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Attention-Deficit/Hyperactivity Disorder (ADHD) and Time Perception in Adults: Do Adults with Different ADHD Symptomatology Severity Perceive Time Differently? Findings from the National Czech Study

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
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Background: Studies show neurological differences between patients with attention-deficit/hyperactivity disorder (ADHD) and healthy controls. Furthermore, it is possible that poor timing is linked with impairments in neural circuitry. This study aimed to test the hypothesis that there is a difference in time perception between adults with severe ADHD symptomatology and adults with no ADHD symptomatology.

Material/Methods: Previously, we collected data from a more extensive set of participants (n=1518) concerning the prevalence of ADHD in adulthood. We recruited participants from 3 groups defined by increasing ADHD severity out of this participant pool. Each participant was presented with 2 experimental tasks (in counterbalanced order): duration estimation and duration discrimination.

Results: In general, we did not find any specific differences in time perception related to the severity of ADHD. Regarding duration estimation, we found that the difference between the actual and estimated durations increased with the actual duration ($F(1, 7028.00)=2685.38$, $P<0.001$). Although the differences between groups were not significant, the group×duration interaction was ($F[1, 7028.00]=10.86$, $P<0.001$), with a very small effect size ($\eta_p^2<0.001$, 95% CI [0.00, 0.01]).

Conclusions: The results suggest that although individuals may demonstrate increased ADHD symptomatology, they may not have objectively more significant difficulties in time perception tasks than their counterparts with mild symptomatology. Nonetheless, time perception should be further studied because, as qualitative research suggests, participants with more severe ADHD symptomatology subjectively perceive more significant differences in time management in real life.

Keywords: Adolescent Psychiatry • Attention Deficit Disorder with Hyperactivity • Neuropsychology • Time Perception

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Background

Attention-deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder with a rate that generally ranges between 5% and 7% among children [1]. This condition has recently been identified as a lifelong disorder, lasting into adulthood in approximately 60% of cases (the adulthood prevalence is estimated to be between 3% and 5%) [2,3]. While it has been exhaustively studied among children, less information is available regarding ADHD in the adult population. In adulthood, ADHD has been linked to eating disorders [4] and alcohol and substance abuse [5,6].

Studies have shown neurological differences between patients with ADHD and healthy controls. Differences have been identified in multiple brain structures, such as the prefrontal cortex white matter, corpus callosum, and cerebellar vermis [7,8]. Therefore, it is hypothesized that these neuroanatomical differences may be one of the causes of difficulties with organization and planning in people with ADHD [9,10].

Time perception, the ability to estimate periods, is associated with working memory and attention. Time estimation is a necessary component of everyday life, as it directly influences planning and organizing abilities. It has been previously shown that children with ADHD have difficulties with time production and time reproduction tasks. It is hypothesized that time perception is impaired in people with ADHD. In 1997, Barkley et al proposed one of the core models of impaired time perception and ADHD, arguing that an underlying impairment compromises neuropsychological functions in behavioral inhibition [11].

Deficits in duration discrimination and duration estimation may affect the temporal organization of behavior in children and adolescents with ADHD. Children with ADHD tend to perform poorly on time reproduction tasks. It has been found in time-based prospective memory tasks that there is a link between the severity of ADHD symptomatology and performance deficits [12]. It is further hypothesized that these deficits may impact other functions, such as perceptual language skills and motor timing [13]. Difficulties with poor timing have been shown, for example, in a study utilizing rope jumping as this is a simple task requiring motor coordination and time perception [14].

It has been shown that deficits traditionally linked with ADHD are found across multiple tasks, such as sensorimotor synchronization, duration discrimination and reproduction, verbal time estimation, and temporal anticipation [15]. Research also suggests a possible link between timing difficulties and neural circuitry. Neural circuitry plays a role in temporal processing [16]. Further research indicates that people with more severe ADHD symptomatology are more inclined toward strategies involving reward-processing brain areas in the face of immediate reward rather than a sustained response to motivational context [17]. Current research on the relevant neurological impairment suggests a deficiency in utilizing temporal information in ADHD rather than a central timing mechanism problem [18].

However, the results are not conclusive overall. For example, in 2004, Brown and Vickers point out that the observed impairment in time perception among individuals with ADHD may be limited to tasks that involve response inhibition, reaction time, and motor actions [19]. Bauermeister further supported this and found that ADHD is associated with a specific impairment in the capacity to reproduce durations but not the ability to estimate durations [20]. In 2010, Hwang offered a different explanation that the errors made during time estimation tasks may be due to the limited attentional capacity rather than a primary problem in timing per se [21].

Finally, time estimation tasks can be used as a therapeutic tool in ADHD. It has been found that these tasks can improve cognitive symptoms in ADHD and increase the activity in cortical areas related to attention and memory [22].

We have previously studied the prevalence of ADHD symptomatology among the adult population in the Czech Republic [23], along with their time perception styles as measured by the Zimbardo Time Perspective Inventory [24]. We wanted to build on our previous research and attempt to replicate prior research performed in the Czech Republic.

This study aimed to test the hypothesis that there is a difference in time perception between adults with severe ADHD symptomatology and adults with no ADHD symptomatology. Based on available foreign research, we hypothesized that adults with more severe ADHD symptomatology would perform worse on time estimation and discrimination tasks than those with milder symptomatology.

Material and Methods

Ethics Statement

This study was fully approved by the Ethics Committee of General Faculty Hospital (approval number: 10/17), and the study upheld all ethical requirements. Participants provided informed consent and were reminded about their right to withdraw.

Participants

This study is a sub-study of a research grant in which we collected data from a large set of participants n=1518) concerning the prevalence of ADHD in adulthood [9,23,25,26]. After participants

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Table 1. Demographics of each group. Means and standard deviations are shown for age, while the rest of the variables are described by counts. Differences between the 3 groups were tested with the *t* test (for age) or with the χ^2 test.

Variable		Group			Test of differences
		First	Second	Third	
Age	Mean (SD)	48.18 (14.34)	39.59 (13.22)	38.95 (13.35)	$F(2,62)=3.11$, $P=0.052$
n (n females)		22 (10)	22 (10)	21 (11)	$\chi^2(2)=0.27$, $P=0.872$
Education	Elementary/apprentice school	8	8	9	$\chi^2(4)=0.86$, $P=0.930$
	High school diploma	7	6	7	
	University	7	8	5	
City size	Less than 4999	4	5	5	$\chi^2(6)=10.263$, $P=0.114$
	5000-9999	3	2	6	
	10 000-99 999	6	1	1	
	More than 100 000	9	14	9	
Income	Less than 20 000	4	2	2	$\chi^2(8)=8.033$, $P=0.430$
	20 001-30 000	4	5	5	
	30 001-40 000	6	3	4	
	More than 40 000	5	11	10	
Medication use		6	8	8	$\chi^2(2)=0.66$, $P=0.720$
Unemployment		14	15	11	$\chi^2(2)=1.20$, $P=0.550$

completed the questionnaire, part of our study involved asking participants to participate in the time estimation tasks. From the original sample of 1518 participants, 899 agreed to be contacted for further studies. We divided the whole sample into 3 groups based on the severity of their ADHD symptoms (complete demographics reported in Vňuková et al [23]). For these purposes, the screening part of the Adult Attention-Deficit/Hyperactivity Disorder Self-Report Scale (ASRS) was usually used. Recently, this questionnaire and its screening part have been validated in the Czech language and were a useful tool for screening ADHD symptomatology among adults [25]. There are 2 typical methods for interpreting the screening part. The first approach gives 1 point for each question that participants answer with a high value (responses of 3 to 5 for questions 1 through 3, and responses 4 to 6 for questions 4 through 6). Therefore, each participant can score 0 to 6 points using this rating scheme. The second approach takes the sum of numerical responses to all 6 questions; thus, participants' scores can range from 0 to 30 points. We classified participants using the following logic. We divided both scores into terciles, which divided participants into 9 groups (3 intervals for each rating scheme). We included only participants in which both rating schemes were assigned to the first, second, or third tercile. By excluding the participants who refused to be contacted for further studies, this approach selected 272 possible participants from the first group, 219 from the second group, and 184 from the third group.

From this pool, we were able to recruit 22 participants from the first group, 22 participants from the second group, and 21 participants from the third group. An entire demographic description of each group is presented in **Table 1**.

Apparatus and Stimuli

The experiment was programmed using PsychoPy software [27] and was presented on an "HP EliteBook 450" IPS screen with an FHD resolution of 1920×1080. Black squares (subtending 25% of the screen height) were presented in the center of the gray screen. Participants were seated approximately 100 cm from the monitor.

After completing the experiment, participants completed the block design subtest of the Wechsler Adult Intelligence Scale (WAIS) and a computerized Continuous Performance Test (CPT).

Methods

Each participant was presented with 2 experimental tasks (in counterbalanced order): duration estimation and duration discrimination.

In the duration estimation experiment, participants estimated the length of the interstimulus interval. In each trial, they

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were presented with square stimuli for 0.5 s, followed by a blank screen for a duration of 7, 12, or 20 s; finally, the square stimuli reappeared for 0.5 s. The participant's task was to select the length of the interval on a scale from 0 to 30 s. Each duration was presented 30 times, resulting in 90 trials. Before the experiment, 3 trials were presented for training purposes; these trials were discarded before the analysis.

In the duration discrimination experiment, participants were repeatedly presented with 4 rectangles (each for 0.5 s). Their task was to respond to the interstimulus intervals between the first and second rectangles or between the third and fourth rectangles that were longer. Between the second and third intervals of the stimulus, a small plus sign was shown as a division between the stimuli. The duration of both intervals was controlled using a 1-up, 3-down staircase procedure. There were 60 trials with a starting difference of 10 s and linearly decreasing step sizes (from 0.8 to 0.1). After the presentation, participants pressed the arrow keys to indicate whether the first interval was longer (left arrow key) or whether the second interval was longer (right arrow key).

Statistical Analysis

Data were analyzed in R statistical software [28]. We computed the difference between the estimated and actual duration for the duration estimation task. We tested the size of these differences (outcome) based on group membership (a categorical predictor) and interval duration (a continuous predictor) using linear mixed models with participants as a random factor. Subsequently, we created 2 additional models – one with sex as another factor, including the interactions with duration and group, and another with education as an additional factor (again including interactions). Finally, we also ran 4 models, each having additional predictors corresponding to several potential confounds (size of the city, income, usage of psychotropic medicine in the past, and whether they were unemployed in the past). Given the exploratory nature of these models, we did not include interaction with other variables, as the high number of tests would lead to a higher chance of type I error. The significance of each predictor was tested using F tests with the Satterthwaite approximation for degrees of freedom, which produces acceptable type I error rates [29]. Fixed-factor effect sizes were expressed using η_p^2, including 95% confidence intervals (CI).

For the duration discrimination task, we computed the estimated threshold as the average difference in intensity for the last 5 trials in which the staircase reversed its direction. To ensure that participants reached their point, we included only participants whose differences for these 5 trials had a standard deviation of less than 0.2. This value was selected by visual inspection of the convergence of the staircase method. Additionally, we reran the analysis with different cutoff values for the standard deviation, obtaining qualitatively similar results. The differences in thresholds between groups were tested using linear models. (Note, we could not take advantage of hierarchical structure, as we averaged the threshold estimate for each participant.) We also ran 2 different models with sex and education as additional factors (including interaction with group variable). Again, we ran 4 exploratory models with other elements similar to the duration estimation.

We also used linear models to test the differences in reaction time on the CPT and performance on the WAIS block design subtest.

Results

We did not find any specific differences in time perception related to the severity of ADHD. The results for both tasks are visualized in **Figure 1**. For duration estimation, we found an increasing difference between the actual and estimated durations as the actual duration increased ($F(1, 7028.00)=2685.38$, $P<0.001$, $\eta_p^2=0.28$, 95% CI [0.26, 0.29]). In particular, for a duration of 7 s, the difference was 2.01 (SD=1.79); for a duration of 12 s, the difference was 3.08 (SD=1.93), while it was 4.94 (SD=2.65) for a 20 s duration. (Note, we reanalyzed the data treating the difference relative to the duration [eg, each difference was divided by 7, 12, or 200], which resulted in a small significant effect size [$P<0.001$, $\eta_p^2=0.03$] for differences between durations. Additionally, we did not observe a significant interaction [$P=0.097$, $\eta_p^2<0.001$].)

Although the differences between groups were not significant ($F(1, 7028.00)=0.21$, $P=0.809$, $\eta_p^2=0.01$, 95% CI [0.00,.04]), the group×duration interaction was ($F(1, 7028.00)=10.86$, $P<0.001$), with a very small effect size ($\eta_p^2<0.001$, 95% CI [0.00, 0.01]).

For duration discrimination, we found differences that were not significant in thresholds between groups ($F(2, 76)=1.77$, $P=0.177$, $\eta_p^2=0.04$, 95% CI [0.00, 0.13]).

Sex and Education Differences

When we added sex as an additional factor, the differences were not significant for both the duration estimation ($P\geq0.171$) and duration discrimination tasks ($P\geq0.09$) for main characteristics and the interaction with the group. For differences in education, we found no differences in the case of duration estimation ($P\geq0.143$). In the case of duration discrimination, we found differences between education categories ($P=0.039$); however, the interaction with the group was not significant ($P=0.487$); therefore, there were no practical differences in time perception concerning the severity of ADHD symptoms.

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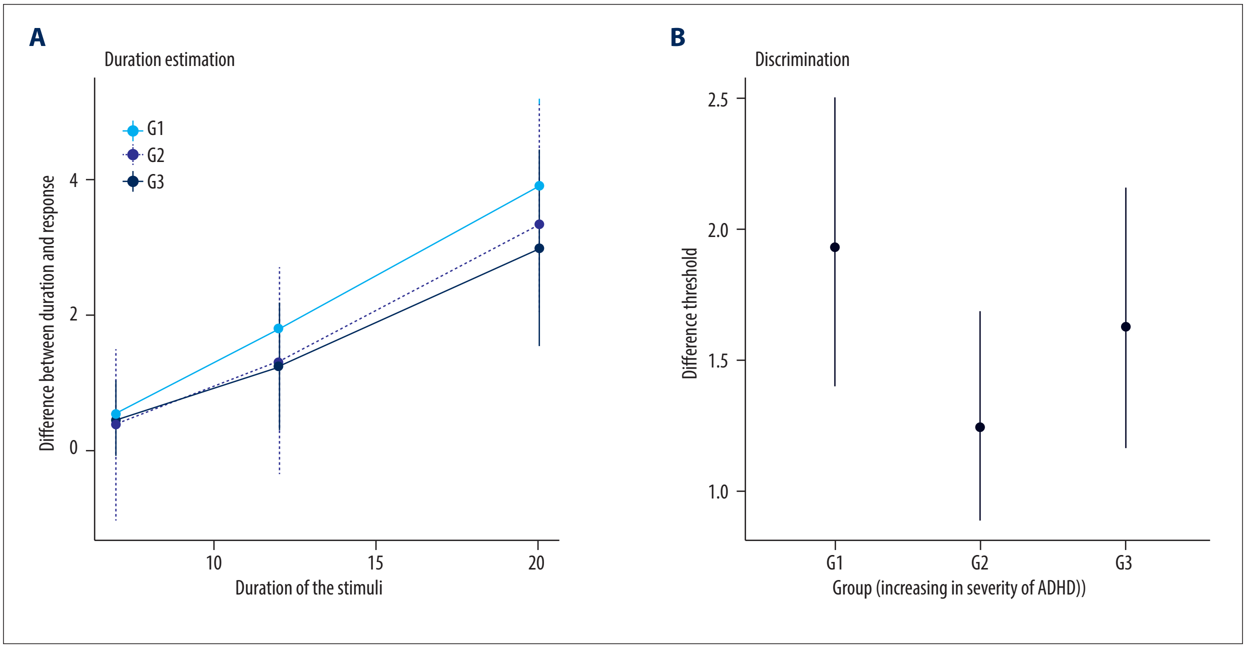

Figure 1. Results for duration estimation (A) and duration discrimination (B). The y axis shows the difference between the actual interval and estimated length for duration estimation. For duration discrimination, the y axis shows averaged threshold computed from the staircase method (only from the last 5 trials and only participants who reached convergence). Vertical bars denote the bootstrapped 95% confidence intervals of the means.

Models with Additional Exploratory Variables

To see the possible influence of additional confounders, we ran 4 different models, each with 1 other independent variable: income, city size, whether the participant was unemployed, and usage of psychotropic medicine for duration estimation and duration discrimination tasks. None of the extended models showed a difference in the main conclusions in comparison with the original model without the variables duration estimation ($P \geq 0.433$) or duration discrimination ($P \geq 0.242$). *P* values were corrected for chance findings using the Benjamini-Hochberg procedure. The complete model description is shown in **Table 2**.

CPT and WAIS Block Design

We found differences that were not significant between groups in CPT reaction time ($F(2, 67)=2.07$, $P=0.134$, $\eta_p^2=0.06$, 95% CI [0.00, 0.16]) and in WAIS block design performance ($F(2, 64)=0.52$, $P=0.596$, $\eta_p^2=0.02$, 95% CI [0.00, 0.08]).

Discussion

The present study aimed to test the hypothesis that there is a difference in time perception between adults with severe ADHD symptomatology and adults with no ADHD symptomatology. We hypothesized that adults with more severe ADHD symptomatology would perform worse on time estimation and discrimination tasks than those with milder symptomatology.

A previous study showed that the prevalence of ADHD symptomatology in adulthood is up to 5%, which corresponds to rates found in the literature [5,23]. Previously, we hypothesized that time perception and the impairment of time perception might be one of the critical components, if not one of the key symptoms, of ADHD [9,30]. Existing research suggests that children with ADHD have problems with tasks such as time reproduction [11]. We believed we could replicate those results in an adult population in our present study.

Research outside the Czech Republic suggests a difference in time perception between patients with ADHD and their counterparts without ADHD [14,20,22]. For example, children with ADHD tend to perform poorly on time reproduction tasks [13]. Our research found no differences in time perception related to the severity of ADHD symptomatology. Furthermore, we saw that time deficits associated with ADHD can be spread across multiple tasks [15]. However, our research did not replicate those previous findings [16,31,32]. Our results do not support those findings. We found no difference in the time estimation or the time discrimination tasks. Therefore, our results align with the findings of Brown and Vickers [19], who pointed out that the differences may be limited to only specific tasks.

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Table 2. Full output from regression models. We report the output of *F* tests (with Satterthwaite approximation for degrees of freedom in case of linear mixed models in duration estimation). We also report the *P* value after correction false discoveries using the Benjamini-Hochberg procedure. Each regression model describes which additional predictor was added. Results for individual regression models with 4 additional predictors. We also report adjusted *P* values to reduce the chance of false findings using the Benjamini-Hochberg procedure (adjustment was computed separately for both tasks). After the correction, none of the additional variables were significant nor changed the original findings.

	Additional predictor	Regression term	df 1	df 2	*F*	*P* value	*P* value after correction
Duration estimation	City size	Duration	1	5872	1433.50	<0.001	<0.001
	City size	Group	2	61	0.85	0.43	0.58
	City size	City_size2	1	61	1.81	0.18	0.29
	City size	Duration_group	2	5872	27.55	<0.001	<0.001
	Income	Duration	1	5872	1433.50	<0.001	<0.001
	Income	Group	2	61	0.54	0.59	0.62
	Income	Income	1	61	1.43	0.24	0.34
	Income	Duration_group	2	5872	27.55	<0.001	<0.001
	Unemployment	Duration	1	5872	1433.50	<0.001	<0.001
	Unemployment	Group	2	61	0.59	0.56	0.62
	Unemployment	Unemployment	1	61	2.75	0.10	0.18
	Unemployment	Duration_group	2	5872	27.55	<0.001	<0.001
	Medication use	Duration	1	5872	1433.50	<0.001	<0.001
	Medication use	Group	2	61	0.72	0.49	0.61
	Medication use	Medication use	1	61	0.00	0.99	0.99
	Medication use	Duration _ group	2	5872	27.55	<0.001	<0.001
Duration discrimination	City size	Group	2	61	1.32	0.28	0.37
	City size	City_size2	1	61	0.09	0.77	0.77
	Income	Group	2	61	0.88	0.42	0.48
	Income	Income	1	61	2.06	0.16	0.35
	Unemployment	Group	2	61	1.69	0.19	0.35
	Unemployment	Unemployment	1	61	5.97	0.02	0.07
	Medication use	Group	2	61	1.55	0.22	0.35
	Medication use	Medication use	1	61	6.21	0.02	0.07

F – *F* value; df – degrees of freedom.

Furthermore, although we previously saw that male participants tend to have higher ADHD symptomatology than female participants [23], sex or even education did not play any role in our presents results either. We found a significant interaction only in the time estimation tasks. This is in line with the findings of Bauermeister et al, who also found that there was no difference in estimation; thus, our results might point to the fact that poor time estimation and discrimination are due to impaired attention capacity rather than caused by the ability to perceive time differently [20].

Therefore, we see that our present results do not support the model demonstrated by Barkley et al, who proposed that an underlying impairment compromises the neuropsychological

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functions of behavioral inhibition [11]. It is possible that while these behavioral inhibitions are one of the primary deficits in childhood, even people with higher ADHD symptomatology can compensate for these problems in adulthood and find adequate coping strategies. Our research, similar to other studies [18-21] shows that there might be some deficiencies; however, the results are not conclusive, and the time management among adults with ADHD needs to be explored even further. We believe that our results show that although adults with higher ADHD symptomatology do show some errors, they are linked to attentional capacity rather than to problems with timing. Even when models were run including certain socio-demographic factors, the results were not significant, and a more complex analysis would not be feasible because of our small sample size. This corresponds to findings by Hwang et al [21]. We believe our results make an essential contribution to the discussion about specific ADHD symptoms in adulthood, their neuropsychological nature, and real-life consequences.

Limitations of the Study

Limitations of this study include that the participants were not clinically diagnosed, but they were divided into groups based on ADHD symptom severity as measured by the ASRS questionnaire. However, this questionnaire has been validated and has shown good psychometric properties. In discussing this limitation, it is necessary to point out that the intensity of ADHD symptomatology was considered rather than the diagnosis itself. As the task was always administered to the participant first, this should not have influenced their performance on the job. The participants were invited to perform the experimental tasks during their free time; therefore, the tasks were administered at different times for each participant. This might have affected their performance due to overall exhaustion after the working day. We suggest comparing a group of clinically diagnosed ADHD participants with a control group without ADHD for future research. This may bring deeper insight if there is a difference between ADHD symptom intensity and the diagnosis itself. Last, the second part of our study was underpowered; therefore, for future research, we recommend a more extensive study group, which was not possible in our research for budgetary reasons. Despite this fact and the complex research design, we believe that the present study brings new insight into this critical issue.

Conclusions

The present results suggest that although individuals may demonstrate increased ADHD symptomatology, they do not have objectively more significant difficulties in time perception tasks than their counterparts with low symptomatology. Nonetheless, time perception should be further studied because, as qualitative research suggests, participants with increased ADHD symptomatology subjectively perceive more significant differences in time management.

Department and Institution Where Work Was Performed

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Data Sharing Statement

Data are available on request from the authors.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or part. Figures in this manuscript were created by Filip Děchtěrenko, co-author of this manuscript.

References:

1. Thomas R, Sanders S, Doust J, et al. Prevalence of attention-deficit/hyperactivity disorder: A systematic review and meta-analysis. Pediatrics. 2015;135(4):e994-e1001
2. Matte B, Rohde LA, Grevet EH. ADHD in adults: A concept in evolution. ADHD Atten Deficit Hyperact Disord. 2012;4(2):53-62
3. Kessler RC, Adler L, Barkley R, et al. The prevalence and correlates of adult ADHD in the United States. Am J Psychiatry. 2010;163(4):716-23
4. Ptacek R, Kuzelova H, Stefano GB, et al. Disruptive patterns of eating behaviors and associated lifestyles in males with ADHD. Med Sci Monit. 2014;20:608-13
5. van Emmerik-van Oortmerssen K, van de Glind G, van den Brink W, et al. Prevalence of attention-deficit hyperactivity disorder in substance use disorder patients: A meta-analysis and meta-regression analysis. Drug Alcohol Depend. 2012;122(1-2):11-19
6. Bitter I, Mohr P, Balogh L, et al. ADHD: A hidden comorbidity in adult psychiatric patients. ADHD Atten Deficit Hyperact Disord. 2019;8(1):83-89
7. Johansen EB, Killeen PR, Russell VA, et al. Origins of altered reinforcement effects in ADHD. Behav Brain Funct. 2009;5:7
8. Tripp G, Wickens JR. Neurobiology of ADHD. Neuropharmacology. 2009;57(7-8):579-89
9. Weissenberger S, Klicperova-Baker M, Vňuková M, et al. ADHD and time perception: Findings and treatments. Act Nerv Super (Praha). 2019;61(3):s41470-019-00027-2
10. Weissenberger S, Děchtěrenko F, Klicperova-Baker M, et al. Motor timing deficits in community and clinical boys with hyperactive behavior: The effect of methylphenidate on motor timing. Front Psychol. 2020;11(1):1-7
11. Barkley RA, Koplowitz S, Anderson T, Mcmurray MB. Sense of time in children with ADHD: Effects of duration, distraction, and stimulant medication. J Int Neuropsychol Soc. 1997;3(4):359-69
12. Talbot KDS, Kerns KA. Event- and time-triggered remembering: The impact of attention deficit hyperactivity disorder on prospective memory performance in children. J Exp Child Psychol. 2014;127:126-43

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13. Smith A, Taylor E, Rogers JW, et al. Evidence for a pure time perception deficit in children with ADHD. J Child Psychol Psychiatry Allied Discip. 2002;43(4):529-42
14. Chen YY, Liaw LJ, Liang JM, et al. Timing perception and motor coordination on rope jumping in children with attention deficit hyperactivity disorder. Phys Ther Sport. 2013;14(2):105-9
15. Noreika V, Falter CM, Rubia K. Timing deficits in attention-deficit/hyperactivity disorder (ADHD): Evidence from neurocognitive and neuroimaging studies. Neuropsychologia. 2013;51(2):235-66
16. Baldwin RL, Flake RA, Meaux JB, et al. Effect of methylphenidate on time perception in children with attention-deficit/hyperactivity disorder. Exp Clin Psychopharmacol. 2004;12(1):57-64
17. Pretus C, Picado M, Ramos-Quiroga JA, et al. Just-in-time response to reward as a function of ADHD symptom severity. Psychiatry Clin Neurosci. 2018;72(9):731-40
18. Radonovich KJ, Mostofsky SH. Duration judgments in children with ADHD suggest deficient utilization of temporal information rather than general impairment in timing. Child Neuropsychol. 2004;10(3):162-72
19. Brown LN, Vickers JN. Temporal judgments, hemispheric equivalence, and interhemispheric transfer in adolescents with attention deficit hyperactivity disorder. Exp Brain Res. 2004;154(1):76-84
20. Bauermeister JJ, Barkley RA, Martínez J V, et al. Time estimation and performance on reproduction tasks in subtypes of children with attention deficit hyperactivity disorder. J Clin Child Adolesc Psychol. 2005;34(1):151-62
21. Hwang SL, Gau SSF, Hsu WY, Wu YY. Deficits in interval timing measured by the dual-task paradigm among children and adolescents with attention-deficit/hyperactivity disorder. J Child Psychol Psychiatry Allied Discip. 2010;51(3):223-32
22. Fontes RM, Marinho V, Carvalho V, et al. Time estimation exposure modifies cognitive aspects and cortical activity of attention deficit hyperactivity disorder adults. Int J Neurosci. 2020;130(10):999-1014
23. Vňuková M, Ptáček R, Děchtěrenko F, et al. Prevalence of ADHD symptomatology in adult population in the Czech Republic – a national study. J Atten Disord. 2021;25(12):1657-64
24. Weissenberger S, Děchtěrenko F, Klicperova-Baker M, et al. ADHD symptoms in adults and time perspectives – findings from a Czech National Sample. Front Psychol. 2020;11:1-7
25. Vňuková M, Ptáček R, Děchtěrenko F, et al. Validity of the Czech translation of the adult Attention-Deficit/Hyperactivity Disorder (ADHD) Self-Report Scale (ASRS). Front Psychol. 2022;13:799344
26. Weissenberger S, Schonova K, Büttiker P, et al. Time perception is a focal symptom of attention-deficit/hyperactivity disorder in adults. Med Sci Monit. 2021;27:e933766
27. Peirce J, Gray JR, Simpson S, et al. PsychoPy2: Experiments in behavior made easy. Behav Res Methods. 2019;51(1):195-203
28. Bunn A, Korpela M. An introduction to dplR. Ind Commer Train. 2008;10(1):11-18
29. Luke SG. Evaluating significance in linear mixed-effects models in R. Behav Res Methods. 2017;49(4):1494-502
30. Ptacek R, Weissenberger S, Braaten E, et al. Clinical implications of the perception of time in attention deficit hyperactivity disorder (ADHD): A review. Med Sci Monit. 2019;25:3918-24
31. Kliger Amrani A, Zion Golumbic E. Spontaneous and stimulus-driven rhythmic behaviors in ADHD adults and controls. Neuropsychologia. 2020;146(December 2019):107544
32. Rubia K, Smith A, Taylor E. Performance of children with attention deficit hyperactivity disorder (ADHD) on a test battery of impulsiveness. Child Neuropsychol. 2007;13(3):276-304

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