trained interviewers using pediatric scales with a precision of 10 g, and the other information was self-reported by the mothers.

From the 11-year follow-up, the following covariates were included: maternal common mental disorders, reading habits, and sleep duration. Maternal common mental disorders were assessed using the Brazilian version of the *Self-Reporting Questionnaire* (SRQ-20) (Mari & Williams, 1986). The cutoff point of 7 points was adopted (Gonçalves et al., 2008). We defined reading habit as the number of days per week that the adolescents read newspapers, magazines, or books (Never, 1–4, and ≥5).

Statistical Analysis

Our main outcomes were ADHD symptoms at 22 years (Inattention symptoms, Hyperactivity-impulsivity symptoms, and Total ADHD symptoms). As our focus was on individuals who had no previous history of ADHD, we restricted analysis to participants without attention difficulties and hyperactivity at 11 years old according to the SDQ and those negative for ADHD at 18 years old (Figure 1).

Descriptive statistics were used to summarize the sample characteristics (absolute and relative frequency). The interactions of Working Memory with sex regarding the ADHD symptoms at 22 years old were tested; however, there was no statistical significance.

ADHD symptom counts followed an overdispersed Poisson distribution (variance greater than the mean). Poisson regression with robust variance was used to unadjusted and adjusted analyses of the association between Working Memory and ADHD symptoms at 22 years. Incident rate ratio (IRR) effect sizes were calculated by exponentiating Poisson regression coefficients and display the proportional change in ADHD symptom counts with each unit increase in Digit Span Backward score (Working Memory).

For adjusted analyses, in a first model, the sex, skin color, household income, reading habit and maternal information—maternal education, alcohol consumption, smoking during pregnancy, and maternal common mental disorder were used as covariates. A second model of regression analysis was used, including IQ into first model. Working Memory × IQ terms were added in subsequent model to test whether IQ modified associations between working memory and ADHD symptoms. If the interaction term was statistically significant, we plotted the moderating variable (IQ) as low/medium (*Z* score, less than 1) and high (*Z* score, 1 or more), and tested the slope of the working memory to identify the association driving the interaction.

Additional sensitivity analyses to address the directionality of the association between working memory and ADHD symptoms are summarized below and detailed in Supplemental Material.

All analyses were conducted using STATA 14.0 (Stata Corp., College Station, USA) and statistical significance was set at 5% (in interaction analyses 10%).

Results

Of the 3,810 participants in the original cohort, 3,466 adolescents (95.1%) had Working Memory and ADHD measure at age 22 (Figure 1). The analytical sample corresponded to 74.6% of original cohort, with the baseline characteristics of this sample are compared with those of the original cohort (perinatal follow-up) in Supplemental Table 1. Participants who were included were more likely to be female. In addition, participants included in the analysis had fewer symptoms of ADHD at 22 years, compared to those positive for ADHD at 11 or 18 years of age excluded (Supplemental Table 2).

The characteristics of the sample studied are shown in Table 1. Most participants were female (53.8%), white (64.5%), and had a family income at birth up to three minimum wages (59.1%). About 8.9% had low birth weight (<2,500 g). At 11 years old, 23.2% read five or more days a week.

Table 1. Descriptive Characteristics of the Sample. 1993 Pelotas Birth Cohort (*N* = 2,845).

	N (%)
Adolescent data	
Sex	
Male	1,314 (46.2)
Female	1,531 (53.8)
Skin color	
White	1,835 (64.5)
Black	418 (14.7)
Brown	481 (16.9)
Others	111 (3.9)
Household income (in minimum wage; *n* = 3,007)	
≤1	509 (17.9)
1.1–3	1,173 (41.2)
3.1–6	725 (25.5)
6.1–10	230 (8.1)
>10	208 (7.3)
Birth weight	
<2,500	253 (8.9)
2,500–2,999	685 (24.1)
3,000–3,499	1,127 (39.6)
≥3,500	780 (27.4)
Reading habit at 11 years (days/week)	
Never	777 (27.3)
1–4	1,408 (49.5)
≥5	660 (23.2)
Maternal data	
Maternal education (years)	
0–4	754 (26.5)
5–8	1,340 (47.1)
9–11	526 (18.5)
≥12	225 (7.9)
Maternal Common Mental Disorder** (*n* = 2,841)	
No	1,564 (55.1)
Yes	1,277 (44.9)
Smoking during pregnancy	
No	1,963 (69.0)
Yes	882 (31.0)
Alcohol consumption during pregnancy	
No	2,702 (95.0)
Yes	143 (5.0)

**≥7 points in the *Self-Reporting Questionnaire* (SRQ-20).

Regarding the characteristics of the mothers, 47.1% had between five and eight successful complete years of schooling and 44.9% had a common mental disorder. During pregnancy, one-third of mothers reported having smoked and 5.0% had consumed alcohol. The average was 97.6 (*SD*: ±11.8) points in the IQ at 18 years and 4.9 (*SD*: ±1.9) points in the digits backward at 22 years. The distribution of data on ADHD symptoms at 22 years is shown in the Figure 2.

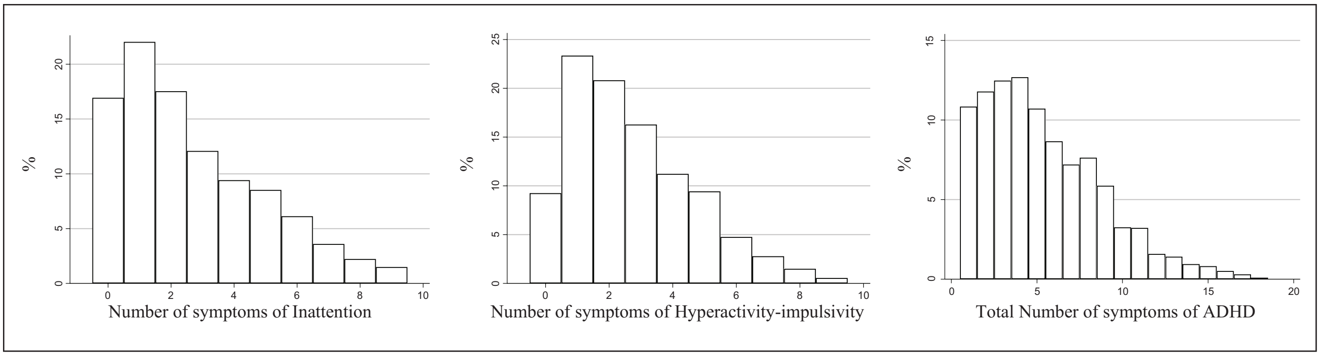

Figure 2. Distribution of ADHD symptoms at 22 years. 1993 Pelotas Birth Cohort (N = 2,845).

The crude and adjusted analyses of the associations between WM and ADHD symptoms at 22 years are shown in Table 2. After adjustment, the working memory was negatively associated with Inattention symptoms of ADHD (Model 1: IRR = 0.97; 95% CI [0.95, 0.99]; Model 2: IRR = 0.98; 95% CI [0.97, 1.00]). The association between WM and hyperactivity-impulsivity symptoms of ADHD varied by IQ (IRR for interaction 0.99; 95% CI [0.99, 0.99], Model 3; Table 2). In high IQ young adults, for every one-unit increase in Digit Span backward score the hyperactivity-impulsivity symptoms rate decreased by 5% (95% CI [0.91, 0.99]; Table 3 and Figure 3). However, this association was not found in those with low and medium IQ scores.

Regarding total ADHD symptoms, in model 1, for every one-unit increase in Digit Span backward score at 22 years the total ADHD symptoms rate decreased by 1% (95% CI [0.97, 1.00]). However, this association did not remain statistically significant after including IQ at 18 in the analysis.

Sensitivity analyses found no significant bidirectional associations in WM associated with ADHD symptoms at age 22 (Supplemental Figure 1).

Discussion

To our knowledge, this is the first longitudinal study to investigate the association between Working Memory and ADHD symptoms in young adults who had no previous history of ADHD considering the moderating role of IQ in this relationship. Our results did not indicate IQ differences in the association between WM and inattention symptoms. However, WM was negatively associated with hyperactivity-impulsivity symptoms only in high IQ individuals.

Previous studies conducted with children and adolescents have reported a negative association between ADHD symptoms and WM regardless of IQ-score (Cadenas et al., 2020; Rohrer-Baumgartner et al., 2014). Similar findings were observed in studies in adults, although those studies mostly provided indirect support since none explicitly tested the interaction between WM and IQ (Antshel et al., 2010; Brown et al., 2009). However, no study was found in the literature that discriminated inattention and hyperactivity-impulsivity symptoms.

In our study, young adults aged 22 years with a poorer performance on WM tended to show a greater inattention symptoms rate, and this effect was not moderated by IQ-score at 18 years old. A review of cross-sectional studies reported mostly weak associations between IQ scores and inattention symptoms in children and adolescents (Jepsen et al., 2009). In addition, these authors suggest that the effects of ADHD attention deficits on performance in IQ tests are the consequence of deficits in specific abilities, such as WM. In support this, the association between IQ and inattention symptoms was not maintained when WM was included in our analysis. This could mean that the association between WM and inattention symptoms and WM is strengthened with increasing IQ-score in some individuals, while the association is weakened with increasing IQ-score in others.

Our results are consistent with the hypothesis that poor working memory function and inattentive behavior are closely associated in non-clinical samples (Aronen et al., 2005). They also fit well with evidence that typically developed adults with low working memory spans are more likely to experience concentration difficulties than individuals with higher working memory spans (Kane et al., 2007).

We found that working memory was negatively associated with hyperactivity-impulsivity symptoms in young adults with high IQ. However, this association was not found in those with low and medium IQ scores. Results primarily support that those with a high IQ can possibly compensate for some of the WM associated with hyperactivity-impulsivity symptoms. However, some studies suggest that ADHD-like behaviors, such as impulsivity and hyperactivity, in high IQ individuals may not be indicative of ADHD, but rather a consequence of their very fast processing style and mismatch with their environments that are often understimulating for highly intelligent

Table 2. Associations of Working Memory at 22 Years and IQ at 18 Years with ADHD Symptoms at 22 Years. 1993 Pelotas Birth Cohort (N = 2,845).

	ADHD symptoms at 22 years					
	Inattention symptoms		Hyperactivity-impulsivity symptoms		Total ADHD symptoms	
	IRR (95% CI)	p-Value*	IRR (95% CI)	p-Value*	IRR (95% CI)	p-Value*
Unadjusted model						
Working memory at 22 years	0.97 (0.95, 0.99)	.003	0.98 (0.97, 1.00)	.112	0.98 (0.96, 0.99)	.004
IQ at 18 years	0.99 (0.99, 0.99)	<.001	0.99 (0.99, 0.99)	.004	0.99 (0.99, 0.99)	<.001
Adjusted models						
Model 1						
Working memory at 22 years	0.97 (0.95, 0.99)	.006	1.00 (0.98, 1.01)	.781	0.99 (0.97, 1.00)	.042
Model 2						
Working Memory at 22 years	0.98 (0.97, 1.00)	.044	1.00 (0.98, 1.01)	.836	0.99 (0.98, 1.01)	.142
IQ at 18 years	1.00 (0.99, 1.00)	.227	0.99 (0.99, 1.00)	.007	1.00 (0.99, 1.00)	.054
Model 3						
Working memory at 22 years	1.01 (0.92, 1.10)	.830	1.13 (1.03, 1.25)	.008	1.01 (0.99, 1.02)	.304
IQ at 18 years	1.00 (0.99, 1.01)	.573	1.01 (1.00, 1.01)	.041	1.15 (0.92, 1.45)	.220
Working memory at 22 years × IQ 18 years	1.00 (1.00, 1.00)	.652	0.99 (0.99, 0.99)	.008	0.97 (0.94, 1.01)	.101

Note. Model 1 = adjustment for covariates; Model 2 = IQ at 18 years and covariates as simultaneous regressors; Model 3 = interaction term added in model 2.
Covariates: sex, skin color, household income, maternal education, alcohol consumption during pregnancy, smoking during pregnancy, maternal common mental disorder, and reading habit.
*Poisson regression with robust variance.

Table 3. Adjusted Association Between Working Memory and Hyperactivity-Impulsivity Symptoms of ADHD at 22 Years, by IQ at 18 Years. 1993 Pelotas Birth Cohort (N = 2,845).

	Hyperactivity-impulsivity symptoms at 22 years					
			IQ at 18 years			
	Interaction		Low/medium IQ (N = 2,364)		High IQ (N = 481)	
	IRR (95% CI)	p-Value*	IRR (95% CI)	p-Value*	IRR (95% CI)	p-Value*
Working memory at 22 years	0.95 (0.91, 0.99)	.033	1.01 (0.99, 1.02)	.234	0.95 (0.91, 0.99)	.041

Note. Adjusted for sex, skin color, household income, maternal education, alcohol consumption during pregnancy, smoking during pregnancy, maternal common mental disorder, and reading habit. Low/medium IQ = less than 1 Z score; High IQ = 1 Z score or more.
*Poisson regression with robust variance.

individuals (Alloway & Elsworth, 2012; Hartnett et al., 2004). Based on this hypothesis, it is possible that those with lower WM are more likely to have hyperactivity-impulsivity symptoms with the "true" disorder. More studies are required to clarify this observation.

Although IQ and WM are considered distinct cognitive domains, these measures are overlapping (Ardila et al., 2000). In our study, the abbreviated IQ assessment did not include the working memory and processing speed subtests, which would underestimate the true effect of WM on ADHD symptoms. In addition, the subtests used are known to highly correlate with the full-scale IQ (Silverstein, 1982) and suitable for screening purposes in clinical practice where a full-scale IQ is too expensive and not always needed.

Our findings contribute to clinical practice by improving understanding of the cognitive differences between ADHD types among young adults. First, and foremost, the relationship of WM and IQ with late-onset ADHD symptoms in young adults are overall similar to those found in children and adolescents, suggesting that similar cognitive domains can be targeted for psychodiagnostic clinical practice. In addition, working memory test performance can prevent misdiagnosis or overdiagnosis of ADHD in the highly intelligent population. Second, the current clinical intervention for impaired working memory in ADHD is still in its infancy (Al-Saad et al., 2021). Our study raises the question of whether these interventions on WM could decrease hyperactivity-impulsivity symptoms in low- and average-IQ individuals.

Our study had several strengths. It is based on prospective data, collected with methodological rigor, from a birth cohort with an expressive sample up to 22 years of age, which allows us a certain degree of generalization of the results to the population of this age group. Regarding the complexity of the phenomenon studied, our analyzes were controlled for a wide variety of sociodemographic factors at

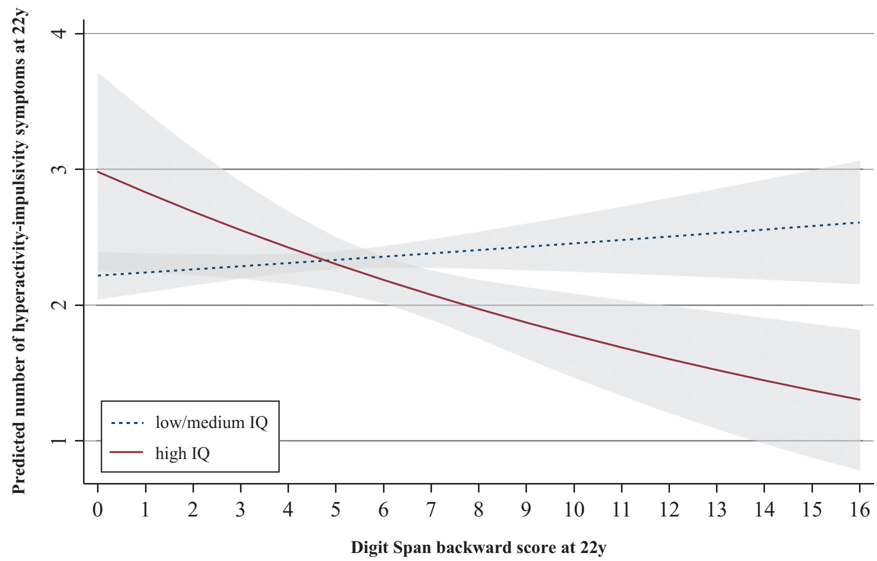

Figure 3. Adjusted margins plots of working memory × IQ interaction effects on hyperactivity-impulsivity symptoms at 22 years, from Table 3. 1993 Pelotas Birth Cohort (N = 2,845). Shading depicts 95% confidence intervals.

11 years of age and psychosocial factors, such as maternal schooling, which is associated with neural development affecting WM performance. In addition, the present sample is drawn from a nonclinical cohort, increasing the likelihood of having a sample with normally distributed IQ-scores.

It is also important to consider that the data collected impose some limitations on the analysis. The most important limitation is the non-availability of data on number of ADHD symptoms in childhood and early adolescence. The instrument used to assess ADHD at ages 11 and 18 years did not allow us to perform separate analyses for each type of symptoms. Therefore, we cannot rule out the possibility of reverse causality that ADHD symptoms during adolescence can lead to WM capacity in early adulthood, especially in participants with few symptoms. The same occurred with IQ. Longitudinal studies suggest, however, that IQ is relatively stable from childhood until late adolescence (Deary et al., 2000; Yu et al., 2018). Another limitation is the operationalization of high IQ used in this study (1 *SD* or more; IQ ≥ 109.3). Since we use abbreviated IQ assessment, we believe this cutoff was appropriate for our analyses. Using a higher cutoff value, such as IQ ≥ 120, may result in different findings.

Conclusions

This longitudinal study provides evidence that IQ should be considered when an ADHD assessment in young adults is undertaken, especially when hyperactivity-impulsivity symptoms are present and IQ score is high. Our findings may contribute new insights to theories about the relationship between ADHD symptoms and WM as well as the development of interventions aimed at improving the performance of WM in ADHD.

Declaration of Conflicting Interests

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Supplemental Material

Supplemental material for this article is available online.

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