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Wiktoria Walenista[1], Katarzyna Sitnik-Warchulska[2], Małgorzata Lipowska[2,3], Marcin Szwed[4], Bernadetta Izydorczyk[4]

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Rola zachowań zdrowotnych rodziny, statusu socjoekonomicznego oraz odziedziczalności zaburzeń neurorozwojowych w nasileniu dysfunkcji poznawczych dzieci w wieku szkolnym z ADHD

The role of family health, socio-economic status, and heritability of neurodevelopmental disorders in the severity of cognitive dysfunctions in school-age children with ADHD

[1] Szkoła Doktorska Nauk Społecznych, Uniwersytet Jagielloński, Kraków, Polska
[2] Instytut Psychologii Stosowanej, Uniwersytet Jagielloński, Kraków, Polska
[3] Instytut Psychologii, Uniwersytet Gdański, Gdańsk, Polska
[4] Instytut Psychologii, Uniwersytet Jagielloński, Kraków, Polska
Adres do korespondencji: Katarzyna Sitnik-Warchulska, Instytut Psychologii Stosowanej, Uniwersytet Jagielloński, ul. Łojasiewicza 4, 30-348 Kraków, Polska, e-mail: katarzyna.sitnik-warchulska@uj.edu.pl

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ORCID iDs
1. Wiktoria Walenista https://orcid.org/0000-0002-6958-8020
2. Katarzyna Sitnik-Warchulska https://orcid.org/0000-0001-8262-8034
3. Małgorzata Lipowska https://orcid.org/0000-0002-7422-159X
4. Marcin Szwed https://orcid.org/0000-0002-2153-7793
5. Bernadetta Izydorczyk https://orcid.org/0000-0001-5808-2211

Streszczenie

Wprowadzenie i cel: Niewiele wiadomo na temat związku między statusem socjoekonomicznym, używaniem alkoholu i tytoniu w rodzinie a poszczególnymi funkcjami poznawczymi, takimi jak uwaga, pamięć robocza czy funkcje wykonawcze w przebiegu zespołu nadpobudliwości psychoruchowej z deficytem uwagi (*attention-deficit/hyperactivity disorder*, ADHD). Celem badania było ustalenie, czy trudności socjoekonomiczne i niezdrowe zachowania w rodzinie są predyktorami funkcji poznawczych u dzieci z ADHD. **Materiał i metody:** 176 polskich dzieci z ADHD w wieku 10–13 lat zostało zbadanych za pomocą Baterii Diagnozy Funkcji Poznawczych PU1, podczas gdy rodzice wypełnili ankietę dotyczącą statusu socjoekonomicznego oraz używania alkoholu i tytoniu w domu na poszczególnych etapach życia dziecka. Przeprowadzono analizę skupień badającą typy rodzin i analizę moderacji, aby sprawdzić, czy dziedziczność zaburzeń neurorozwojowych w rodzinie moderuje związek między statusem socjoekonomicznym, używaniem alkoholu i tytoniu oraz funkcjami poznawczymi dzieci. **Wyniki:** Wyszczególniono trzy typy rodzin, w których wychowują się dzieci z ADHD: 1) rodziny z wyższym statusem socjoekonomicznym, niższym poziomem niezdrowych zachowań w rodzinie i średnim poziomem funkcjonowania poznawczego dzieci, 2) rodziny z niskim statusem socjoekonomicznym, wysokim poziomem niezdrowych zachowań rodzinnych i średnim poziomem funkcjonowania poznawczego dzieci oraz 3) rodziny ze średnim statusem socjoekonomicznym, niskim poziomem niezdrowych zachowań rodzinnych i niskim poziomem funkcjonowania poznawczego dzieci. Nie znaleziono statystycznie istotnych powiązań między predyktorami, moderatorem i funkcjami poznawczymi u dzieci z ADHD. **Wnioski:** Wyniki te stoją w opozycji do dużej liczby badań wskazujących na związek między dysfunkcjami poznawczymi u dzieci z ADHD a statusem socjoekonomicznym oraz używaniem alkoholu i tytoniu w rodzinie.

Słowa kluczowe: ADHD, status socjoekonomiczny, dysfunkcje poznawcze, używanie alkoholu i tytoniu

Abstract

Introduction and objective: Little is known about the association between socioeconomic status, alcohol and tobacco use, and specific cognitive functions, like attention, working memory or executive functions in attention-deficit/hyperactivity disorder. We aimed to determine if socioeconomic adversity and unhealthy family behaviours are predictors of cognitive functions in children with attention-deficit/hyperactivity disorder. **Materials and methods:** We tested 176 Polish children with attention-deficit/hyperactivity disorder aged 10–13 using the PU1 Battery of Cognitive Functions, while the children's parents completed a questionnaire on socioeconomic status and alcohol and tobacco use at home during their child's life stages. We applied cluster analysis of family types and moderation analysis that tested the heritability of neurodevelopmental disorders in family

interactions. **Results:** We identified three family types that raise children with attention-deficit/hyperactivity disorder: 1) families with higher socioeconomic status, lower level of unhealthy family behaviours, and average levels of children's cognitive functioning, 2) families with low socioeconomic status, high level of unhealthy family behaviours, and average levels of children's cognitive functioning, and 3) families with average socioeconomic status, low level of unhealthy family behaviours and low level of children's cognitive functioning. We found no statistically significant associations between family predictors, the moderator variable, and cognitive functions in children with attention-deficit/hyperactivity disorder. **Conclusions:** The results of our study contrast with the large amount of evidence that shows a link between cognitive dysfunctions in children with attention-deficit/hyperactivity disorder and socioeconomic status and alcohol and tobacco use.

Keywords: ADHD, socioeconomic status, cognitive dysfunctions, alcohol and tobacco use

INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder that is characterised by high levels of inattention, hyperactivity, and impulsivity which are disproportionate to the age of the individual (American Psychiatric Association, 2013). ADHD is usually diagnosed in childhood, with prevalence rates of 5.9–7.1% worldwide (Polanczyk et al., 2014) and 3–12% in Poland (Kiejna et al., 2012). ADHD is most often explained by the gene-environment interaction model, which may increase or reduce the severity of the disorder's symptoms in the prenatal period, after birth, and at further stages of the child's development (Tillman and Granvald, 2015).

Socioeconomic status, alcohol and tobacco use and ADHD in the family context

A widely studied family factor related to the development of ADHD is the socioeconomic status (SES) of the family (Martel, 2013; Reder and Brzezewska, 2022) and parental psychoactive substance use (Dong et al., 2018; Han et al., 2015). Many researchers have focused on studying the connections between parental education, family income, social adversity and ADHD symptoms and other cognitive skills that determine children's cognitive functioning (Langauer-Lewowicka et al., 2016; Pawlak, 2013).

SES and ADHD symptoms

SES and its influence on health is usually seen in social sciences as concerning education, income, and occupation levels (Baker, 2014) because these factors describe the socioeconomic background most accurately. When children's functioning is considered in the family context, parental education and family income are the variables which are commonly taken into account. The impact of socioeconomic adversity on the brain can be observed as early as childhood and continues across the lifespan (Tomalski and Johnson, 2010); it is one of the strongest predictors of the severity of ADHD symptoms in children (Russell et al., 2016). When the general influence of SES is considered, it is usually conceptualised as a confounder variable or a risk factor of ADHD symptoms in children. Moreover, the likelihood of more severe and/or persistent ADHD usually increases when more SES adversity factors are present. Several unfavourable SES factors have been found to be significant in the context of ADHD: low family income (Biederman et al., 2002; Pheula et al., 2011), low parental education (Pawlak, 2013; Tillman and Granvald, 2015), being a part of ethnic minority (Martel, 2013), parental ADHD symptoms (Markham and Spencer, 2022), and single parent household (Pheula et al., 2011; Russell et al., 2015). Tillman and Granvald (2015) found that associations between ADHD symptoms and executive functions (inhibition and mental set-shifting) were stronger in the group with higher parental education level, whereas the relation between working memory and ADHD symptoms was similar in both the lower and higher parental education groups.

Alcohol and tobacco use in families raising children with ADHD

The effect of alcohol and tobacco use on ADHD symptoms in children is well documented in the literature (Huang et al., 2021; San Martin Porter et al., 2019), but the nature of this association is not yet clearly established. There is mixed evidence for causal and confounding connections between parental substance use at different stages of child development and ADHD symptoms in children. In their study designs, researchers usually focus on different patterns of alcohol and tobacco use by significant persons (especially the mother and father) and the period of substance exposure, because the impact on a child's development may vary depending on the period during which they are exposed to the effect of a given substance (Han et al., 2015). A substantial amount of evidence shows the impact of parental alcohol and tobacco use during pregnancy on later ADHD symptoms and executive function deficits in offspring (Daseking et al., 2015; Dong et al., 2018; Mick et al., 2002; Nomura et al., 2010; Piper and Corbett, 2012; Thakur et al., 2013). In their cohort study, Han et al. (2015) found that the risk of ADHD in children increased as a result of maternal alcohol use (OR 1.55), maternal smoking during pregnancy (OR 2.64), and paternal smoking during pregnancy (OR 1.17). Second-hand smoke exposure from pregnancy to childhood was associated with a higher likelihood of having ADHD symptoms, and these relations were seen in all three studied periods (prenatal, early postnatal, and childhood) (Lin et al., 2021). Moreover, postnatal parental smoking in the

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first years of a child's life may be a significant factor that leads to a higher likelihood of ADHD symptoms (Kollins et al., 2009). On the other hand, some evidence shows that maternal smoking during pregnancy is not more strongly connected with ADHD diagnosis in children than paternal smoking, than the grandmother smoking when pregnant with the child's mother, or than maternal smoking in previous pregnancies; moreover, this association was not found to be significant in the participants' healthy siblings (Gustavson et al., 2017). A systematic review and meta-analysis conducted by San Martin Porter et al. (2019) found no increased risk of ADHD symptoms in children who were exposed to up to 70 g of alcohol per week during pregnancy. Measuring the severity of maternal alcohol use in pregnancy is crucial due to the risk of foetal alcohol spectrum disorder (FASD). Cognitive symptoms of FASD can be similar to ADHD symptoms, but global impairment and additional symptoms such as dysmorphia are more prevalent in children with FASD than in those with ADHD (Kingdon et al., 2016).

HYPOTHESES

Aims and hypotheses

There is little research on the effect of both SES and parental alcohol and tobacco use variables on ADHD symptoms (Markham and Spencer, 2022; Pfinder et al., 2012), and it measures only ADHD symptoms, not specific cognitive skill deficits in children (Marees et al., 2020). To our knowledge, there is scarce research that considers parental or family alcohol and tobacco use in families raising children in Poland. Even though alcohol and tobacco are not legally prohibited in the Polish context, nowadays there is a cultural stigma that may cause parents to refrain from disclosing this kind of information to researchers or other health professionals. In addition, researchers focus mostly on the genetic and biological effects of psychoactive substance use, while neglecting the environmental influence of unhealthy behaviours on children with ADHD. In this study, we treated parental and family alcohol and tobacco use behaviours as unbalanced and non-adaptive ways of coping with everyday life within a family, not as a biological influence on the children's developing nervous system, especially in the prenatal period. We aimed to determine whether social learning of unbalanced coping strategies, which children with ADHD observe in their parents and other relatives at home, can disorganise and worsen their cognitive functions. As existing evidence also shows, children with ADHD more often have other relatives with neurodevelopmental disorders compared to population controls (Barkley, 2015), so we added a heritability of neurodevelopmental disorders variable as a moderator of the association between SES and unhealthy family behaviours and cognitive dysfunctions.
Considering the above, we put forward a hypothesis regarding the influence of SES and unhealthy family behaviours on the quality of children's cognitive functions. We assumed that lower SES and higher levels of alcohol and tobacco use both during the prenatal and early childhood periods and currently might have a negative impact on the development conditions of children's executive functioning. While the literature already well describes the separate effects on ADHD symptoms of SES, alcohol and tobacco use, there is little evidence of a relation between SES and alcohol and tobacco use by parents (treated as independent predictors) and a child's ADHD.
According to the proposed model (Fig. 1), we tested the following hypotheses:

- **Hypothesis 1:** Children raised in families with socioeconomic adversity and a higher level of unhealthy family behaviours have a low level of cognitive functions.
- **Hypothesis 2:** Lower SES is a predictor of cognitive dysfunctions in children with ADHD.
- **Hypothesis 3:** Higher level of unhealthy family behaviours (alcohol use and smoking) during pregnancy, in the early development period and currently is a predictor of cognitive dysfunctions in children with ADHD.
- **Hypothesis 4:** The association between SES and unhealthy family behaviours and cognitive dysfunction in children with ADHD is moderated by the presence of neurodevelopmental disorders in other family members.

Study variables

Independent variables

Socioeconomic status. We treated SES as the combination of the education level of both parents and family income in the first five years of the child's life and in 2019 (the year just before we conducted the study). We measured this variable with our self-developed General Questionnaire, in which the parents were requested to provide information about their education and income.

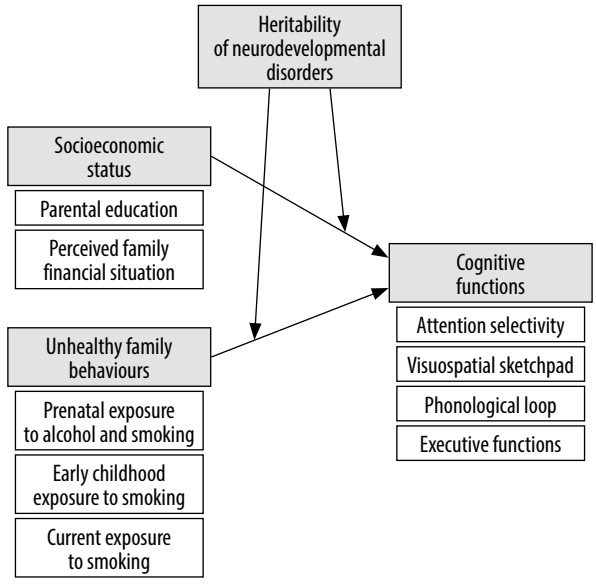

Fig. 1. Research model

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Family unhealthy behaviours. Unhealthy family behaviours relate to the declared parental level of alcohol and tobacco use during pregnancy, in the early childhood of children with ADHD, and currently. We measured this variable with our self-developed General Questionnaire, in which the parents were asked to provide information about the level of alcohol and tobacco consumption during the aforementioned periods of their child's life.

Moderator

Neurodevelopmental heritability is the parent-declared presence of neurodevelopmental disorders (e.g. ADHD, autism spectrum disorder, dyslexia, dysorthography) in the close family, including a child's siblings, parents, grandparents or cousins.

Dependent variables

In this study, cognitive functions comprised four skills: attentional selectivity, visuospatial sketchpad, phonological loop, and executive functions. The indicators of these variables were the respondents' results in the PU1 Battery of Cognitive Functions (Borkowska et al., 2015). The attentional selectivity variable measures the attention skill and relates to the ability to focus on relevant stimuli while ignoring irrelevant distractions (Mason et al., 2003). Both the visuospatial sketchpad and the phonological loop are components of working memory and process visuospatial and verbal information, respectively (Ackermann et al., 2018). The general index of executive functions is understood as the higher-order cognitive processes that are the link between stimulus perception and behavioural response. They include the ability to formulate goals, plan, maintain the purposefulness of actions, and develop effective strategies for achieving goals (Borkowska et al., 2015).

MATERIALS AND METHODS

Methods

General Questionnaire

The questionnaire was developed by Markevych, Baumbach, Grellier, Mysak, Wierzba-Łukaszyk, Sitnik-Warchulska and Skotak for the purpose of the NeuroSmog Project, and it is described in detail in another paper (Markevych et al., 2021). We distributed this tool to the parents from whom we collected the SES, neurodevelopmental heritability and alcohol and tobacco use data. The SES data included questions about the educational level of both parents and their financial situation in earlier life and in 2019 (the year before we conducted the study). We collected the neurodevelopmental disorders heritability data from a question about whether any neurodevelopmental disorders (i.e., ADHD, autism spectrum disorder, dyslexia, dysorthography) were present in other members of the family. In the context of substance use, we asked the following questions: How often did the baby's mother drink alcohol during pregnancy? How often did the child's father consume alcohol during the mother's pregnancy? How often did the child's mother smoke tobacco products (or use nicotine patches/gum) during pregnancy? How often did the child's father smoke tobacco products (or use patches or nicotine gum) during the mother's pregnancy? How often are tobacco products smoked in the house where the child currently lives (including on the balcony or terrace)? How often were tobacco products smoked in the house where the child lived in the first five years of life? The participants answered the questions on a Likert scale, where they could indicate the following answers: never, hardly ever, once a month, once a week, more than once a week, daily, and I don't want to answer that question.

PU1 Battery of Cognitive Functions

The PU1 Battery of Cognitive Functions (Borkowska et al., 2015) tests the three main cognitive skills: attention (orientation to a stimulus, divisibility of attention, inhibition, maintaining alertness, and shifting attention), working memory (visuospatial and visuomotor working memory functioning, short-term auditory memory of verbal material), and executive functions (monitoring, phonological and categorical fluency, planning). This Polish-specific tool consists of 15 tests that examine the full spectrum of cognitive skills in children aged 10–13 years. In this study, we used PU1's scales for attentional selectivity, visuospatial sketchpad, phonological loop, and general index of executive functioning. The internal consistency of the PU1 battery, measured by Cronbach's alpha coefficient for the sample of Polish children, was $\alpha = 0.74$.

We measured the cognitive skills using the following tasks:

- **Attentional selectivity**
  - Divisibility of attention – in two tasks, the clinician read a short story and asked the participants to listen to it while solving mathematic problems. The result obtained for divisibility of attention was the sum of correct answers regarding the story and the solved math problems.
  - Inhibition of external distractors – the clinician asked the participants to count down from 100 in decrements of 7 while the radio played in the background. The result in the task was the number of subtraction errors.
  - Sustaining attention – the clinician asked the participant to only cross out boxes containing five stars on worksheets, which the clinician replaced at intervals of one minute. Each worksheet showed a different combination of stars. In total, the participants completed six sheets. The result of this task was the difference between the number of correctly and incorrectly crossed out boxes.
  - Switching attention – the participants' task was to cross out geometric figures, and every 15 seconds the clinician changed the instruction regarding the specific shape which should be crossed out. The result of switching attention task was the total number of correct answers.
- **Phonological loop**
  - Auditory working memory – this test consisted of two tasks. First, the clinician asked the participants to count

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down from 100 in decrements of 3; second, they were asked to name pictures. The result of the auditory working memory task was the number of correctly named pictures minus the sum of errors in the subtraction task.
  - Short-term verbal and auditory working memory – the clinician asked the participants to repeat out loud the sentences which they had just read. The result obtained in this task was the number of correctly repeated sentences.
- **Visuospatial sketchpad**
  - Spatial Working Memory – the clinician showed a 4 × 4 square matrix to the participants; then, they were asked to remember the sequences of squares and recall them after the presentation. The task was to click the correct sequence in reverse order on the computer screen. The result in this task was the number of correctly clicked reversed sequences and correctly recalled squares.
- **Executive functions**
  - Monitoring – the clinician asked the participants to click the green button when they saw a "normal" picture (i.e. a cat or a cow) on the computer screen, or the red button when the picture was absurd (i.e. a tree with fish on top, or a fly with butterfly wings). The result obtained in this task was the number of correct answers and the response time.
  - Phonological and Categorical Verbal Fluency – in two tasks, the clinician asked the participants to recall words starting with the letter K for 60 seconds. Then, they were to recall as many names of the animals as possible. The result in this task was the number of words/names recalled in both categories.
  - Planning – in this test, called the "park map test", the clinician presented a diagram of a park. The participant's task was to draw a path from the start to the finish point, following detailed requirements. The results obtained in this task were the response time and the number of correctly followed instructions.

Procedure

The detailed procedure for the NeuroSmog Project: Determining the Impact of Air Pollution on the Developing Brain has been described in another paper (Markevych et al., 2021). The Ethics Committee at the Institute of Psychology, Jagiellonian University, Kraków, Poland (# KE_24042019A) approved the study. The clinical trial identifier is NCT04574414. All children involved in the study and their legal guardians provided their written informed consent. All the methods were performed in accordance with the relevant guidelines and regulations.

The psychological evaluation within the study had two main stages. Firstly, field psychologists diagnosed the participants over the course of three meetings at their place of residence. Secondly, an independent council of clinical field psychologists verified the diagnoses, taking into account each child's results and ICD-11 standards. The children who did not meet the criteria were excluded from the study. The inclusion criteria were the child's age (10 to 13 years old), the absence of diagnosed and/or treated mental disorders and diseases, and pharmacologically treated emotional and behavioural disorders.

The analysed data were collected during the first and second diagnostic meetings. The children were tested with the PU1 Battery of Cognitive Functions, and the parents completed the General Questionnaire.

Participants

The participants were children diagnosed with ADHD as part of the NeuroSmog Project. A total of 176 participants were recruited from medical centres, via advertisements in local media, and in cooperating primary schools in 18 cities in southern Poland. The exclusion factors were autism spectrum disorders, foetal alcohol syndrome/foetal alcohol effects, intellectual disability, metabolic diseases, genetic defects, epilepsy, cerebral palsy, mood disorders, Tourette syndrome, other diseases involving pharmacological treatment, an Apgar index <8, low birth weight (less than 2,500 g), and prematurity. In the second stage of diagnosis verification, the independent council excluded the children who presented symptoms of disorders other than ADHD. Fig. 2 shows the scheme for selecting participants for the study.

Data analysis

Statistical analyses were conducted in IBM SPSS Statistics 29. Descriptive statistics of the analytic sample included the percentage (%), means (*M*), standard deviations (*SD*), minimums (min), and maximums (max) for numerical data. The distribution of the dependent variables (attentional selectivity, visuospatial sketchpad, phonological loop, executive functioning) was tested with the Kolmogorov–Smirnov

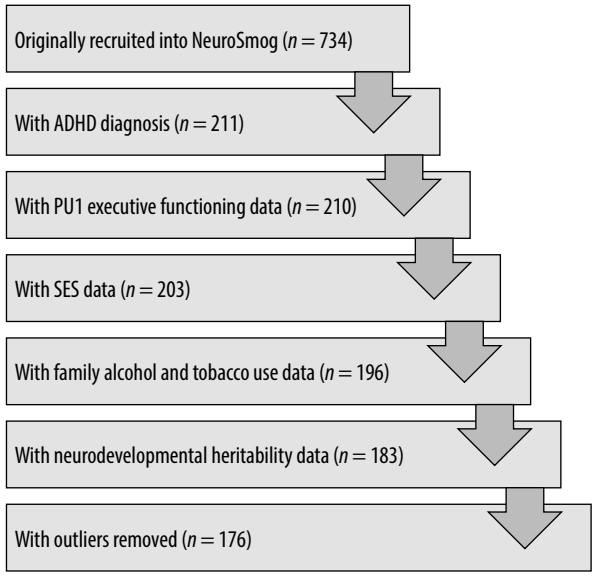

Fig. 2. The scheme for selecting participants for the study

test, which did not reveal any deviation from normal distribution. Since the study variables were on different scales, the predictors, the moderator, and the dependent variables were transformed into *Z*-scores. Eight outliers (observations ±3 *SD*s of the attention selectivity, visuospatial sketchpad, phonological loop, and executive functioning variables) were excluded from the analysis. To determine whether the heritability of the neurodevelopmental disorders variable moderates the connection between SES and family alcohol and tobacco use and cognitive functions in children, we employed moderation analysis. In order to reduce the number of variables in the correlation, cluster and moderation analysis, we combined some variables into the following ones: parental education (maternal and paternal education); perceived family financial situation (perceived family financial situation in 2019 and perceived family financial situation before 2019); and prenatal exposure to alcohol and smoking (maternal alcohol and tobacco use in pregnancy, paternal alcohol and tobacco use in pregnancy). Parental education, perceived family financial situation, and prenatal exposure to alcohol and smoking are the mean scores of the aforementioned variables.

RESULTS

Tab. 1 presents the results of the statistical analysis. In this study group of children with ADHD, there were 61 girls and 115 boys, so the sex ratio was 34.7%:65.3%. The mean age of the children was 11.22 years (*SD* = 0.85). 36.9% of the participants declared having relatives with neurodevelopmental disorders. Most of the participants had parents with a high level of education (65.9% mothers and 46% fathers), with a good perceived family financial situation in 2019 and earlier (63.1% and 58.5%, respectively). 88.1% and 83.5% of mothers declared that in pregnancy they completely abstained from alcohol and tobacco use, respectively, whereas paternal psychoactive substance use in pregnancy was more varied. The fathers' abstinence from smoking was similar to that reported by the mothers, with more than a half of the fathers not declaring that they had smoked during their partner's pregnancy, but the distribution of alcohol use was more varied. When smoking in early childhood and currently is considered, respectively 12.5% and 16.5% of participants were exposed to these behaviours at home every day. The cognitive function variables were average for the Polish population. The mean attention selectivity score was 143.79 (*SD* = 25.00), which is in the 5th sten for the Polish population. Similarly, the result of the phonological loop scale was *M* = 18.17 (*SD* = 5.58), which is also in the 5th sten. The mean score of the visuospatial sketchpad scale was 9.50 (*SD* = 3.42), which is in the 6th sten. Finally, the general index of executive functions obtained by the participants was *M* = 0.33 (*SD* = 9.76), which is in the 4th sten for the Polish population.

The correlation analysis revealed several associations between the study variables, mostly with low or average

Variable	Value	Descriptive statistics
Sex – girls	*n* (%)	61 (34.7)
Sex – boys	*n* (%)	115 (65.3)
Neurodevelopmental heritability – yes	*n* (%)	65 (36.9)
Maternal education		
Primary	*n* (%)	6 (3.4)
Secondary	*n* (%)	46 (26.1)
Higher	*n* (%)	116 (65.9)
Other	*n* (%)	8 (4.5)
Paternal education		
Primary	*n* (%)	8 (4.5)
Secondary	*n* (%)	64 (36.4)
Higher	*n* (%)	81 (46.0)
Other	*n* (%)	17 (9.7)
No information disclosed	*n* (%)	6 (3.4)
Perceived family financial situation in 2019		
Very difficult	*n* (%)	1 (0.6)
Difficult	*n* (%)	4 (2.3)
Made ends meet	*n* (%)	13 (7.4)
Good	*n* (%)	111 (63.1)
Very good	*n* (%)	41 (23.3)
No information disclosed	*n* (%)	6 (3.4)
Perceived family financial situation earlier		
Very difficult	*n* (%)	3 (1.7)
Difficult	*n* (%)	12 (6.8)
Made ends meet	*n* (%)	24 (13.6)
Good	*n* (%)	103 (58.5)
Very good	*n* (%)	27 (15.3)
No information disclosed	*n* (%)	7 (4.0)
Maternal alcohol use in pregnancy		
Never	*n* (%)	155 (88.1)
Hardly ever	*n* (%)	15 (8.5)
Once a month	*n* (%)	0 (0)
Once a week	*n* (%)	0 (0)
More than once a week	*n* (%)	0 (0)
Every day	*n* (%)	1 (0.6)
No information disclosed	*n* (%)	5 (2.8)
Paternal alcohol use in pregnancy		
Never	*n* (%)	17 (9.7)
Hardly ever	*n* (%)	63 (35.8)
Once a month	*n* (%)	45 (25.6)
Once a week	*n* (%)	28 (15.9)
More than once a week	*n* (%)	6 (3.4)
Every day	*n* (%)	3 (1.7)
No information disclosed	*n* (%)	14 (8.0)
Maternal tobacco use in pregnancy		
Never	*n* (%)	147 (83.5)
Hardly ever	*n* (%)	11 (6.3)
Once a month	*n* (%)	2 (1.1)
Once a week	*n* (%)	3 (1.7)
More than once a week	*n* (%)	2 (1.1)
Every day	*n* (%)	5 (2.8)
No information disclosed	*n* (%)	6 (3.4)

Tab. 1. Characteristics of the study variables, N = *176*

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Variable	Value	Descriptive statistics
Paternal tobacco use during pregnancy		
Never	*n* (%)	101 (57.4)
Hardly ever	*n* (%)	14 (8.0)
Once a month	*n* (%)	0 (0)
Once a week	*n* (%)	1 (0.6)
More than once a week	*n* (%)	6 (3.4)
Every day	*n* (%)	45 (25.6)
No information disclosed	*n* (%)	9 (5.1)
Current exposure to smoking at home		
Never	*n* (%)	121 (68.8)
Hardly ever	*n* (%)	16 (9.1)
Once a month	*n* (%)	2 (1.1)
Once a week	*n* (%)	2 (1.1)
More than once a week	*n* (%)	3 (1.7)
Every day	*n* (%)	29 (16.5)
No information disclosed	*n* (%)	3 (1.7)
Early childhood exposure to smoking at home		
Never	*n* (%)	116 (65.9)
Hardly ever	*n* (%)	23 (13.1)
Once a month	*n* (%)	0 (0)
Once a week	*n* (%)	1 (0.6)
More than once a week	*n* (%)	7 (4.0)
Every day	*n* (%)	22 (12.5)
No information disclosed	*n* (%)	7 (4.0)
Age – child	*M* ± *SD* (min–max)	11.22 ± 0.85 (9.92–13.60)
Attention selectivity	*M* ± *SD* (min–max)	143.79 ± 25.00 (82.31–201.65)
Visuospatial sketchpad	*M* ± *SD* (min–max)	9.50 ± 3.42 (–1.05–15.20)
Phonological loop	*M* ± *SD* (min–max)	18.17 ± 5.58 (2.88–29.55)
Executive functions	*M* ± *SD* (min–max)	0.33 ± 9.76 (–23.65–31.89)
M – mean; **max** – maximum; **min** – minimum; ***SD*** – standard deviation.		

Tab. 1. Characteristics of the study variables, N = *176 (cont.)*

strength. We found a negative association of low strength between the perceived family financial situation and early exposure to smoking. Tab. 2 shows the full results of the correlation analysis.

The next step of data analysis was a k-means cluster analysis to illustrate the structure of the family in children with

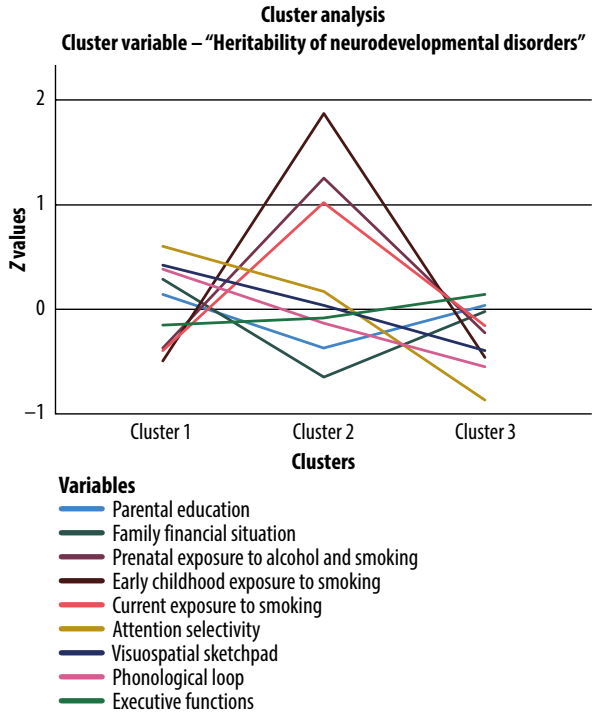

Fig. 3. Cluster analysis of the study group

ADHD and reveal the types of families raising children with ADHD. The cluster variable was neurodevelopmental heritability. The family systems of children can be classified as follows:

- Cluster 1 (*n* = 72): Families with higher SES, lower level of unhealthy family behaviours, and average levels of children's cognitive functioning. This cluster is characterised by the highest levels of cognitive functions in the study group, an average level of parental education and perceived family financial situation, and lower levels of prenatal, early childhood and current unhealthy family behaviours.
- Cluster 2 (*n* = 32): Families with low SES, high level of unhealthy family behaviours, and average levels of children's cognitive functioning. This cluster is distinguished by the highest levels of prenatal exposure to alcohol and smoking, highest levels of early childhood and current exposure to smoking, lowest levels of perceived family

Variables	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Parental education	1	0.114	–0.062	–0.148	–0.067	–0.053	–0.060	0.059	–0.054
2. Perceived family financial situation		1	–0.133	–0.259**	–0.132	0.033	0.001	–0.013	0.036
3. Prenatal exposure to alcohol and smoking			1	0.509**	0.380**	0.023	–0.016	0.006	–0.064
4. Early childhood exposure to smoking				1	0.527**	0.102	0.009	–0.051	–0.129
5. Current exposure to smoking					1	–0.010	–0.093	–0.114	0.029
6. Attention selectivity						1	0.408**	0.263**	–0.385**
7. Visuospatial sketchpad							1	0.399**	–0.222**
8. Phonological loop								1	–0.349**
9. Executive functions									1
Correlation is significant at the 0.01 level** (two-tailed). Spearman's correlation coefficients are reported for all pairwise correlations.									

Tab. 2. Correlation analysis of study variables in the study group, N = *176*

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Models	ß	*p*	Adjusted R^2
Attention selectivity		0.084	
• early childhood exposure to smoking	0.146	0.171	
• current exposure to smoking	−0.221	0.045	
• prenatal exposure to alcohol and smoking × neurodevelopmental heritability	−0.142	0.129	
• early childhood exposure to smoking × neurodevelopmental heritability	0.117	0.373	
• current exposure to smoking × neurodevelopmental heritability	0.155	0.237	
• excluded predictors			0.031
• parental education	−0.025	0.762	
• perceived family financial situation	0.002	0.977	
• prenatal exposure to alcohol and smoking	0.027	0.806	
• parental education × neurodevelopmental heritability	−0.005	0.951	
• perceived family financial situation × neurodevelopmental heritability	0.024	0.772	
• neurodevelopmental heritability	0.029	0.720	
Visuospatial sketchpad		0.120	
• current exposure to smoking	−0.133	0.097	
• parental education × neurodevelopmental heritability	−0.100	0.211	
• excluded predictors			
• parental education	−0.052	0.619	
• perceived family financial situation	−0.024	0.768	
• prenatal exposure to alcohol and smoking	0.068	0.425	0.015
• early childhood exposure to smoking	0.044	0.647	
• perceived family financial situation × neurodevelopmental heritability	−0.041	0.607	
• prenatal exposure to alcohol and smoking × neurodevelopmental heritability	−0.023	0.779	
• early childhood exposure to smoking × neurodevelopmental heritability	0.029	0.748	
• current exposure to smoking × neurodevelopmental heritability	0.091	0.346	
• neurodevelopmental heritability	0.008	0.992	
Phonological loop		0.121	
• perceived family financial situation	−0.161	0.119	
• current exposure to smoking	0.228	0.017	
• perceived family financial situation × neurodevelopmental heritability	0.135	0.192	
• early childhood exposure to smoking × neurodevelopmental heritability	−0.134	0.252	
• current exposure to smoking × neurodevelopmental heritability	0.228	0.076	
• excluded predictors			0.024
• parental education	−0.006	0.943	
• prenatal exposure to alcohol and smoking	0.052	0.560	
• early childhood exposure to smoking	−0.042	0.755	
• parental education × neurodevelopmental heritability	0.038	0.651	
• prenatal exposure to alcohol and smoking × neurodevelopmental heritability	−0.068	0.475	
• neurodevelopmental heritability	0.051	0.524	
Executive functions		0.109	
• early childhood exposure to smoking	−0.137	0.088	
• neurodevelopmental heritability	−0.113	0.158	
• excluded predictors			
• parental education	−0.068	0.441	
• perceived family financial situation	−0.033	0.690	
• prenatal exposure to alcohol and smoking	0.013	0.892	0.016
• current exposure to smoking	0.098	0.304	
• parental education × neurodevelopmental heritability	0.021	0.795	
• perceived family financial situation × neurodevelopmental heritability	0.026	0.746	
• prenatal exposure to alcohol and smoking × neurodevelopmental heritability	−0.037	0.652	
• early childhood exposure to smoking × neurodevelopmental heritability	−0.009	0.926	
• current exposure to smoking × neurodevelopmental heritability	0.053	0.538	

Tab. 3. Beta coefficients in the stepwise regression analysis between socioeconomic and unhealthy family behaviours data and cognitive functions, with neurodevelopmental heritability as a moderator

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financial situation and parental education, and average levels of cognitive functioning results.
- Cluster 3 (n = 69): Families with average SES, low level of unhealthy family behaviours, and low level of children's cognitive functioning. This cluster is characterised by the lowest level of cognitive functions (except for the executive functions result, in which children raised in these families had the highest score across the study group), average level of parental education and perceived family financial situation, and low level of unhealthy family behaviours.

Fig. 3 presents the detailed results of the cluster analysis.

The final part of the data analysis was a moderation analysis to test the hypothesised association between SES and unhealthy family behaviours and cognitive functions in children, moderated by the presence of neurodevelopmental heritability in the close family. Multiple stepwise regression analysis models for attention selectivity, visuospatial sketchpad, phonological loop, and executive functions showed no statistically significant relationships. Tab. 3 illustrates the detailed results.

DISCUSSION

The context of functioning in children with ADHD

In this study, we gathered 176 children, aged 10–13 years, who had a comprehensive and multistage diagnosis of ADHD in Poland. To the best of our knowledge, this is one of the biggest studies on children with ADHD and their parents to date in Poland. The sex ratio was around 65%:35% (number of boys to girls), so the study sample well describes the sex distribution of ADHD occurrence. 36.9% of participants' parents declared they had family members with neurodevelopmental disorders, thus reflecting the heritability rate found in the literature quite closely (Barkley, 2015). We also collected many parental reports on SES and family functioning behaviours. In general, the participants obtained average results for attention selectivity, visuospatial sketchpad, phonological loop, and executive functions; this is surprising because all the participants presented ADHD symptoms and had a diagnosis of this disorder verified by a number of clinicians and tests (see *Methods* in Markevych et al., 2021 for a detailed diagnosis procedure). This unexpected result might be explained by the fact that, due to their complexity, there are not many unified tests or tasks measuring cognitive functions, especially executive functions (Denckla, 2005), and Polish versions of many of those broadly used in other cultural contexts are not available. The PU1 Battery of Cognitive Functions used in this study may not be sensitive enough to specifically measure the cognitive functions in a clinical sample of children with ADHD. In terms of testing children and young adolescents with ADHD, qualitative evaluation (e.g. whether a participant is able to sit and endure a long procedure) is just as important as quantitative evaluation, but here we focused exclusively on quantitative data. The SES and unhealthy family behaviours data seem to adequately illustrate the family backgrounds, except for the data regarding maternal alcohol consumption in pregnancy, where only 11.9% of the participants' mothers declared they had drunk alcohol during pregnancy or did not disclose information about it. This fact stands in contrast to other evidence (Scott and Sher, 2023) of a higher population percentage of alcohol consumption in pregnancy. These data may be due to the social stigma experienced by mothers who drink alcohol during pregnancy, especially when their offspring have difficulties such as ADHD. On the other hand, it is conceivable that the study sample data on alcohol consumption reflects the effect of public health campaigns advising against consuming alcohol during pregnancy. The participants of this study were born in 2009–2012, when campaigns of this kind were quite effectively implemented in Poland. Even though the other data on alcohol or tobacco use at home in the different developmental stages were more varied, in general the participants' parents who disclosed unhealthy family behaviours data did not seem to fully acknowledge their alcohol and tobacco use during pregnancy, the early childhood period and currently.

Family types raising children with ADHD

We found three family types in which the participants are raised. Two of them (Cluster 1 and 3) are similar in terms of SES and unhealthy family behaviour results, but the children raised in Cluster 3 families had the lowest levels of cognitive functioning, despite having quite good socioeconomic and family-environmental conditions. Moreover, the children with socioeconomic and family adversity (Cluster 2) presented an average level of cognitive functions. These results do not support the hypothesis that socioeconomic adversity and unhealthy family coping strategies predict cognitive dysfunctions in young adolescents with ADHD. On one hand, this is in line with Bronfenbrenner and Ceci's bioecological models of gene-environment interactions (Tillman and Granvald, 2015), where genetic differences underlying ADHD are more prominent in richer environments because they can be more genetically expressed. Given the fact that children with ADHD in Cluster 3 presented the lowest levels of attention and working memory skills, which are more genetically conditioned, they had the highest level of executive functions, which are more sensitive to environmental impact than attention and working memory. The protective effect of being raised in a more affluent environment is probably seen in this particular context. On the other hand, we expected the results of the children in Cluster 2 to be similarly low to those of Cluster 3 children, but they were average in terms of cognitive dysfunctions. This suggests there are some other protective factors which influence the cognitive skills of these participants, whose rates are high in this group, or maybe the exposure to smoking, especially during the various developmental stages, caused ADHD in young adolescence. The latter explanation would be in line with a large number of studies which show this association (Han et al., 2015; Kollins et al., 2009; Lin et al., 2021). Finally,

Cluster 1 may present children who were raised in a more affluent environment and display milder ADHD severity and cognitive impairment. This result may suggest that there are other factors, not included in this study, which have an impact on ADHD expression in this group of participants.

Neurodevelopmental heritability as a moderator of cognitive functioning in children with ADHD

In this study, we did not find any statistically significant relationships between SES and unhealthy family behaviours and cognitive functions in children with ADHD. Moreover, no moderation interaction of neurodevelopmental disorder heritability in close family was found. On one hand, this result would support the more common research approach to SES data, which involves treating parental education and family income more as confounders or risk factors than as predictors of ADHD symptoms in children. On the other hand, the lack of associations between unhealthy family behaviours and ADHD symptoms is surprising because one might intuitively think that unhealthy family behaviours should be related to cognitive dysfunctions via the genetic influence of alcohol and tobacco exposure or environmental social learning of non-adaptive coping strategies. This result may be attributed to the lower than expected level of test accuracy in measuring cognitive dysfunctions in children with ADHD (see *Discussion* above), or an insufficient number of participants. Some of the results might have been significant if we had included more observations in the study. Finally, the lack of statistically significant associations may be an interesting case that contradicts the existence of a relationship between SES and psychoactive substance use at home and its impact on the development of children with ADHD. This would contradict the substantial body of research that shows a negative impact of low SES and a high level of unhealthy family behaviours on ADHD symptoms (Biederman et al., 2002; Daseking et al., 2015; Dong et al., 2018; Han et al., 2015; Kollins et al., 2009; Martel, 2013; Mick et al., 2002; Nomura et al., 2010; Pheula et al., 2011; Piper and Corbett, 2012; Thakur et al., 2013; Tillman and Granvald, 2015). The result of this study is in line with previous research that found mixed or weak evidence of a negative influence of family alcohol and tobacco use on children with ADHD. Gustavson et al. (2017) reported some associations between maternal smoking during pregnancy and ADHD diagnosis in children, but these were not stronger than the associations found for other family members' smoking, even though the risk of epigenetic damage in children that would later cause cognitive impairment should be higher as a result of smoking while pregnant. In this case, the approach suggested by Marceau et al. (2018) might be more applicable. Possibly, research into the effect of maternal smoking on pregnancy and other stages of development should be undertaken on population samples, not only on people who have DSM criteria-based ADHD diagnoses. This could be another reason why these associations were not found in this study. Ultimately, a systematic review and meta-analysis (San Martin Porter et al., 2019) showed that maternal alcohol drinking of up to 7 portions (70 g) of alcohol per week did not increase the risk of ADHD symptoms in children. In light of these results and the study described in this paper, the negative influence of small portions of alcohol on ADHD-related cognitive dysfunctions might not be of major importance.

CONCLUSIONS

As this study used one of the biggest samples of children with ADHD in young adolescence in Poland, future research should focus on replicating similar study conditions to verify the accuracy of these results. Moreover, given the limited research that treats SES variables as predictors of ADHD in children, this kind of study design should be thoroughly studied because it is in line with Bronfenbrenner and Ceci's bioecological model of gene-environment interactions. Consequently, perhaps the socioeconomic background should not be reduced to the role of only a confounder. An interesting approach would be to combine the perspectives of parents and people from other significant environments where children spend time, such as teachers or other family members, because this might be more informative than one-sided opinions on children's cognitive functioning (Novita et al., 2023).

KEY TAKE-AWAYS

- The study results showed three types of families raising children with ADHD, but found no statistically significant connections between socioeconomic status, unhealthy family behaviours, and cognitive dysfunctions in the Polish context.
- Contrary to previous research, the environmental influence of socioeconomic status and unhealthy family behaviours on cognitive dysfunctions in children with ADHD was not present in this study.
- Future research should be focused on exploring the role of socioeconomic status as a predictor variable of cognitive dysfunctions in children with ADHD.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organisations which might negatively affect the content of this publication and/or claim authorship rights to this publication.

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Author contribution

Original concept of study; collection, recording and/or compilation of data; critical review of manuscript; final approval of manuscript: WW, KSW, ML, MS, BI. Analysis and interpretation of data; writing of manuscript: WW, KSW, ML, BI.

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