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ORIGINAL CONTRIBUTION

Testing the evolutionary advantage theory of attention-deficit/hyperactivity disorder traits

Trine Wigh Arildskov[1,2] · **Anne Virring**[1] · **Per Hove Thomsen**[1,2] · **Søren D. Østergaard**[2,3]

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Abstract

To reconcile the strong secular persistence of attention-deficit/hyperactivity disorder (ADHD) despite its impairing effects, ADHD traits have been postulated to offer an evolutionary advantage. It has been proposed that such advantages should in particular be observable under time-critical, novel, and resource-depleted conditions requiring response-readiness and high levels of scanning and exploration/foraging. Our objective was to provide the first behavioral test of this hypothesis. Schoolchildren from the general population with no/few ($n = 56$), mild ($n = 50$), moderate ($n = 48$), and severe ($n = 48$) ADHD traits, defined according to their ADHD-Rating Scale IV (ADHD-RS-IV) total score, participated in an exploratory foraging and response-readiness laboratory test. Here, children searched for coins hidden in locations of varying obscurity in an unfamiliar room for 1 min. Test-performance (number of coins found) adjusted for age, sex, and estimated IQ was analyzed categorically using multiple linear regression analyses and dimensionally by fitting a regression model including the ADHD-RS-IV score as a continuous measure. There were no differences in the mean number of coins between the No/Few (Mean = 7.82), Mild (Mean = 7.76), Moderate (Mean = 7.58), and Severe (Mean = 7.88) groups [$F(3,195) = 0.24$, $p = 0.871$]. Furthermore, excluding children with functional impairment, adjusting for verbal working memory and response inhibition, and stratifying for sex did not change these findings. Finally, continuous ADHD traits were not found to be related to test-performance [$F(3,195) = 0.73$, $p = 0.536$]. While our results do generally not support the evolutionary advantage theory (i.e., ADHD traits neither conferred an advantage nor a disadvantage), this does not disprove that ADHD traits may have offered advantages via other mechanisms.

Keywords ADHD · Dimensionality · Natural selection-based theories of ADHD · Children · Adaptive advantages

Introduction

The persistence and high, and in some cases escalating, prevalence of mental disorders (e.g., [1]) presents a conundrum for advocates of neo-Darwinian accounts of human evolution [2]. Why should behavioral and mental states that are by definition associated with disability, distress and negative functional outcomes—that will inevitably undermine fitness—not be bred out through the processes of chance mutation and natural selection [2, 3]? Attention-deficit/hyperactivity disorder (ADHD) is a case in point—a highly prevalent and heritable disorder [4] associated with adverse health and functional outcomes [5] and increased mortality rates [6].

One explanation for this apparent evolutionary paradox is that ADHD traits may have conveyed advantages at some point in our evolutionary history where they were selected over long periods of time [7–9], and that comprehensive changes in human societies have occurred so rapidly that they have outpaced the much slower evolutionary changes required to select out those traits [7]. Due to such evolutionary time lags [10], we may carry around traits that were adaptive in and designed for our ancestral environments

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✉ Trine Wigh Arildskov
trine.wigh.arildskov@ps.rm.dk

1 Department of Child and Adolescent Psychiatry, Aarhus University Hospital, Psychiatry, Aarhus N, Denmark

2 Department of Clinical Medicine, Aarhus University, Aarhus, Denmark

3 Department of Affective Disorders, Aarhus University Hospital, Psychiatry, Aarhus N, Denmark

during the Pleistocene epoch, but are maladaptive in today's environment—also known as the mismatch theory [11, 12] or what others have called "*the anachronism of ADHD*" [13].

In terms of specifics, the natural selection-based theory by Jensen et al. [7] seems to be the most plausible (see Thagaard et al. [14] for a brief review of the theories). According to Jensen et al. [7], ADHD traits may have been adaptive in ancestral hunter-gatherer environments characterized by resource-depleted, time-critical, and novel/rapidly changing conditions. In this context, hyperactivity is considered an adaptive exploratory behavior useful in resource-depleted environments for spotting of new opportunities, effective foraging, or migration and expansion toward better climates. Likewise, impulsivity is considered as response-readiness and the ability to fight-or-flee—a requirement for survival in time-critical situations [7, 14]. Finally, inattention is seen as hypervigilance and high-scanning behavior likely to be adaptive in rapidly changing or novel environments for monitoring of threats and danger [7].

Whereas efforts have been devoted to the formulation and discussion of natural selection-based theories, a systematic review by Thaagaard et al. [14] only identified three empirical studies of such theories of ADHD. Two of these studies [15, 16] investigated the seven-repeat allele of the dopamine receptor D4 gene (DRD4 7R) which has been associated with ADHD [17] and novelty-seeking [18, 19]. They reported that this allele arose as a rare mutational event about 40,000–50,000 years ago around the last out-of-Africa expansion, suggesting that the increased 7R frequency may be a result of positive selection. The third study addressed group fitness using a simulation paradigm and found that groups consisting of 5% with unpredictable and 95% with predictable behavior had increased group survival under rapidly changing conditions [20]. Although these studies, at least indirectly, seem to support the theory by Jensen et al. [7], they do not actually test the behavioral advantages of the core ADHD symptoms of inattention, hyperactivity, and impulsivity [14]. Therefore, Thagaard et al. [14] concluded that the evolutionary theories of ADHD remain hypothetical and are yet to be addressed in behavioral studies.

In the current study, we tested the theory by Jensen et al. [7] for the first time directly by creating an exploratory foraging and response-readiness laboratory test where ADHD traits could be expected to confer an advantage. Specifically, in a sample of schoolchildren with varying levels of ADHD traits (no/few, mild, moderate, and severe), we tested whether these traits would confer an advantage in a test designed to mimic a time-critical, novel, and resource-depleted situation. This laboratory test consisted of a 1-min coin search in an unfamiliar room with coins placed in different locations with varying degrees of obscurity to make them more or less easy to locate. Our hypothesis was that children with moderate and sub-threshold ADHD traits would outperform their peers with lower and higher levels of ADHD traits—as children with severe ADHD traits were assumed to be too impaired by their symptoms and associated difficulties to outperform children with lower levels of ADHD traits.

Methods

Recruitment procedure

Schoolchildren were recruited after their parents had participated in a survey [21]. In brief, the survey was distributed in Aarhus Municipality, Denmark, through (i) a web-based intranet at public schools for 1st to 3rd grade and (ii) to an online digital mailbox linked to the Danish personal registration number of parents to children who were aged 7–9 on February 1, 2017.

For this study, children were recruited based on the total score on the ADHD Rating Scale-IV (ADHD-RS-IV) [22] completed by their parent(s) in the survey to cover the entire ADHD traits severity continuum. For practical reasons, data from the first 447 out of 2044 survey responses, comprising 238 boys aged 8.15 (SD = 1.03) and 209 girls aged 8.11 (SD = 0.97), were used to define four ADHD traits groups. For the normal range (no/few ADHD traits), we aimed at obtaining a group with ADHD-RS-IV total scores below or equal to the 60th percentile (exact percentile given the distribution of ADHD-RS-IV scores in the sample: ≤ 62), a mild range group with ADHD-RS-IV scores in the 61th–79th percentiles (exact percentiles: 63–79), a moderate range group with ADHD-RS-IV scores in the 80th–89th percentiles, and the severe range group having ADHD-RS-IV scores equal to or above the 90th percentile. About 50 children were recruited in each group while aiming at obtaining equal sex distribution.

The inclusion criteria were as follows: (1) attending 1st, 2nd, or 3rd grade in Aarhus Municipality at the time of the survey, (2) sufficient Danish language proficiency to participate, and (3) if the child was treated with a central nervous system stimulant, he/she was required to be off the medication for at least 24 h before participation. The following exclusion criteria were employed: (1) severe physical disabilities or neurological disorders, (2) an autism spectrum disorder (ASD) diagnosis, (3) pronounced sensory disabilities, and (4) treatment with atomoxetine (due to long half-life).

Participants

Two hundred and thirty-one schoolchildren were screened for eligibility. A detailed sample flowchart is available in Online Resource 1. Out of the 231 children, 19 declined participation, 5 families either did not turn up for the scheduled assessment and were subsequently unreachable or it was not possible to obtain consent from both custodial parents, and four children were excluded due to ASD or neurological disorders. Finally, the first participant (a boy in the No/few group) was excluded because of minor refurnishing in the test room after the assessment. Thus, the total sample consisted of 202 children (101 girls and 101 boys) aged 6–11 comprising a No/few ADHD traits group (32 girls and 24 boys), a Mild ADHD traits group (25 girls and 25 boys), a Moderate ADHD traits group (22 girls and 26 boys), and a Severe ADHD traits group (22 girls and 26 boys). Table 1 shows the ADHD-RS-IV scores in the four groups.

Eight children (4.0%) were diagnosed with ADHD, out of which six were medicated with and were off methylphenidate at least 24 h before participation. For these children, parents were instructed to complete the ADHD-RS-IV based on their child's behavior when he/she was off medication. The children with ADHD had a mean ADHD-RS-IV total score of 40.13 (SD = 10.18). Four of these children were reported by their parents to have at least one of the following comorbid conditions: a behavioral disorder, a sleep disorder, an emotional disorder, and/or a mixed specific developmental disorder (categorized based on parent-report). The remaining children were not reported in the survey to have any psychiatric diagnoses (except a few children with dyslexia) or to use any kind of psychotropic medication. The sample included five sibling pairs.

The exploratory foraging and response-readiness laboratory test

We designed a laboratory test to operationalize the theory by Jensen et al. [7] by tapping into the potential adaptive response-readiness, high-scanning and exploratory/foraging behavior through a test aimed at mimicking time-critical, resource-low, and novel conditions. In this laboratory test, the child searched for and collected objects (coins) in 1 min in a test room (see Fig. 1) that the child had not previously been exposed to.

Setting

Twenty Danish 2-kroner coins (each corresponding to ≈0.27 Euro) were hidden by the assessor in a 3.95 × 3.91 m room before the assessment took place. The coins were hidden in the same locations for every child and varied in level of obscurity and so difficulty to find. The room was furnished with a filing cabinet, chairs, a computer, a carpet, and tables, and all furniture was placed along the walls in the same position every time. A black curtain-like fabric was hanging from the doorframe shielding the room from the hallway. Figure 1 illustrates the test room.

Administration

To avoid distractions or disruptions, instructions were given by the assessor in a room next door. The child was told that he/she was going on a 'treasure hunt', that a number of coins were hidden in the room next door and that he/she could keep those found in 1 min. The child was given a small paper gift bag and was told to use it for collecting coins. No further information was provided. The child and the assessor then went to the front of the test room, the assessor 'counted down' ("on your marks, get set, go"), drew back the curtain, and started the timer as the child entered the room. When the timer went off, the assessor entered the room, counted the number of coins found and went through all hiding places recording which coins the child had found.

Outcomes

The primary outcome was the number of coins found (range 0–20) and the secondary outcome was the difficulty level of the types of coins found. Three independent assessors, without prior knowledge of how frequently each coin was found, rated the difficulty level of each coin as either easy ($n = 6$), medium ($n = 10$), or hard ($n = 4$) based on how visible the coins were (e.g., visible or completely hidden) and their location in the room (e.g., on the floor or behind a curtain). In case of disagreement, the coin was assigned to the level two out of three assessors had chosen ($n = 6$) or the intermediate level (i.e., the medium difficulty level) in the case that none of the assessors agreed on the difficulty level ($n = 1$). The coins were then converted into a difficulty score (easy = 1, medium = 2, or hard = 3) and added up to yield a total coin difficulty score (range 0–38).

Measures

ADHD traits were assessed using the ADHD-RS-IV [22, 23]. The ADHD-RS-IV has been validated in Denmark [24] and consists of 18 items corresponding to the symptom criteria for ADHD in DSM-IV where higher scores indicate higher frequency of and greater severity of ADHD symptoms [22]. The item scores are summed up into an Inattention score (range 0–27), a Hyperactivity/Impulsivity score (range 0–27), and a total score (range 0–54) [22].

Functional impairment was measured using the mean score on the Weiss Functional Impairment Rating Scale-Parent report (WFIRS-P) [25] assessing ADHD-related functional impairment across different domains of functioning. In the absence of Danish norms, functional impairment was defined as a mean score ≥ 0.65. This cut-off has been shown to differentiate functional impairment in children with ADHD from children without ADHD with a sensitivity of 83% and a specificity of 85% [26].

Table 1 Sample characteristics in the four ADHD traits groups

	No/few ADHD traits ($n=56$)	Mild ADHD traits ($n=50$)	Moderate ADHD traits ($n=48$)	Severe ADHD traits ($n=48$)	F test or χ^2 test[g]
Boys, n (%)	24 (42.9%)	25 (50.0%)	26 (54.2%)	26 (54.2%)	$\chi^2(3)=1.81$, $p=0.613$
Age, M (SD)	8.70 (0.89),	8.85 (0.90),	8.77 (0.95),	8.78 (0.86),	$F(3,198)=0.25$, $p=0.864$
Range	7–10	7–11	6–10	7–10	
ADHD-RS-IV, M (SD)					
Hyperactivity/impulsivity score	2.50 (2.20),	5.40 (2.56),	9.75 (2.99),	15.15 (4.53),	Welch' $F(3,104.71)=136.80$, $p<0.001$. S > Mo > Mi > NF***
Range	0–8	1–10	1–18	6–27	
Inattention score	2.77 (2.61),	8.32 (2.55),	9.15 (3.32),	16.67 (4.60),	Welch' $F(3,105.82)=128.84$, $p<0.001$. S > Mo, Mi, NF***; Mo > NF***; Mi > NF****
Range	0–10	3–13	3–17	9–27	
Total score	5.27 (3.63),	13.72 (1.33),	18.90 (1.75),	31.81 (7.26),	Welch' $F(3,101.56)=310.38$, $p<0.001$. S > Mo > Mi > NF***
Range	0–11	12–16	17–22	23–52	
FSIQ estimate, M (SD)	108.57 (11.45),	105.28 (14.17),	104.44 (11.38),	100.38 (12.04),	$F(3,198)=3.87$, $p=0.010$. NF > *S***
Range	88–142	64–139	82–127	70–130	
Digit Span Backwards[a], M (SD)	10.28 (2.45)	9.39 (3.04)	10.27 (2.41)	8.87 (2.43)	$F(3,177)=3.25$, $p=0.023$. NF > *S**
Range	3–14	1–15	5–14	4–14	
Stop Signal Reaction Time last half[b], M (SD)	275.97 (70.86)	317.02 (98.36)	291.55 (105.28)	285.48 (92.96)	$F(3,195)=1.88$, $p=0.135$
Range	142.95–458.63	147.95–607.35	152.55–628.68	144.25–545.08	
Parental education (years)[c], M (SD)	15.73 (1.74)	15.25 (1.70)	15.39 (1.79)	14.51 (2.41)	Welch' $F(3,107.84)=2.88$, $p=0.040$. NF > S*
Range	10.00–17.50	11.00–17.50	11.50–17.50	9.50–17.50	
At least one referral[d], n (%)	2 (3.6%)	4 (8.0%)	7 (14.6%)	17 (35.4%)	$\chi^2(3)=23.55$, $p<0.001$
Special educational needs[e], n (%)	0 (0.0%)	4 (8.0%)	3 (6.3%)	14 (29.2%)	$\chi^2(3)=25.85$, $p<0.001$
WFIRS-P mean score, M (SD)	0.17 (0.17)	0.33 (0.22)	0.41 (0.24)	0.66 (0.37)	Welch' $F(3,104.21)=28.03$, $p<0.001$. S > Mo**, Mi***, NF***; Mo > NF***; Mi > NF**
Range	0.00–0.84	0.02–1.17	0.06–1.08	0.10–1.65	
WFIRS-P impairment[f], n (%)	2 (3.6%)	3 (6.0%)	9 (18.8%)	20 (41.7%)	$\chi^2(3)=32.50$, $p<0.001$

M mean, SD standard deviation, *NF* no/few group, *Mi* mild group, *Mo* moderate group, *S* severe group, *FSIQ* Full Scale Intelligence Quotient estimate, *ADHD-RS-IV* Attention-Deficit/Hyperactivity Disorder–Rating Scale IV, *WFIRS-P* Weiss Functional Impairment Rating Scale–Parent Report

[a]This subtest was missing for the first 21 children participating in the project for practical reasons, and are based on $n=46$ in the No/few group, $n=46$ in the Mild group, $n=44$ in the Moderate group, and $n=45$ in the Severe group

[b]Based on 47 and 46 cases in the Moderate and Severe group, respectively

[c]Parental years of education was based on biological parents ($n=190$), adoptive parents or on the biological mother and her spouse/partner ($n=6$), or the biological mother alone ($n=6$) if there was no or limited contact to the biological father or if paternal information was insufficient

[d]Defined as referral to the Pedagogical Psychological Counseling Center, to the child and adolescent psychiatry, or referrals to both

[e]Special educational need was defined as attending a special class/school or a mainstream school with educational support at the time the parents participated in the survey [21]

[f]Defined as a WFIRS-P mean score ≥ 0.65 [26]

[g]χ^2 tests were used to examine group differences on categorical variables, and analyses of variance with Tukey post-hoc tests or Welch's adjusted F-ratio with Games-Howell post-hoc tests were used to examine group differences on continuous variables. Only significant differences between groups (post-hoc tests) are shown

*$p<0.05$, **$p<0.01$, ***$p<0.001$

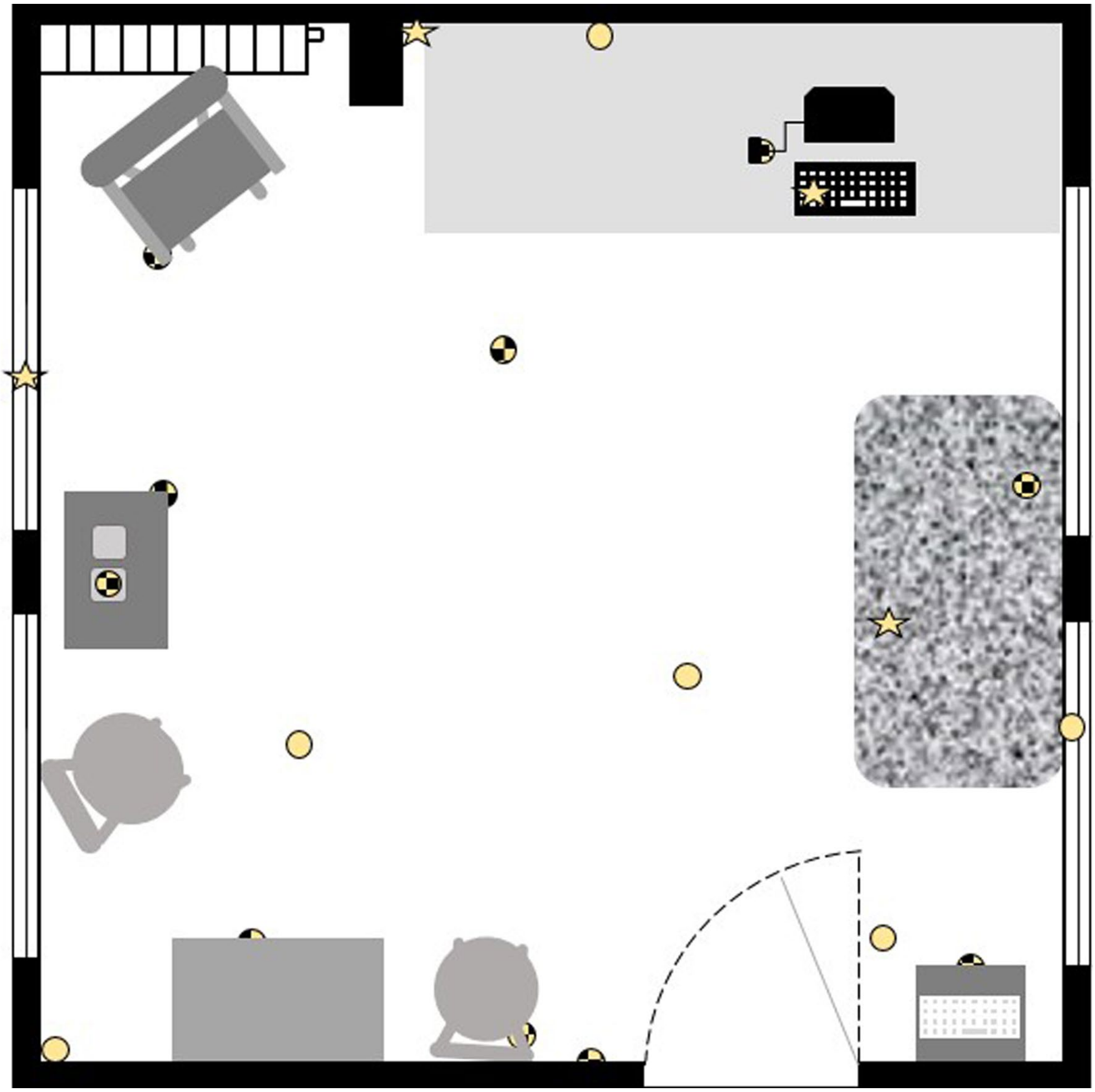

Fig. 1 Illustration of the room used for the exploratory foraging and response-readiness laboratory test (dimensions: 3.95 × 3.91 m). Circles and stars indicate where the coins were hidden. Stars illustrate the coins rated as hard to find ($n = 4$). Circles with checked patterns illustrate the coins rated as medium ($n = 10$) and plain circles illustrate the coins rated as easy to find ($n = 6$)

A two-subtest short form of the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV) [27] consisting of Vocabulary and Matrix Reasoning was administered to obtain an estimate of general intelligence (IQ) derived using the Tellegen and Briggs formula [28, 29]. The WISC-IV Digit Span subtest was also administered, and the scaled process score for the Digit Span Backward (range 1–19) was used as a measure of verbal working memory.

The Stop Signal Task from the Cambridge Neuropsychological Test Automated Battery (CANTAB) [30] was administered on a touchscreen tablet to measure response inhibition defined as the Stop Signal Reaction Time (last half) in milliseconds.

Background information was collected in the survey [21] on socio-economic status (SES) defined as the average length of parental years of education (range 0.00–17.50 years), psychiatric diagnoses, referrals to the child and adolescents psychiatry and/or the Pedagogical Psychological Counseling Center (i.e., school psychologists), and special educational needs.

Procedure

The Danish Regional Ethics Committee and the Danish Data Protection Agency approved the project. Eligibility was determined based on survey data and through a telephone interview (i.e., based on parent-reported information), and written informed consent was obtained from the holder of custody. The current study is part of a broader assessment including, among others, experiments addressing objectively quantified hyperactivity and prospective memory. All children were assessed by the first author or by trained research assistants (master's degree students in psychology) during approximately 2 h from 9.00–11.00 am (± 30 min) from June 2016 to October 2017. The laboratory test and tasks were administered in a fixed order (see Online Resource 2 for a complete list of the test order), using a script specifying all instructions to ensure standardized assessment. The parent(s) completed the WFIRS-P at the day of assessment, except in one case where it was completed the following day.

Statistical analyses

Sample characteristics

Group differences (No/few, Mild, Moderate, and Severe) on continuous sample characteristic variables were explored using analyses of variance with Tukey post-hoc tests or Welch's adjusted F-ratio with Games-Howell post-hoc tests when the assumption of homogeneity of variance was not met. χ^2 tests were used to examine group differences on categorical sample characteristic variables. Sex differences were addressed by independent *t*-tests (see Online Resource 3).

Number of coins found in the laboratory test

Categorical and dimensional analyses were performed to investigate test-performance (number of coins found) in the exploratory foraging and response-readiness laboratory test. First, we compared the number of coins found in the four groups using multiple linear regression analyses adjusted for age, sex, and estimated IQ. A post hoc logistic regression analysis adjusted for the same covariates was also carried out to explore if there were group differences in the odds ratio for finding more coins than the total sample mean ($M = 7.76$), i.e., finding ≥ 8 coins. In the categorical analyses, the Moderate group was chosen as the reference group due to our hypothesis. Second, to explore if continuous ADHD traits were related to the primary outcome through a dimensional approach, we fitted a regression model with ADHD-RS-IV total score as the independent and the number of coins as the dependent variable while adjusting for age, sex, and estimated IQ. The ADHD-RS-IV total score was included using a restricted cubic spline with four knots (standard placement at the 5th, 35th, 65th, and 95th percentile corresponding to a total score of 1, 13, 19, and 36.8, respectively) to investigate the expected non-linear relationship between ADHD traits and coins found. An ADHD-RS-IV total score of zero was chosen as the reference group. The categorical and dimensional analyses were repeated with the total coin difficulty score as the outcome variable.

Finally, a series of sensitivity analyses using the categorical and dimensional approach on the primary outcome (i.e., number of coins found), available in Online Resource 4, were carried out as follows. First, to explore if non-impairing yet high ADHD traits may serve as an advantage, the analyses were carried out after excluding 34 cases with a WFIRS-P mean score ≥ 0.65 [26]. Second, due to the potential role of working memory and response inhibition, we repeated the analyses while adjusting for Digit Span Backwards and Stop Signal Reaction Time. Third, because hyperactivity and impulsivity rather than inattention may convey an advantage in terms of exploration and response-readiness [7], the analyses were carried out with the ADHD-RS-IV Hyperactivity/Impulsivity score as the independent variable and with four Hyperactivity/Impulsivity groups defined using the aforementioned stratification procedure by percentiles (for details see Online Resource 4, Table S3). Finally, sex-stratified analyses were performed.

The level of statistical significance was set at 0.05 and no adjustment for multiple comparisons was applied due to the highly exploratory nature of this study. The analyses were performed in Stata version 15.1 [31] and SPSS version 20.0 [32].

Results

Sample characteristics

The total sample consisted of 101 girls and 101 boys with a mean age of 8.77 (SD = 0.90), a mean estimated IQ of 104.83 (SD = 12.56), and an ADHD-RS-IV total score ranging from 0 to 52 ($M = 16.91$, SD = 10.55). No significant sex differences were found when comparing age, estimated IQ, and ADHD-RS-IV scores (see Online Resource 3). Table 1 shows the sample characteristics in the four ADHD traits groups.

Number of coins—categorical approach

In the total sample, the number of coins found ranged between 2 and 12 ($M = 7.76$, SD = 1.68). Figure 2 and Table 2A shows the number of coins found in each group as well as the crude and adjusted (for age, sex, and estimated IQ) mean differences using the Moderate group as reference. Overall, there were no significant between-group differences in the number of coins found, $F(3,195) = 0.24$, $p = 0.871$. Moreover, no differences were found when comparing the number of coins between the four groups without cases with functional impairment [$F(3,161) = 0.02$, $p = 0.997$] or after adjusting for the effect of working memory and response

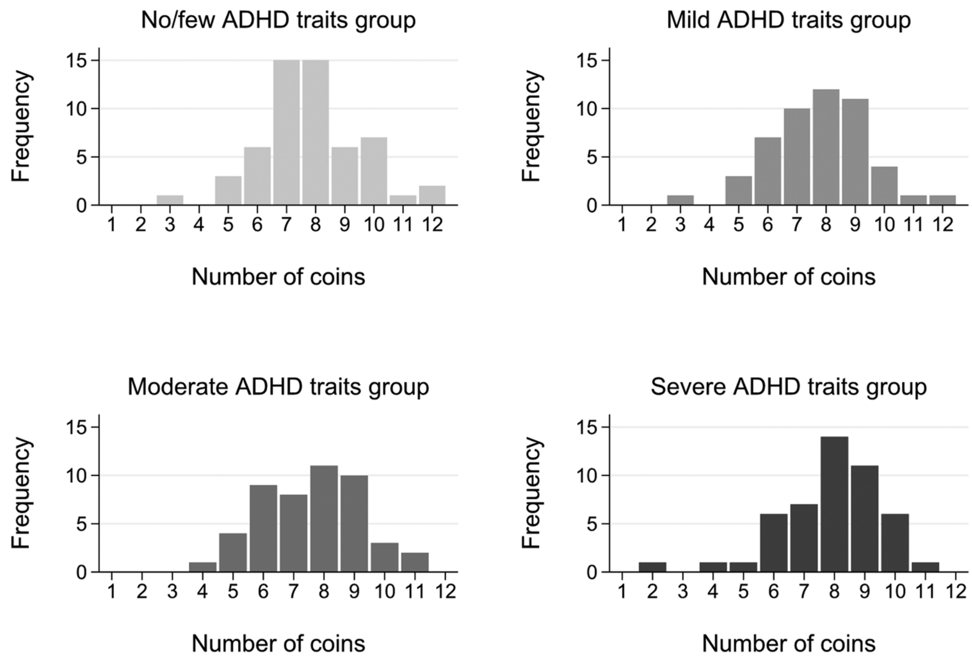

Fig. 2 Distribution of the number of coins found in the laboratory test in each group. *ADHD* attention-deficit/hyperactivity disorder

Table 2 Results of the exploratory foraging and response-readiness laboratory test

A. Group differences in number of coins found

	No. of coins, *M* (SD), range	Crude difference [95% CI][a]	*p* value[a]	Adjusted difference [95% CI][b]	*p* value[b]
No/few ADHD traits (*n* = 56)	7.82 (1.73), 3–12	0.24 [− 0.42; 0.89]	0.475	0.21 [− 0.45;0.88]	0.529
Mild ADHD traits (*n* = 50)	7.76 (1.68), 3–12	0.18 [− 0.50; 0.85]	0.606	0.17 [− 0.51;0.84]	0.624
Moderate ADHD traits (*n* = 48)	7.58 (1.65), 4–11	Ref	Ref	Ref	Ref
Severe ADHD traits (*n* = 48)	7.88 (1.70), 2–11	0.29 [− 0.39; 0.97]	0.399	0.28 [− 0.41;0.96]	0.426

B. Group differences in finding ≥ 8 coins

	≥ 8 coins, *n* (%)	Crude OR [95% CI][c]	*p* value[c]	Adjusted OR [95% CI][d]	*p* value[d]
No/few ADHD traits (*n* = 56)	31 (55.4%)	1.05 [0.48; 2.28]	0.903	1.06 [0.48; 2.32]	0.893
Mild ADHD traits (*n* = 50)	29 (58.0%)	1.17 [0.53; 2.60]	0.702	1.15 [0.51; 2.57]	0.741
Moderate ADHD traits (*n* = 48)	26 (54.2%)	Ref.	Ref.	Ref.	Ref.
Severe ADHD traits (*n* = 48)	32 (66.7%)	1.69 [0.74; 3.87]	0.212	1.64 [0.71; 3.80]	0.247

No. number, *M* mean, *SD* standard deviation, *CI* confidence interval, *OR* odds ratio, *ADHD* attention-deficit/hyperactivity disorder, *ref.* reference group

[a]Unadjusted multiple linear regression analysis with the Moderate ADHD traits group as the reference group, $F(3,198) = 0.27$, $p = 0.845$

[b]Multiple linear regression analysis adjusted for age, sex, and an estimate of IQ with the Moderate ADHD traits group as the reference group, $F(3,195) = 0.24$, $p = 0.871$

[c]Unadjusted logistic regression analysis with the Moderate ADHD traits group as the reference group, $\chi^2(3) = 1.91$, $p = 0.592$

[d]Logistic regression analysis adjusted for age, sex, and an estimate of IQ with the Moderate ADHD traits group as the reference group, $\chi^2(3) = 1.59$, $p = 0.662$

inhibition [$F(3,169) = 0.54$, $p = 0.654$]. Furthermore, no differences emerged when comparing the four Hyperactivity/Impulsivity groups [$F(3,195) = 0.36$, $p = 0.780$] or after stratifying for sex [$F_{boys}(3,95) = 0.03$, $p = 0.993$; $F_{girls}(3,95) = 0.64$, $p = 0.588$]. Notably, as evident from Fig. 2, it was only participants in the No/few and Mild ADHD traits groups who managed to find 12 coins (the maximum number of coins retrieved by any participant) during the laboratory test.

Table 2B shows the crude and adjusted odds ratio for finding more coins than the sample mean in the No/few, Mild, and Severe groups compared to the Moderate group.

A post hoc logistic regression analysis adjusted for age, sex, and estimated IQ revealed no significant group difference in the odds ratio for finding eight or more coins, $\chi^2(3)=1.59$, $p=0.662$. In addition, no significant differences emerged after excluding cases with functional impairment ($\chi^2(3)=1.63$, $p=0.654$), after adjusting for working memory and response inhibition ($\chi^2(3)=2.22$, $p=0.527$), when comparing the four Hyperactivity/Impulsivity groups ($\chi^2(3)=3.49$, $p=0.322$), or in the sex-stratified analyses ($\chi^2_{boys}(3)=0.49$, $p=0.922$; $\chi^2_{girls}(3)=3.15$, $p=0.369$).

Number of coins—dimensional approach

Figure 3 shows the adjusted fitted regression model plotting the differences in number of coins found compared to an ADHD-RS-IV total score of zero against the ADHD-RS-IV total score as a continuous measure. In this fitted model, for instance, a child with an ADHD-RS-IV total score of 35 (i.e., in the severe range) found 0.48 more coins but between 0.44 less to 1.40 more coins than a child with a total score of zero. However, the curve was not statistically significant, $F(3,195)=0.73$, $p=0.536$, meaning that the ADHD-RS-IV total score was not significantly related to the number of coins found. The same was found when conducting the analysis without cases with functional impairment [$F(3,161)=0.36$, $p=0.779$], when taking the effect of working memory and response inhibition into account [$F(3,169)=0.38$, $p=0.767$], or when a fitted regression model was carried out with the ADHD-RS-IV Hyperactivity/Impulsivity score as the independent variable [$F(3,195)=0.58$, $p=0.631$]. Moreover, the ADHD-RS-IV total score was not significantly related to the number of coins found by boys [$F_{boys}(3,95)=0.27$, $p=0.845$] or girls [$F_{girls}(3, 95)=0.72$, $p=0.544$].

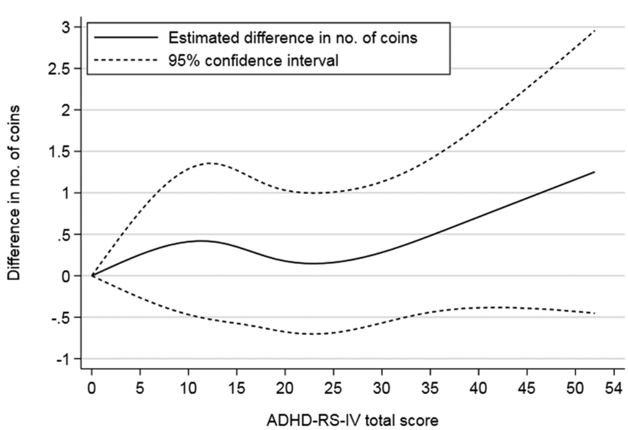

Fig. 3 Estimated differences in number of coins found against the ADHD-RS-IV total score. Fitted regression model with the total score from the Attention-Deficit/Hyperactivity Disorder–Rating Scale IV (ADHD-RS-IV) included as the independent variable using restricted cubic splines, $F(3,195)=0.73$, $p=0.536$. An ADHD-RS-IV total score of zero is the reference group

Total coin difficulty scores

All 20 coins were found by at least one child in each group (but none of the children found all 20 coins). The total sample had a mean total coin difficulty score of 12.11 (SD = 3.20, range 3–21). The No/few group had a mean total difficulty score of 12.38 (SD = 3.38), the Mild group a difficulty score of 11.86 (SD = 3.09), the Moderate group scored in average 11.88 (SD = 3.27), and the Severe group had a mean difficulty score of 12.31 (SD = 3.09). There were no group differences in the total coin difficulty score adjusted for age, sex, and estimated IQ, $F(3,195)=0.35$, $p=0.786$. Moreover, the ADHD-RS-IV total score was not significantly related to the total coin difficulty score, $F(3,195)=0.96$, $p=0.411$.

Discussion

So far, the empirical literature on the evolutionary theories of ADHD is limited to studies using simulation [20] or genetic approaches [15, 16] without taking the core symptoms of ADHD into account [14]. To address this gap in the literature, we designed a behavioral paradigm (an exploratory foraging and response-readiness laboratory test) to investigate potential advantages of ADHD traits, assessed using an ADHD-specific rating scale, in schoolchildren under environmental conditions mimicking those described in the natural selection-based theory of ADHD by Jensen et al. [7]. To our knowledge, this is the first study to focus on the core symptoms and to use a behavioral paradigm when investigating potential advantages of ADHD. Contrary to our expectations, having ADHD traits in the moderate range did not confer an advantage over having lower or higher levels of ADHD traits, respectively. Overall, no group differences were found in the number of coins or the total coin difficulty scores. Similarly, although the estimated differences in number of coins found seemed to increase with higher continuous ADHD traits levels, this increase was not statistically significant. Thus, neither continuous ADHD traits nor hyperactivity/impulsivity traits seemed to be related to test-performance. The results did not change after excluding children with functional impairment, when adjusting for verbal working memory and response inhibition, or when stratifying on sex.

Although ADHD traits were not found to hold an advantage, the four groups, irrespective of functional impairment, behavioral inhibition and working memory, performed equally well in a test requiring timed exploration in a novel environment. Thus, schoolchildren with ADHD traits in the moderate and even in the severe range (≥ 90th percentile) showed no disadvantage despite the severe group being characterized by poorer verbal working memory (but not response inhibition) as compared to the No/few group, and more pronounced functional impairment as compared to the three other groups (see Table 1). This may indicate that under such circumstances, children with severe and pronounced ADHD traits may not be as impacted by their ADHD traits, associated deficits and ADHD-related impairment, suggesting a better environmental fit. Similarly, a recent study of foraging patterns in a non-clinical sample of children reported that having high levels of ADHD traits did not affect performance in a timed, visuo-spatial, paper-and-pencil search for objects [33]. Moreover, children with higher levels of ADHD traits were found to display increased exploratory over exploitation foraging patterns as indicated by longer distances and more "jumps" in their paper-and-pencil search [33]. This potential bias towards information/resource exploration has also been addressed in a study of visual information foraging of infants in a low- or high-risk group for ASD who were presented with a visual scene with five images in each trial while having their eye-movement tracked [34]. Infants who had a sibling with ASD and low ADHD traits levels were found to have decreased exploration in terms of a higher re-visitation likelihood (i.e., returning to and a preference towards an image already seen and visited) compared to a control group and to infants with an older sibling with ASD and high ADHD traits levels. Although these results seem to suggest that a familial risk of ADHD traits may moderate the more restricted patterns of exploration typically associated with ASD in favor of more balanced visual exploitation-exploration foraging patterns, the group differences was only observed at 8 months of age but not when the infants were 14 and 36 months old, respectively [34]. Thus, children with different levels of ADHD traits may differ in their searching [33], but also in their navigation strategies [35] with a potential bias towards exploration rather than exploitation [33, 34]. This possibility should be subjected to further investigations to better understand the underlying mechanisms and potential (adaptive) consequences of ADHD traits.

While our study did not find support for potential advantages of ADHD traits and the theory of Jensen et al. [7], we cannot rule out the possibility that situations exist or have existed in the past where ADHD traits have been advantageous and favored by selection forces. For instance, it is possible that ADHD traits have persisted because they increased reproductive success through other mechanisms than those mimicked by our exploratory foraging and response-readiness laboratory test, and therefore have been favored by sexual selection. Indeed, studies have shown that individuals with ADHD are more likely to be younger at first sexual intercourse, to have more sexual partners, to engage in more casual sex, and to be involved in more (partner) pregnancies and teenage parenthood compared to individuals without ADHD [36–38]. The significant genetic correlations between ADHD and younger age of having children and the number of children ever born reported in a recent genome-wide association study lend further support to this hypothesis [39]. Indeed, the increased frequency of the 7R allele may be due to sexual selection [15, 16].

Yet, it is also possible that ADHD traits have persisted despite of rather than because of natural or sexual selection [12, 40]. For example, ADHD has been suggested to be a maladaptive spandrel rather than an adaptation [40]. That is, a by-product of genetically linked traits that may have increased fitness and reproductive success [40], such as novelty-seeking and risk-taking behavior. In general, the criticism of the adaptationist perspectives on ADHD call into question how a disorder associated with deficits in executive functions and response inhibition possibly can hold any kind of advantage [40–43]. However, putting this common error of inclusion aside [44], ADHD is a heterogeneous disorder [4] and not all children with ADHD show executive and inhibitory deficits (e.g., [45, 46]). Furthermore, verbal working memory and response inhibition showed a non-significant relation to the number of coins found in our laboratory test suggesting that under such conditions, these covariates do not affect performance.

Another explanation for our results could be that our test did not measure what we intended. The laboratory test was designed to mimic the environmental conditions proposed by Jensen et al. [7] under which ADHD traits may have been adaptive, i.e., in resource-low, time-critical, and novel environments. To tap into the exploratory/foraging behavior proposed to be adaptive in situations where resources are depleted [7], we designed a test where the child had to search for and collect objects (coins) in a room. With regard to resource depletion, it can be argued that the experimental setup is in fact rich in resources (coins). However, when considering the participants in the study (children), we believe that they feel somewhat depleted in this context (always having a need for extra pocket money) and that the experiment is therefore also valid in this regard. Furthermore, it was our impression that the children were highly motivated to find coins in the experiment—which can be interpreted as an indirect manifestation of their sense of resource-depletion from the outset. The short time available (1 min) along with the prospect of obtaining coins, chosen for motivational reasons, was hypothesized to create a "time-critical" situation fostering response-readiness, excitement, and a feeling to hurry up and be quick while completing the test. The novelty of the situation was ensured in several ways. First, the child had not been exposed to the room before and no information was revealed regarding what the room looked like. Second, we sustained a situation characterized by novel stimuli by withholding information about how many coins were hidden and not providing any clues on how and where they could be found. Third, the test in itself can be seen as a novel situation, assuming that it is not a familiar setup encountered by schoolchildren. Although it is difficult to create a situation mimicking (hypothesized) ancestral environmental conditions, this was our best effort to operationalize the theory. Nevertheless, the test may not have been sufficiently sensitive to capture between-group differences. One concern may be that there was not enough variation or dispersion in the hiding places and number of coins found. However, no floor or ceiling effect was observed, the distribution in the total sample approximated normality (see Fig. 2), and all types of coins were found in each group. In a similar vein, a maximum of 12 out of 20 coins hidden in the room were found in the test. As we aimed at hiding enough coins at various locations and with variable difficulty levels in the room to avoid floor and ceiling effects and to allow for dispersion in the type of coins found, the finding that no participants managed to find all coins was as intended. Another concern may be that having only 1 min to collect coins was too short a time interval. However, creating a "time-critical" situation was essential for the validity of the laboratory test. In addition, a longer time interval might have introduced a ceiling effect given the size of the test room.

There may be aspects of the laboratory test that could be improved or modified to increase the validity and sensitivity of the test. For instance, future research should address if the type of reward (coins) used or if the available time limit in a foraging test may play a role for the motivation and the level of exploration. Also, it may be that the potential advantages associated with ADHD traits operate at the group level (rather than the individual level assessed in the present study) where the presence of such traits in a smaller proportion of the group benefits the entire group and thereby increases group rather than individual fitness as the costs remains at the individual level [20]. Alternatively, the level of exploration may potentially increase when having to compete with others for resources [34]. Future studies should aim at addressing the possibility of group selection of ADHD traits or whether such traits are more adaptive under competitive conditions by investigating potential advantages in group settings rather than individually as done in the present study.

There are limitations to this study that should be taken into account. First and foremost, the study was limited by only using parent-reported ADHD traits (using the ADHD-RS-IV) and thereby relying on a single informant. Second, whereas the ADHD-RS-IV captures the presence and frequency of each DSM-IV ADHD symptom [22], the Strengths and Weaknesses of ADHD Symptoms and Normal behaviour (SWAN) questionnaire was developed to capture the dimensional nature of ADHD [47]. However, we opted for using the ADHD-RS-IV because it has been validated in Denmark [24]. Third and finally, the study is limited by not measuring spatial working memory but only verbal working memory.

In conclusion, although we, contrary to our hypothesis, did not find support for the superiority of moderate ADHD traits in an exploratory foraging and response-readiness laboratory test, those with moderate and severe ADHD traits performed just as well as their peers with lower or no ADHD traits. Hence, our results do not seem to concur with the view that ADHD traits always are impairing across virtually all settings.

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Compliance with ethical standards

Conflict of interest Professor Per Hove Thomsen has received speaker's fee from Medice and Shire within the last 3 years. The remaining authors declare no conflicts of interests.

Ethical standards This study was approved by the Danish Regional Ethics Committee (1-10-72-241-15) and the Danish Data Protection Agency (1-16-02-542-15). The holder of custody (parents, adoptive parents, etc.) provided written informed consent on behalf of their children. The study has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

References

1. Atladottir HO, Gyllenberg D, Langridge A et al (2015) The increasing prevalence of reported diagnoses of childhood psychiatric disorders: a descriptive multinational comparison. Eur Child Adolesc Psychiatry 24:173–183. https://doi.org/10.1007/s00787-014-0553-8
2. Keller MC, Miller G (2006) Resolving the paradox of common, harmful, heritable mental disorders: which evolutionary genetic

models work best? Behav Brain Sci 29:385–404. https://doi.org/10.1017/S0140525X06009095
3. van Dongen J, Boomsma DI (2013) The evolutionary paradox and the missing heritability of schizophrenia. Am J Med Genet Part B Neuropsychiatr Genet 162:122–136. https://doi.org/10.1002/ajmg.b.32135
4. Faraone SV, Asherson P, Banaschewski T et al (2015) Attention-deficit/hyperactivity disorder. Nat Rev Dis Prim 1:15020. https://doi.org/10.1038/nrdp.2015.20
5. Nigg JT (2013) Attention-deficit/hyperactivity disorder and adverse health outcomes. Clin Psychol Rev 33:215–228. https://doi.org/10.1016/j.cpr.2012.11.005
6. Dalsgaard S, Østergaard SD, Leckman JF et al (2015) Mortality in children, adolescents, and adults with attention deficit hyperactivity disorder: a nationwide cohort study. Lancet 385:2190–2196. https://doi.org/10.1016/S0140-6736(14)61684-6
7. Jensen PS, Mrazek D, Knapp PK et al (1997) Evolution and Revolution in Child Psychiatry: ADHD as a Disorder of Adaptation. J Am Acad Child Adolesc Psychiatry 36:1672–1681. https://doi.org/10.1097/00004583-199712000-00015
8. Shelley-Tremblay JF, Rosén LA (1996) Attention deficit hyperactivity disorder: an evolutionary perspective. J Genet Psychol 157:443–453. https://doi.org/10.1080/00221325.1996.9914877
9. Hartmann T (1993) Attention deficit disorder: a different perception. Underwood Books, California
10. Buss DM (2008) Evolutionary psychology: the new science of the mind, 3rd edn. Pearson/Allyn and Bacon Publishers, Boston
11. Crawford C, Salmon C (2002) Psychopathology or adaptation? Genetic and evolutionary perspectives on individual differences and psychopathology. Neuro Endocrinol Lett 23:39–45
12. Durisko Z, Mulsant BH, McKenzie K, Andrews PW (2016) Using evolutionary theory to guide mental health research. Can J Psychiatry 61:159–165. https://doi.org/10.1177/0706743716632517
13. Arcos-Burgos M, Acosta MT (2007) Tuning major gene variants conditioning human behavior: the anachronism of ADHD. Curr Opin Genet Dev 17:237. https://doi.org/10.1016/j.gde.2007.04.011
14. Thagaard MS, Faraone SV, Sonuga-Barke EJ, Østergaard SD (2016) Empirical tests of natural selection-based evolutionary accounts of ADHD: a systematic review. Acta Neuropsychiatr 28:249–256. https://doi.org/10.1017/neu.2016.14
15. Wang E, Ding Y-C, Flodman P et al (2004) The genetic architecture of selection at the human dopamine receptor D4 (DRD4) gene locus. Am J Hum Genet 74:931–944. https://doi.org/10.1086/420854
16. Ding Y-C, Chi HC, Grady DL et al (2002) Evidence of positive selection acting at the human dopamine receptor D4 gene locus. Proc Natl Acad Sci 99:309–314. https://doi.org/10.1073/pnas.012464099
17. Gizer IR, Ficks C, Waldman ID (2009) Candidate gene studies of ADHD: a meta-analytic review. Hum Genet 126:51–90. https://doi.org/10.1007/s00439-009-0694-x
18. Benjamin J, Li L, Patterson C et al (1996) Population and familial association between the D4 dopamine receptor gene and measures of Novelty Seeking. Nat Genet 12:81–84. https://doi.org/10.1038/ng0196-81
19. Ebstein RP, Novick O, Umansky R et al (1996) Dopamine D4 receptor (D4DR) exon III polymorphism associated with the human personality trait of Novelty Seeking. Nat Genet 12:78–80. https://doi.org/10.1038/ng0196-78
20. Williams J, Taylor E (2006) The evolution of hyperactivity, impulsivity and cognitive diversity. J R Soc Interface 3:399–413. https://doi.org/10.1098/rsif.2005.0102
21. Arildskov TW, Virring A, Lambek R et al (2020) The factor structure of attention-deficit/hyperactivity disorder in schoolchildren. medRxiv. https://doi.org/10.1101/2020.06.15.20126789
22. DuPaul GJ, Anastopoulos AD, Power TJ et al (1998) Parent ratings of attention-deficit/hyperactivity disorder symptoms: factor structure and normative data. J Psychopathol Behav Assess 20:83–102. https://doi.org/10.1023/A:1023087410712
23. DuPaul GJ, Power TJ, Anastopoulos AD, Reid R (1998) ADHD rating scale—IV: checklists, norms, and clinical interpretation. The Guilford Press, New York
24. Szomlaiski N, Dyrborg J, Rasmussen H et al (2009) Validity and clinical feasibility of the ADHD rating scale (ADHD-RS) A Danish Nationwide Multicenter Study. Acta Paediatr 98:397–402. https://doi.org/10.1111/j.1651-2227.2008.01025.x
25. Canadian Attention Deficit Hyperactivity Disorder Resource Alliance (CADDRA) (2011) Canadian ADHD practice guidelines, 3rd edn. CADDRA, Toronto
26. Thompson T, Lloyd A, Joseph A, Weiss M (2017) The Weiss Functional Impairment Rating Scale-Parent Form for assessing ADHD: evaluating diagnostic accuracy and determining optimal thresholds using ROC analysis. Qual Life Res 26:1879–1885. https://doi.org/10.1007/s11136-017-1514-8
27. Wechsler D (2003) Wechsler intelligence scale for children–Fourth Edition (WISC-IV). San Antonio
28. Tellegen A, Briggs PF (1967) Old Wine in new skins: Grouping Wechsler subtests into new scales. J Consult Psychol 31:499–506. https://doi.org/10.1037/h0024963
29. Sattler JM (2001) Assessment of children: cognitive applications, 4th edn. Jerome M. Sattler, Publisher, Inc., San Diego
30. Cambridge Cognition Limited (2014) CANTABeclipse Test Administration Guide, version 6.0.0. Cambridge Cognition Limited, Cambridge
31. StataCorp. (2017) Stata statistical software: release 15. StataCorp LLC, College Station
32. IBM Corp (2011) IBM SPSS statistics for windows, version 20.0. IBM Corp, Armonk
33. Van den Driessche C, Chevrier F, Cleeremans A, Sackur J (2019) Lower attentional skills predict increased exploratory foraging patterns. Sci Rep 9:10948. https://doi.org/10.1038/s41598-019-46761-0
34. Gliga T, Smith TJ, Likely N et al (2018) Early visual foraging in relationship to familial risk for autism and hyperactivity/inattention. J Atten Disord 22:839–847. https://doi.org/10.1177/1087054715616490
35. Robaey P, McKenzie S, Schachar R et al (2016) Stop and look! Evidence for a bias towards virtual navigation response strategies in children with ADHD symptoms. Behav Brain Res 298:48–54. https://doi.org/10.1016/j.bbr.2015.08.019
36. Barkley RA, Fischer M, Smallish L, Fletcher K (2006) Young adult outcome of hyperactive children: adaptive functioning in major life activities. J Am Acad Child Adolesc Psychiatry 45:192–202. https://doi.org/10.1097/01.chi.0000189134.97436.e2
37. Østergaard SD, Dalsgaard S, Faraone SV et al (2017) Teenage parenthood and birth rates for individuals with and without attention-deficit/hyperactivity disorder: a nationwide cohort study. J Am Acad Child Adolesc Psychiatry 56:578-584.e3. https://doi.org/10.1016/j.jaac.2017.05.003
38. Flory K, Molina BSG, Pelham WE et al (2006) Childhood ADHD predicts risky sexual behavior in young adulthood. J Clin Child Adolesc Psychol 35:571–577. https://doi.org/10.1207/s15374424jccp3504_8
39. Demontis D, Walters RK, Martin J et al (2019) Discovery of the first genome-wide significant risk loci for attention deficit/hyperactivity disorder. Nat Genet 51:63–75. https://doi.org/10.1038/s41588-018-0269-7
40. Andrews PW, Gangestad SW, Matthews D (2002) Adaptationism—how to carry out an exaptationist program. Behav Brain Sci 25:489–504. https://doi.org/10.1017/S0140525X02000092

41. Baird J, Stevenson JC, Williams DC (2000) The evolution of ADHD: a disorder of communication? Q Rev Biol 75:17–35. https://doi.org/10.1086/393256
42. Hecht GM (1998) ADHD as a disorder of adaptation. J Am Acad Child Adolesc Psychiatry 37:799–799. https://doi.org/10.1097/00004583-199808000-00004
43. Goldstein S, Barkley RA (1998) ADHD, hunting, and evolution: "Just so" stories. ADHD Rep 6:1–4
44. Swanson J, Moyzis R, Fossella J et al (2002) Adaptationism and molecular biology: an example based on ADHD. Behav Brain Sci 25:530–531. https://doi.org/10.1017/S0140525X02490097
45. Nigg JT, Willcutt EG, Doyle AE, Sonuga-Barke EJS (2005) Causal heterogeneity in attention-deficit/hyperactivity disorder: do we need neuropsychologically impaired subtypes? Biol Psychiatry 57:1224–1230. https://doi.org/10.1016/j.biopsych.2004.08.025
46. Lambek R, Tannock R, Dalsgaard S et al (2011) Executive dysfunction in school-age children with ADHD. J Atten Disord 15:646–655. https://doi.org/10.1177/1087054710370935
47. Swanson JM, Schuck S, Porter MM et al (2012) Categorical and dimensional definitions and evaluations of symptoms of ADHD: history of the SNAP and the SWAN rating scales. Int J Educ Psychol Assess 10:51–70