https://doi.org/10.22364/bjp.23.07
pp. 128–148

BALTIC JOURNAL
OF PSYCHOLOGY

XXIII

PROFILES OF COGNITIVE ABILITY DOMAINS IN CHILDREN WITH AND WITHOUT ADHD SYMPTOMS

Dana Skara, Edmunds Vanags[1]

Abstract

Studies to date have most often compared the mean scores of an ADHD and control group to see if there are differences between them. Various cluster or linear data processing methods have also been used in studies to group children into certain subgroups according to various characteristics, but so far we have not found any study that has succeeded in dividing both ADHD and control group children into such subgroups. Results vary from study to study. Therefore, the aim of this study was to investigate and compare the heterogeneity of different cognitive ability domains in children with and without ADHD symptoms with qualitative data analysis methods - creating unique profiles of cognitive ability domains for each child. In this study participated 76 children aged 8–13 and were divided into two groups: ADHD group – 46 children (*M* = 10.08; *SD* = 1.67), control group – 30 children (*M* = 9.41; *SD* = 1.60). Four methods were used to calculate cognitive ability domain scores: Stroop's Word and Color Test, Symbol Digit Modalities Test, Digit Span Test, and Continuous Performance Test. The analysis of the profiles revealed a wide heterogeneity in both groups. Also, it was observed in these profiles that children with ADHD experience had more pronounced difficulties in cognitive ability domains compared to the control group. At the same time, it can be concluded that not all children with ADHD experience them. Comparing profiles of children from either of these two groups it can be concluded that some of the children with ADHD symptoms have profiles similar to typically developing children.

Keywords: ADHD, cognitive ability domains, executive functions, cognitive deficit, typically developed children

[1] Corresponding author: Edmunds Vanags, University of Latvia, Imantas 7. linija 1, Riga, LV-1083, Latvia. Email: edmunds.vanags@lu.lv

Attention deficit hyperactivity disorder (ADHD) is the most common mental health disorder diagnosed in children and adolescents (Willcutt, 2012). Depending on the diagnostic criteria and methods used, the number of children affected by ADHD varies significantly around the world. According to a meta-analysis by researcher Willcutt (2012), the overall prevalence of ADHD ranges from 4% to 13.3%, depending on the various interventions used to identify this disorder. These results clearly show that disorder prevalence estimates are sensitive to methodological differences.

Clinical description of ADHD has not changed significantly for several decades: DSM-V and ICD-11 state that ADHD begins in childhood and is often seen in preschool age (APA, 2013; World Health organization, 2019). A specialist looking at the disorder description might come to think that every person with ADHD will have an identical clinical picture, or that this disorder is linearly dependent on the number of symptoms or age of onset. To date ADHD symptoms have consistently clustered quite reliably on two correlated dimensions in factor analysis. However, children with ADHD vary so much in their symptom profiles, trajectories, and clinical outcomes, biological and psychological correlates, that the field is seeking alternative approaches that incorporate the emotional, cognitive, and behavioral dimensions of functioning, based on psychiatric categories to create informative phenotypes that would improve clinical prognosis and better explain etiology (Karalunas & Nigg, 2020).

Research to date has showed that children with ADHD tend to vary widely in their symptom profiles, trajectories of impairment, etiology, deficits in various abilities, and competencies (Fair et al., 2012; Nigg et al., 2005; E. Sonuga-Barke et al., 2010). Our understanding of the etiology and neurobiological underpinnings of ADHD is likely to remain limited without adequate characterization of this disorder's heterogeneity. Studies using neuropsychological data show that not all individuals with ADHD have deficits in all relevant neuropsychological domains (Fair et al., 2012; Sonuga-Barke et al., 2010). Therefore, it is important to also examine typically developing population variation to better understand atypical developmental trajectories (Costa Dias et al., 2015).

Categorical or dimensional approaches are commonly used to interpret ADHD symptoms. Both use binary symptom counts (present or absent) with little attention paid to individual combinations of symptoms. Therefore, two individuals with the same clinical diagnosis and number of symptoms according to the DSM or ICD may have quite different profiles and clinical manifestations. Focusing only on the sum of symptoms, one may miss useful clinical information, hindering the identification of underlying etiological factors and potential biomarkers (Rosales et al., 2015). An important feature of ADHD is its interindividual heterogeneity in cognitive profiles and comorbidities (Steinhausen, 2009; Willcutt, 2012). A better understanding of the cognitive profiles of ADHD could help guide more precise treatment approaches (Silk et al., 2019). Therefore, the main task of this study is to qualitatively investigate cognitive difficulties in both children with ADHD and neurotypical development.

ADHD and heterogeneity of deficits in cognitive ability domains

Deficits in cognitive ability domains are considered a core component of ADHD symptomatology (Castellanos & Tannock, 2002; Kofler et al., 2019). Children with ADHD may experience difficulties in various areas (Sonuga-Barke, 2002). Most often, these children show deficits in cognitive abilities such as attention span, executive functions (EF) and self-regulation. To date, EFs have been most closely associated with ADHD symptoms of hyperactivity and inattention (Willcutt et al., 2005).

In order to more qualitatively identify the mechanisms related to mental illnesses, it is necessary to compare them with well-adapted individuals with the same cognitive style profiles. The group profiles most consistently identified are characterized by EF deficits (working memory and inhibition, which most often cluster together) and slow or variable reaction time (Fair et al., 2012).

To date, there have been several efforts to group all children with ADHD into specific subgroups based on temperament, cognitive deficits, and personality traits. However, none of these approaches has so far been able to classify all children with ADHD into such subgroups (Bergwerff et al., 2019). Therefore, the main goal of this study is to gain more clarity in the cognitive profiles of this disorder, which would be examined not at the level of subgroups of children, but according to an individual approach. At the same time, to similarly study the profiles of children with typical development in order to better understand where "typical" development ends and "atypical" begins, leading to a diagnosis of ADHD, if such a line can be drawn at all.

Therefore, this study promoted two research questions: are there statistically significant differences between the scores of cognitive ability domain tasks in children with and without ADHD symptomology; and what is the heterogeneity of cognitive ability domain tasks of these two groups.

Method

Participants

A Facebook campaign inviting parents / legal guardians to join the study was chosen for purposes of recruiting study participants, due to the epidemiological restrictions of COVID-19. The campaign was active from 22nd of March to 28th of August 2021, and during this time 519 applications were received. All potential participants received emails containing full information about the study, its goals and testing procedure, and informed consent about participation. To ensure equal testing conditions, calls were made to each parent or legal guardian who responded to the email in order to explain the process of the remote testing and all the instructions and necessary preparations. In the end, 151 participants successfully completed the testing procedure due to initial screening or participants dropping out. Exploro.lv platform was used to carry out the remote testing. From these, due to the ambiguity of their clinical symptoms, data from 76 participants were used for the data analysis in this study. Children were divided into relevant groups by either clinical diagnosis of ADHD as reported by their parents (n = 21) or by results from the Conner's ADHD index subscale results (n = 25), with remaining children assigned to the control group. Overall, 76 children were enrolled in the study, divided into two groups as follows: ADHD (n = 46, M = 10,08; SD = 1,67, boys – 72%) and control group (n = 30, M = 9,41; SD = 1,60, boys – 73%).

Instruments

1) *Stroop Color and Word Test* (SCWT, Stroop, 1935, modification Vanags & Ekmanis, 2018). The test consists of 3 parts with congruent, non-congruent and control stimuli. In the first part the participant must press a key each time when the color name appears on the screen. In the second part the participant must press a key only when the color name matches the color of the word. During the third part the participant must press a key only when the color name does not match the color of the word. The reaction time and missed reactions or incorrect reactions for each step are calculated.

   Three test indicators were used: reaction time measuring information processing speed and sustained attention from the first step. The average number of correct responses from the second and third steps, which reflects the ability of working memory, inhibitory control and selective attention (Strauss et al., 2006). From the third step the number of incorrect clicks was used as a measure to reflect impairments in inhibitory control (cognitive inhibition) (Sørensen et al., 2013).
2) *Digit Span Test* (Terman, 1916, modification Vanags, Ekmanis, 2018) was used to measure motor speed and sustained attention. The test consists of two parts: (1) a series of numbers that must be memorized and entered in the required field in the order in which they were displayed, and (2) a series of numbers that must be memorized and entered in the required field in the reverse order in which they were displayed. Each string of numbers is displayed once, and with every step one digit is added to the string.

   This study used the number of all correctly entered digits as a measure of an individual's short-term memory capacity (Jarrold & Towse, 2006). And the number of digits entered correctly in the opposite order reflects an individual's working memory abilities (switching, manipulation, and dual processing) (Beblo et al., 2004). In child, adolescent, and adult factor analyses, these abilities cluster into separate factors (Alloway et al., 2004; Gathercole et al., 2004).

3) *Computerized Symbol Digit Modalities Test* (SDMT (SDMT, Smith, 1968), modification Vanags & Ekmanis, 2018). On the top of the screen are 2 rows – the first contains numbers, the second corresponding symbols. The test taker must fill in the corresponding number for each symbol that appears on the screen. For example, the symbol "@" is given, for which the corresponding number is "1", then when the symbol "@" appears, the respondent must press the number "1", Errors cannot be corrected, the participant must continue till the time limit ends.
   Indicators of processing and motor speed, and sustained attention were measured with the SDMT. Most traditional measures of information processing speed also require a motor response to facilitate performance (Low et al., 2017). This goes also for Symbol Digit Modalities test, where the individual has to fill in the empty box as quickly as possible with the relevant symbol – both motor speed and the ability to switch their attention from the given sample to the empty box and back are required, and the speed of information processing is also important.
4) *Computerized CPT test* (E. J. S. Sonuga-Barke et al., 2008, modification by Vanags & Ekmanis, 2018). The continuous performance test allows the evaluation of sustained and selective attention, impulsivity (Sonuga-Barke et al., 2008). Various letters are displayed on the screen and the participant must press the spacebar each time when a letter that is not "B" is being displayed and restrain their reaction to press the button when the letter "B" appears. The test continues for 2 minutes.
5) Demographic survey. Each parent or legal guardian completed the demographic survey about the child's age, ability to read and diagnosis (if applicable).
6) Conner's Parent Rating scale (Conners et al., 1998). The questionnaire consists of 80 statements and 13 subscales. Parents are asked to report according to the child's behavior during the last month. Statements are on a Likert scale from 0 to 3, where 0 is "Not at all (very seldom, never)", 1 is "A little (sometimes)", 2 is "Quite a lot (often, quite a lot)" and 3 is "Very (very often)". To more accurately divide children into the clinical or control group, an ADHD index subscale was used. The scoring was performed according to the test manual and established cutoff points for possible and likely ADHD (≤ 58 standardized T-score for control group and ≥ 75 standardized T-score for ADHD group).

Table 1. Cognitive ability domains and test variables used in the data analysis

Variable from test	Cognitive ability domain
SDMT correct answer mean response time	Information processing and motor speed
SDMT incorrect number of answers	Sustained attention
DST number of digits in forwards	Visual short-term memory
DST number of digits in backwards	Visual working memory
SWCT mean response time	Information processing speed
SWCT 2nd and 3rd step mean correct number of answers	Working memory, inhibition, selective attention
SWCT 2nd and 3rd step mean incorrect number of answers	Inhibition control (cognitive inhibition)
CPT number of impulse taps	Inhibition control (response inhibition
CPT number of correct taps	Selective and sustained attention

For the most part, the cognitive tests measure various cognitive ability domains in general, but to make it easier to navigate the results, the cognitive ability indicators obtained from the tests were conceptualized. In further statistical calculations, the description of the results, the discussion part and the conclusions, these conceptualized names of the indicators of cognitive ability domain tasks will be used, which can be seen in Table 1.

Procedure

The study used data from the project "Development of a screening method for children with ADHD and CSWS in children aged 7–15 years". This project was implemented in collaboration with students and researchers of the University of Latvia (UL) and Children's Clinical University Hospital (CCUH) specialists (Vanags et al., 2022). Permission for the research was received from the Ethics Commission of the UL (Institute of Cardiology and Regenerative Medicine) and CCUH. Parents were able to enroll their children in the study through a survey that gathered initial information for selection purposes (age, literacy, diagnoses made, child's difficulties, computer availability, etc.). Also, the procedure of the study and its goals were agreed upon with the participants through informed consent. Because of the epidemiological situation in the country (Covid-19 restrictions), testing was moved to a remote environment. The testing took place via exploro.lv platform, where the necessary cognitive test battery, informative data survey and survey were created. Detailed testing instructions were developed, which were sent to the email provided by the parents and then discussed individually with each child's parent to achieve the most equivalent conditions for testing. Afterwards a link to the test battery created by exploro.lv was sent to the parents. The testing of the children was administered by the parents. The parent or legal guardian completed the demographic survey and the Conner`s parent survey. After the testing was completed, the parent had an opportunity to report whether there were circumstances that could have left a negative impact on the child's testing results.

Results

Descriptive statistics

The empirical data of the study were collected in an Excel program and statistically analyzed with SPSS 22nd version. For the task indicators of cognitive ability domains to be mutually comparable, their standardized values were initially calculated. Descriptive statistics indicators were calculated for the empirical data of both groups, as well as determining the conformity of the data to a normal distribution with the Shapiro-Wilks criterion, which can be seen in more detail in Table 2.

To classify the children more accurately into the clinical or control group, in addition to the ADHD diagnosis as a criterion, the ADHD index of the subscale of the Conner's survey for parents was also used. The Cronbach's alpha reliability coefficient calculated for this study was excellent for both the entire Conner Parent Survey (α = 0.95) and the subscale of the ADHD Index (α = 0.97).

Table 2. Descriptive statistics of age and cognitive abilities used in this study in ADHD and control groups

Demografic data and indicators of cognitive abilities	Group					
	ADHD (n = 46)			Control (n = 30)		
	M	***SD***	***S-W***	***M***	***SD***	***S-W***
Age	10.80	1, .67	0.97*	9.41	1.60	0.94*
Processing and motor speed	0.04	1.16	0.61	−0.06	0.70	0.96*
Sustained attention	0.03	1.06	0.68	−0.04	0.93	0.83
Visuospatial short-term memory	−0.02	1.11	0.98*	0.04	0.81	0.93*
Visuospatial working-memory	−0.08	0.97	0.98*	0.12	1.06	0.88
Processing speed, sustained attention	0.04	1.03	0.88	−0.06	0.97	0.94*
Working-memory, inhibition, selective attention	−0.11	1.22	0.64	0.16	1.47	0.82
Inhibition control (cognitive)	0.13	1.22	0.66	−0.25	0.40	0.86
Inhibition control (response)	0.14	1.19	0.76	−0.21	0.56	0.82
Sustained and selective attention	−0.15	1.27	0.40	0.23	0.09	0.97*

* p > 0,05, S-W Shapiro Wilk test of distribution

Inferential statistics

To answer the first question of the study: are there statistically significant differences between the scores of cognitive ability domain tasks of the two groups, the Mann-Whitney statistical criterion was used (see Table 3). Although the ADHD group tended to show lower results in all indicators of cognitive ability domain tasks, this trend was not statistically significant. Statistical power calculations with the program G* Power were made, and the results indicate that at least 92 respondents per group are needed to detect differences by the Mann-Whitney test between two groups and to control for Type I and II errors (Faul, Erdfelder, Buch & Lang, 2009).

Table 3. Mann-Whitney test differences of cognitive ability domain task (test) mean scores between ADHD group (n = 46) and control group (n = 30)

Indicators of cognitive abilities	Group				
	ADHD (n = 46)		Control (n = 30)		
	M	*SD*	*M*	*SD*	*U*
Processing and motor speed	0.04	1.16	−0.06	0.70	665.00
Sustained attention	0.03	1.06	−0.04	0.93	635.50
Visuospatial short-term memory	−0.02	1.11	0.04	0.81	654.00
Visuospatial working-memory	−0.08	0.97	0.12	1.06	653.00
Processing speed, sustained attention	0.04	1.03	−0.06	0.97	635.00
Working-memory, inhibition, selective attention	−0.11	1.22	0.16	1.47	670.00
Inhibition control (cognitive)	0.13	1.22	−0.25	0.40	647.00
Inhibition control (response)	0.14	1.19	−0.21	0.56	642.00
Sustained and selective attention	−0.15	1.27	0.23	0.09	675.00

* $p < 0,05$

Table 4. Distribution of deficits in cognitive ability domain tasks (tests) per percentile groups in the ADHD group and control group

Indicators of cognitive abilities	Percentile	ADHD	Control	*U*
Processing and motor speed	86.	8 (17.4%)	4 (13.3%)	662.00
Sustained attention	86.	6 (13%)	6 (13%)	642.00
Visuospatial short-term memory	14.	9 (19.6%)	5 (16.7%)	670.00
Visuospatial working-memory	14.	8 (17.4%)	3 (10%)	639.00
Processing speed, sustained attention	86.	8 (17.4%)	4 (13.3%)	662.00
Working-memory, inhibition, selective attention	14.	8 (17.4)	3 (10)	639.00
Inhibition control (cognitive)	86.	12 (26.1)	2 (6.7)	556.00*
Inhibition control (response)	86.	10 (21.7)	1 (3.3)	563.00*
Sustained and selective attention	14.	10 (21.7)	1 (3.3)	609.00

* $p < 0,05$, U – Mann-Whitney test

To perform further steps in the data analysis an index of the levels of cognitive ability domain tasks was created. Each measure of cognitive ability domain task was dichotomized: a high level of deficit or presence (below the 14th percentile or above the 86th percentile depending on each ability domain task) corresponds to 1, and a low level of deficit or absence (above the 14th percentile or below the 86th percentile depending on each ability domain task) corresponds to 0. Dichotomization of the indicators was done following a similar procedure in another study (Fried & Nesse, 2015). In Table 4 can be seen the distribution of cognitive ability task deficits by group and the calculations of their differences. This table shows that only the Sustained attention indicator (13%) has the same percentage of deficit in both groups. When examining the expressiveness of cognitive ability domain task deficits between groups with the Mann-Whitney statistical criterion, significant differences appeared only between the two Inhibitory Control indicators. A deficit in the index of cognitive inhibition was observed in 26.1% of children from the ADHD group and only 6.7% or two children from the control group ($U = 556.00$, $p < 0.05$). In addition, 21.7% of children from the ADHD group and only one child from the control group had a deficit in response inhibition ability ($U = 563.00$, $p < 0.05$). Although it is possible to observe that the level of other cognitive ability domain task deficits is more pronounced in the ADHD group than in children from the control group, these differences between those levels are not statistically significant and can only be seen at the level of trends.

To answer the second question of the study: what is the heterogeneity of cognitive ability domain indicators in children with and without ADHD, in further data analysis a method of qualitative data analysis was chosen (Fried & Nesse, 2015), which would allow for a more detailed analysis of each research group separately, and to observe the differences between the two samples. First, the frequencies of deficits in cognitive ability domain tasks were calculated, as can be seen in Figure 1.

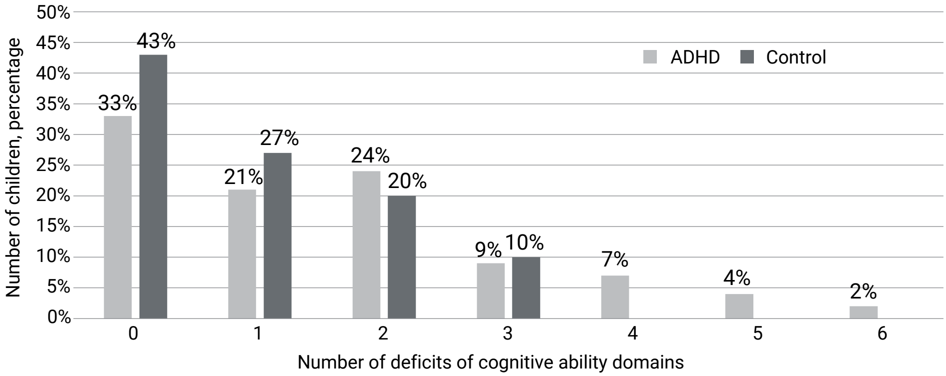
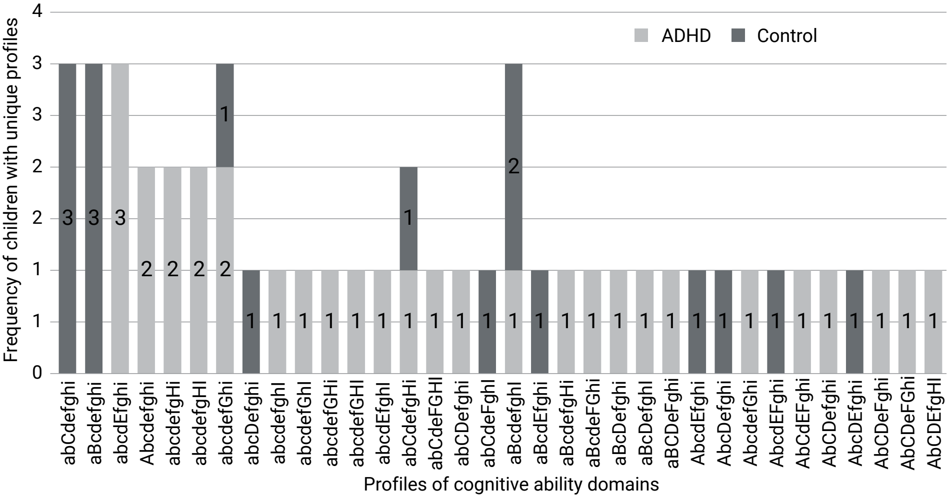


Figure 1. The number of cognitive ability domain tasks (tests) in which the child demonstrated deficits, listed by frequency of children in the ADHD group and control group



Note: uppercase letter indicates a deficit in this ability domain, the lowercase letter indicates typical performance.
A, a – Processing and motor speed; B, b – Sustained attention; C, c – Shortterm memory; D, d – Working memory; E, e – Processing speed and sustained attention; F, f – Working memory, selective attention, inhibition control (WSI); G, g – Cognitive inhibition H, h – Response uppercaseinhibition; I, i – Sustained, selective attention

Figure 2. Frequency distribution of unique cognitive ability domain task (test) profiles in the ADHD group and control group

The first Figure arranges the groups according to the frequencies of cognitive ability domain task deficits. Most often both groups have profiles of cognitive ability domain tasks without deficits (Control – 43% , ADHD – 33%). Children in the control group more often than children with ADHD had deficits in 1 cognitive ability domain task (Control – 27%; ADHD – 21%) and 3 cognitive ability domain tasks (Control – 10%; ADHD – 9%). But children with ADHD had more pronounced deficits with 2 cognitive ability domains (ADHD – 24%; Control – 20%) and showed deficits also with 4, 5 and 6 cognitive ability domains. It must be noted that children in the control group did not show more than 3 deficits in cognitive ability domains.

Based on the previously created dichotomous variables, a corresponding cognitive ability domain task profile was created for each child in each groups. Each profile shows whether a particular level of cognitive ability domain task is low or adequate and the combination of these levels of cognitive ability domain tasks. The second figure shows the frequency distribution of cognitive ability domain task profiles, which allows observing the heterogeneity in both groups. Each letter represents a certain cognitive ability task – the uppercase letter indicates a low level or deficit of this ability domain task, and the lowercase letter indicates the correspondence of the ability domain task to typical performance. As can be seen in Figure 2, with the exception of the most frequent profile (without deficits in cognitive ability domain tasks), the other 35 profiles (out of 512 possible combinations of profiles) can be observed in either of the two groups of children. There are 9 unique profiles in the control group, from which 7 profiles are different for each child (23%). In the ADHD group there are 22 unique profiles from which 18 profiles are different for each child (39%) and 3 profiles that are overlapping for both groups.

Looking at each deficit of cognitive ability domain task separately, the most common deficits in the ADHD group are in the inhibition of control indicators (cognitive inhibition – in 12 profiles and response inhibition – in 10 profiles, in 5 profiles both disorders overlap). Low scores for sustained and selective attention indicators appeared in 10 profiles and for short-term memory indicator in 9 profiles. Eight different profiles show low scores on working memory indicator or on an indicator of working memory, inhibition control and selective attention, as well as processing and motor speed and processing speed and sustained attention indicator. Difficulties with sustained attention are less common (6 profiles). Looking at the combinations of two deficits, it can be observed that there are more frequent combinations involving low short-term and working memory indicators: both in combination with each other (in 6 profiles) and with other cognitive indicators – CF, CA – in 5 profiles each, respectively; DA – in 4 profiles; in DB, DF – 3 profiles each respectively. Deficits of inhibition control indicators were also often combined both with each other and with other indicators: GH, GI, HI – in 5 profiles each, respectively; GA, GF – in 3 profiles each, respectively. As well as combinations of low memory and inhibition control indicators (CG, CH – 3 profiles each, respectively; DG – 2 profiles). Combinations of low processing and motor speed indicators can also be observed: AC – in 5 profiles, AD – in 4 profiles, AE, AF, AG – in 3 profiles, as well as VF disorders: FC – in 5 profiles; FA, FB, FD, FG – in 3 profiles). The most common combinations of three cognitive ability domain task deficits are in ACD – 4 profiles and ACF – 3 profiles, as well as CDG – 2 profiles.

When looking at the control group, the most frequent low indicators can be observed in attention measurements (B – 6 profiles, I – 3 profiles), processing and motor speed (A – 4 profiles, E – 4 profiles), short-term and working memory (4 and 3 profiles respectively), indicator of working memory, selective attention and inhibition control (3 profiles). Only one child has shown difficulties with response inhibition and two with cognitive inhibition. The most pronounced combinations of two cognitive deficits were related to processing speed (AE – in 3 profiles and AF – in 2 profiles).

Comparing the cognitive ability domain task profiles from both groups, apart from the profile without cognitive ability domain task deficits, which is the most pronounced for both groups, there are only three common profiles. The two unique profiles have in common the low scores in inhibition control (ADHD – 3 individuals, Control – 3 individuals) – both cognitive and response inhibition, as well as

1 unique profile with low sustained and selective attention indicators (Controls – 2 individuals, ADHD – 1 individual). The other profiles for the two groups are unique and do not overlap.

Discussion

The aim of this study was to find out whether there are statistically significant differences between the ADHD and the control group in the indicators of different cognitive ability domain tasks. As well as to find out what are the profiles of these ability domain tasks in both samples of children with the qualitative data analysis method in order to better understand the heterogeneity in both groups.

In response to the first raised question, it should be concluded that although there is a tendency for children with ADHD symptomology to show lower indicators of the respective cognitive ability domain tasks, this tendency is not statistically significant. And the calculations of G* Power program suggests that to avoid I and II type error while searching for differences, at least 92 respondents in each group are needed. Since the entire sample in this study was numerically smaller than one of the required group sizes, based on the calculations of this sample, there is a 33% probability of committing a type I error, or wrongly accepting the null hypothesis, and a type II error, rejecting the wrongly accepted null hypothesis and accepting the alternative. Even in previous studies, these results have so far been ambiguous – there are studies showing differences in various ability domain indicators between children with ADHD and typically developed children (Castellanos & Tannock, 2002; Kofler et al., 2019; Nigg et al., 2005; Rubia et al., 2009; Willcutt et al., 2005). But there are also several studies in which some cognitive ability domain task differences were not statistically significant (Bergwerff et al., 2019; Fair et al., 2012; Sonuga-Barke et al., 2010; Van Hulst et al., 2014; Willcutt et al., 2005). Comparing the two groups according to the levels of cognitive ability domain task deficits calculated in the study (1 – presence of impairment, 0 – absence of impairment), it should be concluded that the ADHD group shows higher deficits in both inhibition control ability indicators: 26.1% of children from the ADHD group showed difficulties in cognitive inhibition and relatively only 6.7% of children from the control group, which are statistically significant differences ($U = 556.00$; $p < 0.05$) and 21.7% of the ADHD group and only 3.3% or one individual from the control group showed difficulties in response inhibition ($U = 563.00$; $p < 0.05$). Deficits in inhibitory control have been implicated also several other studies as a major deficit of EF (Cortese, 2012; Fair et al., 2012; Rubia et al., 2009). The differences between the other levels of cognitive ability domain task deficits were not statistically significant. Looking at these calculations, it should be concluded that the comparison of averages might not reflect the true severity of cognitive ability domain task deficits between the two samples. Therefore, for the further calculations, it was chosen to analyze the groups qualitatively – by creating profiles of cognitive ability domain tasks for each child in both groups.

When performing a frequency analysis of cognitive ability domain task profiles for the ADHD group, it is concluded that 33% of children from the sample do not show any difficulties in the cognitive ability task indicators measured in the study. This is also consistent with the findings of several studies that only 50%–60% of children show cognitive deficits (Nigg et al., 2005; Willcutt et al., 2005). And another quarter of children (22%) show deficits in only one of nine indicators of cognitive ability domain tasks and 24.2% of children show two low indicators of cognitive ability domains. Only one third of all children in the sample have three or more cognitive ability domain task deficits. Also, looking at the calculations of these frequencies, it is possible to conclude that almost half of the children in the sample (43%) have unique profiles of cognitive ability domain tasks that do not overlap with other children. Thus, it can be concluded that children who are diagnosed with one of the three types of ADHD may not show common deficits of cognitive ability domains – each of them may have their own pronounced difficulties, and therefore also need different interventions to reduce these difficulties (Rosales et al., 2015; Sibley et al., 2012; Silk et al., 2019).

Taking a closer look at the different profiles of cognitive ability domain tasks, it should be concluded that, similar to what was previously revealed in other studies, difficulties with inhibition control are most often shown in those profiles – both cognitive inhibition and response inhibition (Cortese, 2012; Fair et al., 2012; Rubia et al., 2009). But in general, the expressiveness of different deficits can be observed in all measured cognitive ability domain tasks. When looking at the combinations of cognitive ability domain task deficits, difficulties with short-term and working memory tasks appear more often, which would be natural, because although in several studies, in the factor analysis, short-term and working memory are grouped into different factors (Alloway et al., 2004; Gathercole et al., 2004), correlational studies fail to separate these ability domains (Aben et al., 2012). Similarly, deficits in short-term and working memory indicators combines with inhibition control indicators (3 profiles with short-term memory and 2 with working memory). Also, other studies to date indicate that these ability domains are closely related to each other, and therefore often experiencing difficulties in one of them can also lower the other domain (Diamond, 2013; Hale et al., 1997; Raiker et al., 2012). Deficits in processing speed indicator also combines with deficit in working and short-term memory indicators, showing that children who have difficulty remembering and manipulating with instructions also have difficulty quickly processing information to complete the task. Similar information is also indicated in studies on the relationship between working memory and processing speed deterioration (Pereiro et al., 2008; Zimprich & Kurtz, 2013). Also, in the combinations of deficits in three cognitive ability domain tasks, processing speed, working and short-term memory indicators appear together, which indicates their clear connection with each other.

Analysis of the control group profiles reveal that there are relatively fewer unique profiles in number – only 13. The most common of which is without cognitive ability domain task deficits – 43% of children from the sample. Just under a third of children have difficulty with only one cognitive ability domain task, and the remaining 30% have difficulties with 2 or 3 cognitive ability domain tasks. When comparing both groups, it can be concluded that children without pronounced ADHD symptomatology also have less pronounced difficulties in cognitive ability domain tasks. Why, however, the children of the control group have difficulties with cognitive ability domain tasks is certainly a question worthy of a separate study. But considering that more and more studies show information that ADHD is a spectrum disorder, it should be taken into account that typically developing children are also the same spectrum, which is also subject to developmental changes that should be better studied (Costa Dias et al., 2015). Due to the numerically small sample, this study did not look at the data by age, and it is possible that some of the children have not developed the relevant ability domains enough yet. As might be the case, for example, with the more frequently reported difficulties in indicators measuring sustained selective or only sustained attention (9 profiles) (Fisher, 2019), information processing speed (8 profiles) (Pereiro et al., 2008; Zimprich & Kurtz, 2013), and working and short-term memory (7 profiles) (Pereiro et al., 2008; Zimprich & Kurtz, 2013). In the group of typically developed children, there are also no significant combinations of cognitive ability domain task deficits.

Only 4 profile combinations out of 35 profiles overlap between the two groups. The profiles that overlap have deficits in both inhibition control indicators, which are the most frequently reported deficits in the ADHD group and the least frequently reported in the control group. And combinations of measures of sustained attention and sustained selective attention. Which leads to the conclusion that not all children with ADHD show high deficits in all ability domains and may equally well be somewhere on the spectrum of cognitive ability domains of typically developing children as mentioned in studies before (Fair et al., 2012).

In conclusion it should be stated that because ADHD is a very heterogeneous disorder, statistical methods used to date are not always the best predictors to separate children with and without ADHD symptoms. In this study it could be observed that even though no statistically important differences in cognitive ability domain tasks were found, cognitive ability domain task profiles reveal noticeable differences between the two groups in this study. It could be observed that children with ADHD symptomology show numerically more unique profiles than children with typical development. And the profiles of ADHD group had a higher expressiveness of cognitive ability domain task deficits – that is, more deficits within one profile than in the profiles of the control group. It should also be concluded that almost half of all children with ADHD symptomology form unique profiles of combinations of cognitive ability domain task characteristics. Which indicates how diverse are the cognitive difficulties children with ADHD live with. As well as the fact that children with the same diagnosis can experience difficulties of a completely different nature, which can affect, for example, their academic performance. Cognitive ability domain task profiles reveal that also typically developed children have difficulties in various cognitive ability domain tasks, but these difficulties are not as pronounced as in the ADHD group. And this most likely indicates that children with typical development may also have difficulties in certain areas, which probably could be explained by behavioral, emotional states or the maturation of these cognitive ability domains. And this fact highlights the necessity to research more children with typical development. Because as can be seen, some of cognitive ability domain task profiles are overlapping in both groups, indicating that children with ADHD symptomology at some points are struggling with the same difficulties as children with typical development and that it is not that easy to draw a line where typical child development ends and ADHD begins.

Strengths and limitations

This study has developed a novel method how to look at the heterogeneity of cognitive ability domains in children with and without ADHD symptomology. It should be mentioned that to date authors have not found a study that have researched cognitive ability domain profiles in such an individualistic approach. And this gives a small opportunity to observe how heterogenous can children cognitive ability domains and deficits of those domains be.

This study also has several important limitations that should be considered in future studies. Remote testing during the COVID-19 pandemic should be mentioned as the first most significant limitation. For children, cognitive tests were administered by parents and were not laboratory controlled. Therefore, it is not possible to provide the same conditions for all children. Although test instructions were verbally given to all parents, the study leaders cannot be sure that the entire protocol discussed for testing was followed. It should also be considered that the low scores shown in the tests could also be due to technical reasons, and not due to the child's low abilities. Children whose parents reported technical difficulties were not included in the study, but it is possible that not all parents recorded these difficulties or indicated them in the survey.

As another important limitation should be mentioned the possible effect of medication in children with ADHD. Although the study included only those children whose parents indicated that no medication had been taken on the day of testing, the possibility cannot be ruled out that exposure to long-term medication may affect the child's cognitive abilities and, therefore, children's performance on these tests may not accurately reflect the ability domain measured in the study difficulty level without medication. Which could affect the overall group performance as well as the analysis of individual cognitive profiles.

As an additional criterion to include children in the ADHD or control group, the standardized *T* scores of the ADHD index subscale of the Conner survey were used. This survey is only adapted, but not standardized in the Latvian population. And although children with average scores ($T = 59 - T = 74$) on this subscale were not included in the study to limit the possible mixing between groups, it should be noted that the chosen method may inaccurately form the division into two specific groups.

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