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Internalising behaviours and executive functions among early adolescents: the moderating role of age and sex

Zachowania internalizacyjne a funkcje wykonawcze we wczesnej adolescencji:
moderująca rola wieku i płci


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Abstract

Introduction: Entry into adolescence, a key period for mental health development, is associated with a higher risk of psychopathology. Existing findings on the nature of the relationship between internalising behaviours and specific executive functions are inconsistent. This study aimed to determine whether internalising behaviours are risk factors for specific domains of executive functions – working memory, verbal fluency, and planning – in a stratified random sample of young adolescents. The study also aimed to investigate whether sex and age have a moderating role in the aforementioned association. **Materials and methods:** Participants were 477 adolescents (aged 10–13 years, including 223 girls and 254 boys) from southern Poland. To assess the independent variable of internalising behaviours, the Youth Self-Report (YSR) was used. The components of executive functions (including working memory, verbal fluency, and planning) were measured using a battery of neuropsychological tests known as PU1. Associations between internalising symptoms and executive functions were evaluated using quasi-Poisson regression models, adjusted for potential confounders. **Results:** The study did not confirm the impact of internalising behaviours on the efficiency of executive functions in the studied group of adolescents. However, significant associations not covered by the research hypotheses were discovered: variance in working memory and phonological and categorical fluency is explained by age, and variance in categorical verbal fluency is also explained by parental education. **Conclusions:** Future exploration of predictors of executive functions components may reveal psychological risk factors, such as individual emotional and behavioural functioning in adolescence or family bonds; this could provide practical benefits in working with adolescents.

Keywords: executive functions, internalising behaviours, early adolescence

Streszczenie

Wprowadzenie i cel: Okres adolescencji jest szczególnie dla rozwoju zdrowia psychicznego, a samo dorastanie wiąże się z większym ryzykiem psychopatologii. Dotychczasowe doniesienia dotyczące natury związku między zachowaniami internalizacyjnymi a poszczególnymi funkcjami wykonawczymi są niejednoznaczne. Celem prezentowanych badań było określenie, czy zachowania internalizacyjne stanowią predyktory konkretnych obszarów funkcji wykonawczych (pamięć operacyjna, fluencja słowna i planowanie) w losowo dobranej grupie osób w wieku dorastania. Badanie miało również na celu zbadanie, czy płeć i wiek pełnią funkcję moderatorów we wspomnianej zależności. **Materiał i metody:** Uczestnikami badania było 477 adolescentów (w wieku 10–13 lat; 223 dziewcząt i 254 chłopców) z obszaru Polski południowej. Do oceny zmiennej niezależnej – zachowań internalizacyjnych użyto Kwestionariusza Samooceny dla Młodzieży (Youth Self-Report, YSR). Funkcje wykonawcze (obejmujące

pamięć operacyjną, fluencję słowną i planowanie) zostały zmierzone przy użyciu baterii testów neuropsychologicznych PU1. Związki między objawami internalizacyjnymi a funkcjami wykonawczymi oceniono za pomocą modelu regresji quasi-Poissona, z uwzględnieniem zmiennych zakłócających. **Wyniki:** Przeprowadzone analizy nie potwierdziły związku między zachowaniami internalizacyjnymi a pamięcią operacyjną, fluencją słowną i planowaniem w badanej grupie adolescentów. W analizach uzyskano jednak istotne wyniki poza hipotezami badawczymi. Okazało się, że wariancję w zakresie pamięci operacyjnej oraz fluencji fonologicznej i kategoryalnej wyjaśnia wiek badanych osób, a wariancję w zakresie fluencji słownej kategoryalnej – również poziom wykształcenia rodziców. **Wnioski:** Analiza predyktorów poszczególnych funkcji wykonawczych jest wskazana ze względu na potrzebę identyfikacji psychologicznych czynników ryzyka związanych m.in. z indywidualnymi aspektami funkcjonowania emocjonalnego i zachowania w okresie dorastania czy kontekstem więzi rodzinnych. Ich rozpoznanie jest korzystne dla sformułowania praktycznych wskazówek w pracy klinicznej z adolescentami.

Słowa kluczowe: funkcje wykonawcze, zachowania internalizacyjne, wczesna adolescencja

INTRODUCTION

Internalising behaviours

Entering adolescence is associated with a higher risk of psychopathology (Costello et al., 2011; Lynch et al., 2021). Considering empirically based taxonomies and the specificity of psychological problems in children and adolescents, two broad dimensions have been identified: internalising and externalising problems (Achenbach, 2020). Externalising problems are directed at others and include aggressive and delinquent behaviours. In contrast, internalising problems reflect internal stress and include somatic complaints, social withdrawal, depression, and anxiety (Achenbach et al., 2016). Previous research has primarily focused on externalising symptoms, as they can be easily noticed by an external observer, and adolescents with such behaviours are often perceived as problematic (Sourander and Helstelä, 2005). Internalising problems, however, are largely subjective perceptions of internal stress. Adolescents with such symptoms are quieter and withdrawn, and are more likely to be perceived as non-problematic by an external observer. However, internalising problems may influence self-esteem, physical health, social competence, and future psychological adjustment (Christina et al., 2021; Pedersen et al., 2019; Szejka, 2014; Trawicka et al., 2019). Research has shown that girls are at an increased risk of internalising their symptoms (Alloy et al., 2016; Sitnik-Warchulska, 2016). Anxious-depressed symptoms are the most common form of adolescent psychopathology (Merikangas et al., 2010). Somatisation is prevalent among children and adolescents, with children reporting a variety of somatic problems, including headache, stomachache, dizziness, chest pain, and nausea (Karkhanis and Winsler, 2016; Silber, 2011). Internalising symptoms, such as depression, anxiety, and somatisation, are interconnected (Wolańczyk, 2002) and have a broad impact on the functioning of children (Pedersen et al., 2019).

Influencing factors on early adolescent executive functions

Executive function (EF) is an umbrella term for higher cognitive processes involved in goal-oriented behaviours,

problem-solving, and self-control (Anderson, 2002). EF processes are necessary to formulate personally important goals, find appropriate methods to achieve them, and then implement them (Savcı et al., 2019). EF is not a homogenous process; it consists of several independent but interrelated components, including working memory, inhibition, shifting, cognitive flexibility, planning, and verbal fluency. From a developmental perspective, EF deficits tend to decrease with age (Gur et al., 2012; Huizinga and Smidts, 2011). Research on the factors influencing EF development in children and adolescents has shown a diversity of important variables: genetic, socioeconomic, and social. Genetic influences on EFs are significant across different stages of development (Engelhardt et al., 2015, 2016; Li and Roberts, 2017). Studies have also shown that the level of EF can be influenced by the socioeconomic status of parents (Hackman et al., 2015; Lawson et al., 2018). Kao et al. (2018) reported that parental EF plays a major role in early childhood EF skills, especially in children who are raised in lower-income households. Social influences on EF development are equally significant, as the development of the frontal cortex and its neural connections are highly dependent on environmental factors (Piccolo and Noble, 2019). Parent-child interactions and the family environment can influence EF development with both positive and negative effects. Family factors have a positive impact on EF; for example, organised and predictable family life or providing children with successful experiences of problem-based learning (Fay-Stammach et al., 2014; Hughes, 2011). However, there are also negative early life experiences and family factors, such as neglect, maltreatment, family chaos, stress, or early brain injury (Hughes, 2011). EF deficits have primarily been studied in the context of neurodevelopmental disorders (Crisci et al., 2021; Dajani et al., 2016). However, EF is essential for almost every aspect of daily life, enabling goal-oriented planning and flexible responses. Thus, EF deficits are also associated with a wide range of psychopathologies (Snyder et al., 2015).

Executive functions and internalising problems

The relationship between psychopathology and EF is bidirectional: on the one hand, deficient EF is a risk factor for

developing psychopathology; on the other hand, impaired EF may be a consequence of psychopathology (Romer and Pizzagalli, 2021). The results of a longitudinal study by Romer and Pizzagalli (2021) revealed that EF deficits predicted the development of psychopathology after two years. However, in this study, a higher basic level of psychopathology predicted EF deficits over time. Some studies exploring the relationship between EF and psychopathology have treated EF deficits as predictors of psychopathology (Hatoum et al., 2018; Letkiewicz et al., 2014; Stange et al., 2016), while others (Brieant et al., 2022; Mullin et al., 2020) as an outcome of it. Collectively, the findings indicate that EF deficits can be both a risk factor for and a consequence of psychopathology. However, the subject of EF as a consequence of developing psychopathology remains comparatively underexplored.

Many studies indicate that externalising behaviours and deficits in EF are interlinked (Cassidy, 2016; Romero-López et al., 2017; Schoemaker et al., 2013). Adolescents who exhibit aggressive behaviours and face peer rejection have more deficits in EF (Poland et al., 2016). However, less attention has been paid to the relationship between internalising symptoms and EF. Moreover, findings on internalising symptoms and EF are less consistent than those for externalising symptoms and EF. A systematic review on this topic concluded that depressed adults had impairments in EF, but research in children and adolescent populations revealed mixed findings (Vilgis et al., 2015). Additionally, while some studies included in the review demonstrated deficits in specific domains of EF within clinical groups of adolescents and children, most failed to find deficits in verbal fluency, inhibition, or set shifting (Vilgis et al., 2015). The relationship between depressive disorders and spatial working memory or planning remains unclear.

Most studies examining the relationship between internalising behaviours and EF have focused exclusively on adolescents or adults within clinical populations (Bahri and Bahri, 2018; Mullin et al., 2020; Smitherman et al., 2007; Toazza et al., 2014). It is important to note that varying intensities of internalising behaviours can also be observed in the general population of children and adolescents. Children who seek the help of a specialist constitute only a small percentage of those who exhibit emotional and behavioural problems (Szwejk, 2014; Wolańczyk, 2002).

Considering the inconsistencies in previous findings and gaps in the literature, this study was conducted on a population-based, nonclinical group of 10–13-year-old adolescents. Children of this age enter adolescence, which is a critical period for mental health development but is also associated with an increased risk of psychopathology (Costello et al., 2011).

Therefore, early adolescence is an important period for assessing maladaptive behaviours to prevent the development of clinical impairments in EF. Exploring the specific connections between internalising behaviours and EF components could help identify psychological risk factors for

developing EF deficits. Incorporating this knowledge into therapeutic and preventive programmes may provide practical benefits for working with early adolescents.

STUDY OVERVIEW

This study aimed to determine whether internalising behaviours are risk factors for specific domains of EF – working memory, verbal fluency, and planning – among 10–13-year-old adolescents from a nonclinical population.

Based on the literature, the following research hypotheses were developed:

1. The effectiveness of working memory, phonological verbal fluency, categorical verbal fluency, and planning is associated with the level of internalising behaviour.
2. Sex has a moderating role in the association between internalising behaviours and EF.
3. Age has a moderating role in the association between internalising behaviours and EF.

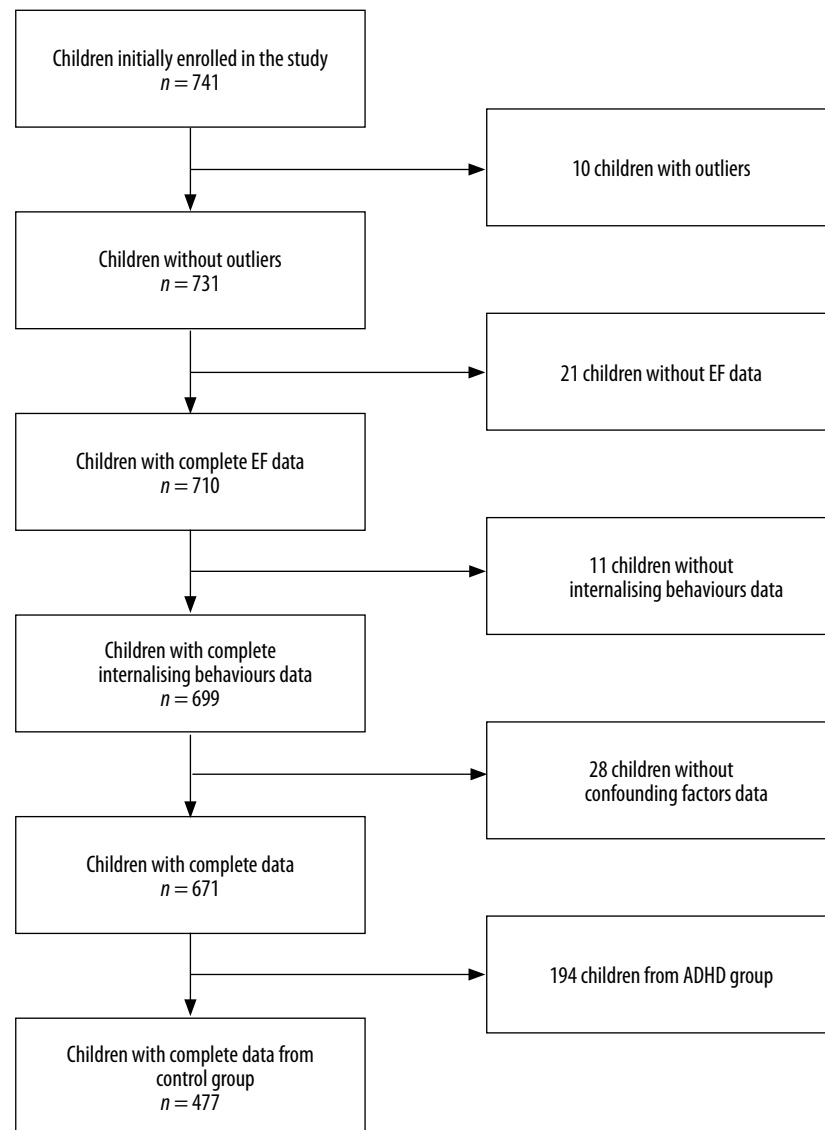
In the study model, internalising behaviours were treated as the independent variable. In accordance with the literature (Achenbach et al., 2016; Radziwiłłowicz, 2020), this variable is defined as manifestations of internal stress perception dominated by psychological and physical discomfort, and consists of the following domains: withdrawn, avoidance of social contact with other people; somatic complaints, reports of physical health issues without apparent medical reasons; anxious-depressed – connected with negative affect; feelings of sadness, unhappiness, inferiority, and difficulties controlling worry or fear.

The dependent variable in this study comprised specific components of EF. The first component is working memory, a system that stores and processes information temporarily to guide behaviours (Baddeley, 2010). The second is the planning process, which is necessary for achieving aims and determining activities required to accomplish them (Friedman and Scholnick, 1997). The third is verbal fluency, which involves the ability to generate words that belong to a specified category (categorical verbal fluency) or start with a specified letter (phonological verbal fluency) (Patterson, 2011). This study treated verbal fluency as an EF component because performing verbal fluency tasks requires participants to keep the instructions and earlier responses in working memory, focus on the task, avoid repetition, select words that meet certain conditions, and switch between tasks, all of which involve executive control processes (Shao et al., 2014).

MATERIALS AND METHODS

Participants and procedures

The data analysed in this study were collected as part of the NeuroSmog project. Briefly, the NeuroSmog project aimed to explore whether air pollution affects the neurodevelopment of adolescents with attention deficit



EF – executive functions; **ADHD** – attention deficit hyperactivity disorder. Confounding factors: age in years, minimum education of both parents, and perceived financial situation of the family in 2019.

Fig. 1. Flowchart illustrating the definition of the analytic sample

hyperactivity disorder (ADHD; cases) and their typically developing counterparts (controls). Data from 477 adolescents in the control group were analysed, and Fig. 1 illustrates how the analytic sample was defined. The adolescents were recruited from randomly selected non-specialised primary schools in 18 towns in southern Poland. Within the project, each child and their legal guardian completed a series of psychological tests and questionnaires, which were administered over three sessions with field psychologists with at least five years of clinical experience. The recruited adolescents were aged 10–13, attended the fourth, fifth, or sixth grade of primary school, and had a typical educational path (without repeated school years, individual education plans, or significant absenteeism). They were fluent Polish speakers with an average or above-average IQ,

undisturbed sensory perception, and normal or corrected vision and hearing. The adolescents were not diagnosed with any mental, emotional, behavioural, developmental, or neurological disorders, nor did they receive any medication affecting the nervous system. Adolescents born before the 35th week of pregnancy, with a birth weight of less than 2,500 g, or an Apgar score lower than 8, were excluded. Written informed assent was obtained from all adolescents participating in the study, and written informed consent was obtained from their legal guardians. This study was approved by the Ethics Committee of the Institute of Psychology, Jagiellonian University, Kraków, Poland (# KE_24042019A). The clinical trial identifier was NCT04574414. The details of the recruitment and procedures for the NeuroSmog study are described in the project protocol (Markevych et al., 2021).

Methods

Diagnostic Battery for Cognitive Functions Evaluation (PU1)

The Diagnostic Battery for Cognitive Functions Evaluation is a Poland-specific neuropsychological test battery that examines memory, attention, and EF in children (Borkowska et al., 2015). For the assessment of specific EF domains, the following tests from the PU1 battery were used in the current study.

1. “Squares Test” is a measure of spatial working memory. The test is performed on a computer, where the child sees a 4×4 square matrix with squares marked in sequences. The task is to remember the sequence and then recall it in reverse by clicking on the previously marked squares. The result is the sum of correctly recalled sequences in reverse order and correctly recalled squares, even if they are in an incorrect order. The internal consistency, measured by Cronbach’s alpha coefficient for the sample of Polish children, was 0.74.
2. “Verbal Fluency Test I” is a measure of phonological fluency. The child recalls words starting with the letter “K” in 60 seconds. The result is the number of words recalled.
3. “Verbal Fluency Test II” is a measure of categorical fluency. The child is asked to recall the names of animals in 60 seconds. The result is the number of words recalled. The reliability of the fluency tests was measured in a standardized sample of Polish children using a test-retest method. The correlation (Spearman’s rho) for the “Verbal Fluency Test I” was 0.69, and for the “Verbal Fluency Test II” it was 0.83, which demonstrates the stability of the measurement.
4. “Map of the Park Test” is a measure of planning ability. A child views a worksheet with a schematic map of a park. The task is to draw a path through the park, following the requirements mentioned under the map. There are two results: time taken and the number of fulfilled requirements. The internal consistency, measured by Cronbach’s alpha coefficient in the sample of Polish children, was 0.61.

Youth Self-Report (YSR)

The Polish adaptation of the Youth Self-Report (YSR) was used to assess internalising behaviours (Achenbach and Rescorla, 2001; Wolańczyk, 2002). The YSR is part of the Achenbach System of Empirically Based Assessment (ASEBA), a widely used tool for assessing behavioural and emotional problems in children and adolescents. In the YSR, emotional and behavioural functioning is self-reported by children or adolescents. The tool consists of eight subscales: withdrawn, anxious-depressed, somatic complaints, aggressive behaviour, rule-breaking behaviour, attention problems, social problems, and thought problems. The subscales for somatic complaints, anxious-depressed, and withdrawn are summarised in the internalising problems scale used in this study. The withdrawn and somatic complaints subscales consist of nine items each, while the anxious-depressed

subscale consist of 16 items. The maximum possible score was 18 for withdrawn, 18 for somatic complaints, and 32 for anxious-depressed.

Each participant completed the YSR questionnaire by marking their answers on a three-point Likert scale (“not true”, “somewhat true”, “true”). The Cronbach’s alpha reliability coefficient for internalising behaviours in this study was 0.85.

General Questionnaire

The following data were obtained from the General Questionnaire, which was developed specifically for the Neuro-Smog project: sex, age, the perceived financial situation of parents in 2019, and parents’ education. Age was calculated as the difference in days between the date of completion of the General Questionnaire and the date of birth and then divided by 365.25 to express it in years.

The education of both parents was measured with the following options: *primary education*, *secondary education*, *higher education*, *other* (what kind?) with an input field for specification, and *I do not know/I do not wish to answer*. The answer *I do not know/I do not wish to answer* was treated as missing data. The lowest level of education between both parents was employed for analysis. Parents also assessed their perceived financial situation in 2019 (before the pandemic, which could have had an impact on the financial circumstances). The parents had the following options: *very difficult*, *quite difficult*, *we managed to make ends meet*, *good*, *we had enough to live a comfortable life*, *I do not know/I do not wish to answer*.

For analysis, the categories *very difficult*, *rather difficult*, and *we managed to make ends meet* collapsed due to the small number of responses. Again, the answer *I do not know/I do not wish to answer* was treated as missing data.

Statistical analysis

Statistical analysis was performed using R software, version 4.1.1 (R Core Team, 2018). Overall, 10 outliers were identified by visual inspection of scatter plots and removed from the dataset (Fig. 1). Descriptive characteristics of the total study population are reported as frequencies and percentages for categorical variables and as means, standard deviations, minima, and maxima for continuous variables.

PU-1-derived EF measures – working memory, phonological fluency, categorical fluency, planning success, and planning time – were treated as the dependent variables. The YSR-derived internalising symptom score was used as the independent variable. Associations between each independent and dependent pair were tested separately.

The diagnostics of the models were checked, and a good fit was confirmed. To account for the nature of four of the five dependent variables, as well as over- and under-dispersion, we used quasi-Poisson regression models. Since the working memory and planning success data distributions had a long tail on the left instead of on the right, they could

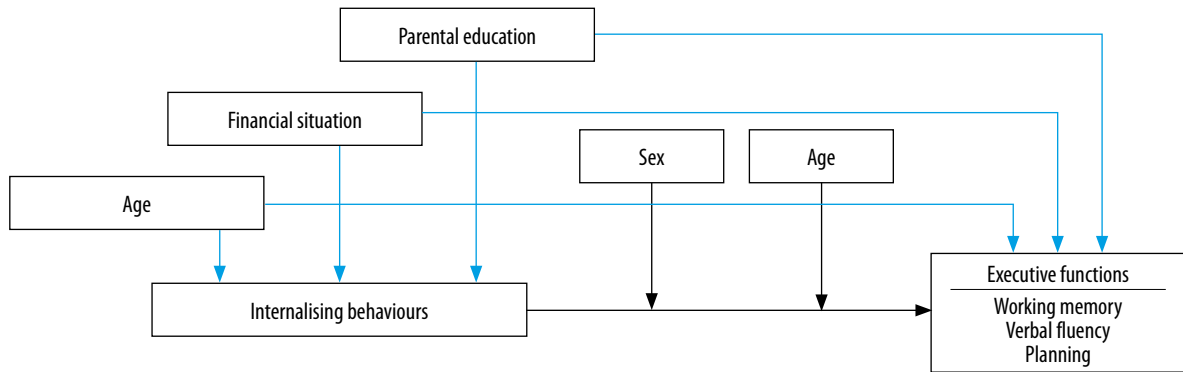


Fig. 2. Empirical model

not be fitted with quasi-Poisson models. Instead, the values of working memory and planning success were subtracted from their respective maximum possible scores ($n = 24$ and $n = 8$, respectively). Hence, the newly created variables can be interpreted as “poor working memory” and “poor planning”. Betas from quasi-Poisson models were exponentiated and presented as risk ratios (RR), together with their respective 95% confidence intervals (CIs). As the planning time variable was a continuous variable, we analysed its associations using linear models but log-transformed the variable prior to the analysis to improve model fit. These betas were also exponentiated to obtain mean ratios (MR) with corresponding 95% CIs. As a sensitivity analysis, to check the robustness of our findings, we used population-normalized variables for EF instead of the original raw scores. For this analysis, associations with planning time were also examined using quasi-Poisson regressions. To check for potential moderation, analyses were stratified by age (10 years vs. 11 years vs. 12 years) and sex (male vs. female).

All models were adjusted using the minimum set of confounders identified through a directed acyclic graph (DAG), including exact age in days expressed in years (except for the age-stratified models), parental education, and the perceived financial situation of the family in 2019. The DAG was constructed using dagitty.net (Textor et al., 2016), and the empirical model for this study is presented in Fig. 2.

RESULTS

The mean age of the study participants was 11.3 years, and 46.8% of them were females. Beyond the inclusion and exclusion criteria, IQ was also estimated for research purposes ($M: 103.36$; $SD: 10.87$). However, it was not the subject of the analyses presented due to the aim of the study. Notably, 42.8% of the study participants had parents with a high level of education. Descriptive statistics for the continuous and categorical research variables are presented in Tab. 1. Tab. 2 presents the full regression results of the adjusted quasi-Poisson regressions. Internalising behaviours were not associated with any EF outcomes: risk ratios for poor working memory, phonological fluency, categorical fluency, and poor planning, and the mean ratio for planning time

were close to 1 and insignificant. However, age was significantly related to working memory, phonological fluency, and categorical fluency, with risk ratios indicating that EF improved with increasing age.

Moreover, a relationship between parental education and categorical fluency is visible: the risk ratios for medium vs. low and high vs. low education were 1.09 and 1.13, respectively, indicating that higher parental education is associated with a 9–13% increase in categorical verbal fluency. These findings did not change when standardised instead of raw outcomes were used (data not shown).

The results of the moderation analysis for age and sex are presented in both Figs. 3 and 4. Neither age nor sex

Variable	Type of statistics	Descriptive statistics
Sex:		
• female	n (%)	223 (46.8)
• male	n (%)	254 (53.2)
Perceived financial situation in 2019:		
• very difficult/quite difficult/just managed to make ends meet	n (%)	40 (8.4)
• doing alright	n (%)	305 (63.9)
• living comfortably	n (%)	132 (27.7)
Minimum parental education:		
• low	n (%)	68 (14.3)
• medium	n (%)	205 (43.0)
• high	n (%)	204 (42.8)
Age [years]	$M \pm SD$ (min–max)	11.3 \pm 0.7 (10.0–13.0)
Working memory	$M \pm SD$ (min–max)	19.1 \pm 3.0 (7.0–24.0)
Phonological verbal fluency	$M \pm SD$ (min–max)	12.1 \pm 3.9 (3.0–28.0)
Categorical verbal fluency	$M \pm SD$ (min–max)	18.8 \pm 4.8 (4.0–40.0)
Planning success	$M \pm SD$ (min–max)	5.8 \pm 1.2 (1.0–8.0)
Planning time	$M \pm SD$ (min–max)	63.0 \pm 49.8 (8.0–570.0)
Internalising behaviours	$M \pm SD$ (min–max)	12.6 \pm 8.4 (0.0–51.0)

SD – standard deviation; Min – minimum; Max – maximum.

Tab. 1. Descriptive statistics of the studied sample ($n = 477$)

Variable	Poor working memory RR (LCI–UCI)	Phonological fluency RR (LCI–UCI)	Categorical fluency RR (LCI–UCI)	Poor planning RR (LCI–UCI)	Planning time MN (LCI–UCI)
Internalising behaviours	1.00 (0.99–1.01)	1,00 (1.00–1.00)	1,00 (1.00–1.00)	1.00 (0.99–1.00)	1.00 (1.00–1.01)
Age	0.90 (0.84–0.97)	1.06 (1.02–1.10)	1.04 (1.01–1.08)	0.95 (0.88–1.01)	0.93 (0.87–1.00)
Minimal education (medium vs. low)	0.87 (0.74–1.02)	1.06 (0.97–1.16)	1.09 (1.01–1.17)	1.03 (0.88–1.19)	1.08 (0.92–1.26)
Minimal education (high vs. low)	0.88 (0.75–1.04)	1.08 (0.99–1.19)	1.13 (1.05–1.21)	0.97 (0.83–1.13)	1.02 (0.87–1.20)
Finances (doing alright vs. hard)	1.03 (0.84–1.26)	1.04 (0.94–1.16)	1.01 (0.92–1.10)	0.90 (0.75–1.08)	0.98 (0.81–1.18)
Finances (living comfortably vs. hard)	0.99 (0.79–1.23)	1.07 (0.95–1.20)	1.05 (0.96–1.16)	0.96 (0.79–1.17)	1.01 (0.82–1.24)

RR – risk ratio; LCI – lower confidence interval; UCI – upper confidence interval; MN – mean ratio.
Bold text – statistical significance at the 5% level.

Tab. 2. Results of the adjusted quasi-Poisson regressions on the associations between internalising behaviours and EF. Each column refers to a separate model

moderated the associations between internalising behaviours and EF, as effect estimates across groups were similar, and the confidence intervals largely overlapped.

DISCUSSION

The study investigated the potential relationship between internalising behaviours and specific aspects of EF among early adolescents in Poland. No evidence was found to support a relationship between internalising behaviour and verbal fluency, planning, or working memory. Additionally, no moderating effect of sex or age on the relationship between internalising behaviours and EF was observed. Previous research on this topic has yielded mixed results. Studies on verbal fluency have mainly focused on clinical

groups of adolescents (Favre et al., 2009; Toazza et al., 2014; Vilgis et al., 2015). Toazza et al. (2014) reported that adolescents in clinical groups had difficulties with phonemic verbal fluency, whereas Favre et al. (2009) found no group differences. An explanation for the inconsistent findings in the field of verbal fluency could be that different categories for semantic tasks and letters for phonemic tasks were chosen across the studies. Quistberg and Mueller (2020) identified reciprocal relationships between internalising behaviours and working memory in a nonclinical population of adolescents. It was also observed that depressed adolescent girls made more mistakes than their peers in spatial working memory tasks (Matthews et al., 2008), but Maalouf et al. (2011) found no group differences. Adolescents with internalising symptoms demonstrate more impulsive behaviour

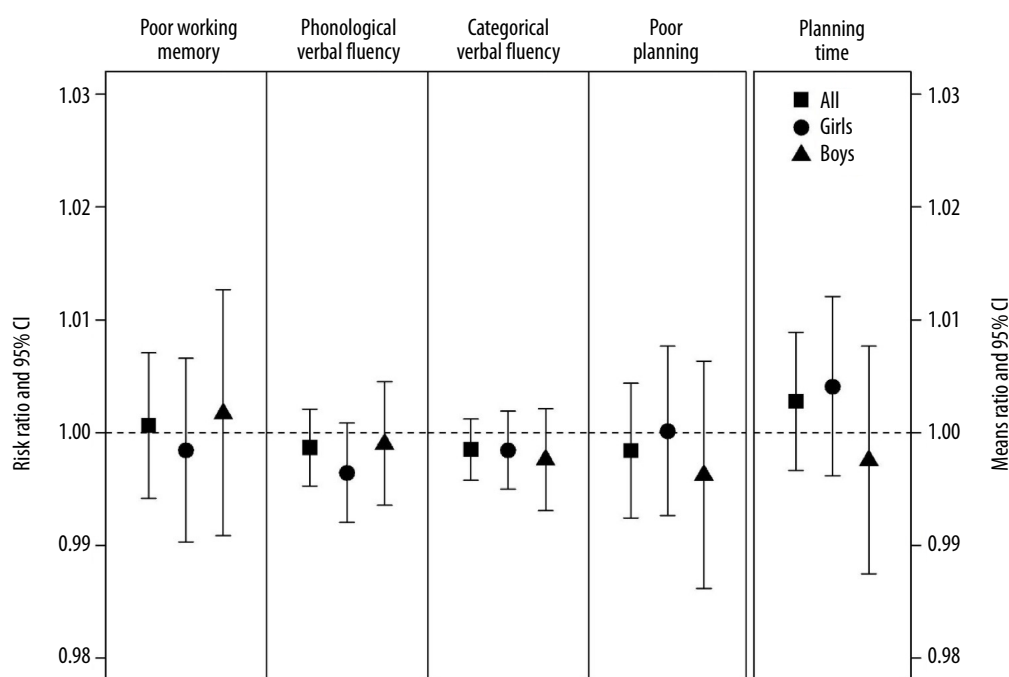


Fig. 3. Results of adjusted quasi-Poisson regression on the associations between EF and internalising behaviours stratified by sex

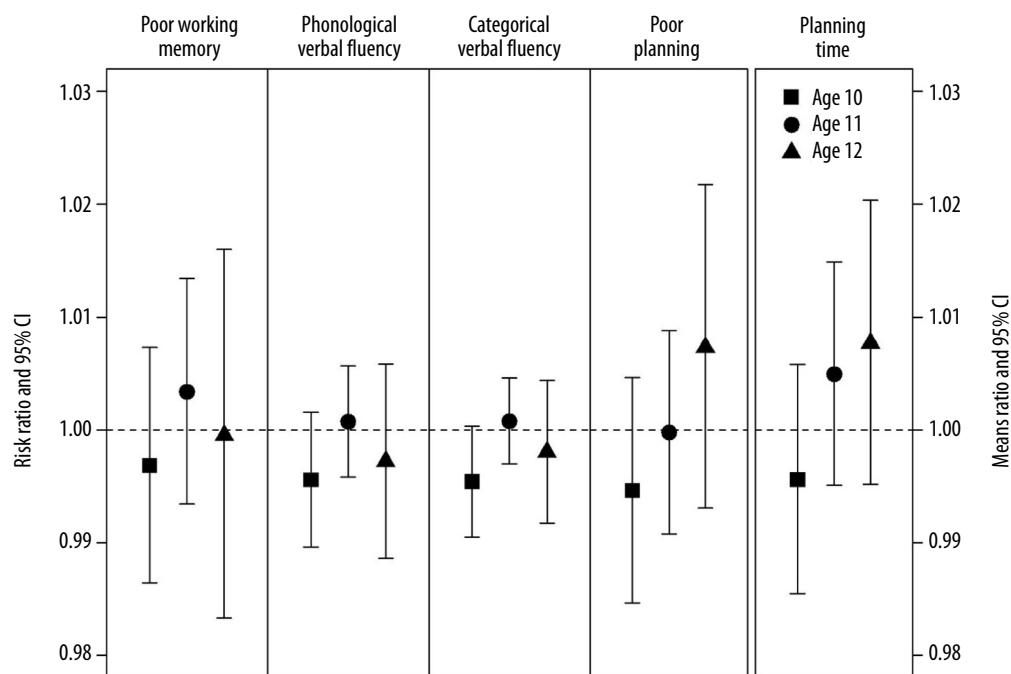


Fig. 4. Results of adjusted quasi-Poisson regression on the associations between EF and internalising behaviours stratified by age

while performing decision-making tasks (Kyte et al., 2005), but Matthews et al. (2008) did not find any differences between clinical and nonclinical groups in tasks requiring planning. Van Deurzen et al. (2012) found an association between EF and internalising behaviours in girls from non-clinical populations, but Agnes Brunnekreef et al. (2007) reported no differences between boys and girls. Hatoum et al. (2018) showed that EF predicted the covariance in internalising and externalising behaviours, but only in boys. This raises the possibility that the specific age of the participants is relevant, with some studies showing that the difference between boys and girls in internalising behaviours starts to appear around ages 12.5 to 13 years (Jane Costello et al., 2006). However, Cassidy (2016) did not find any age differences in the associations between EF and internalising/externalising problems. Given the mixed results from previous studies, one explanation for our null findings is that there is no relationship between internalising symptoms and these specific EF within the general population of preadolescents.

Our findings show that some components of EF can be explained by age and parental education, which aligns with the literature (Hackman et al., 2015; Lawson et al., 2018) and demonstrates the validity of our data. The observed increases in working memory, phonological fluency, and categorical fluency with age appears to be clear in a developmental context, although studies in this area remain inconclusive (Aki et al., 2022). Firstly, the development of working memory is essential for verbal competencies (Witruk, 2019). Verbal fluency is highly sensitive to cognitive deficits (Álvarez Medina et al., 2023), and the presented

study analysed a population of children without identified difficulties, selected through randomisation. Verbal fluency, which reflects the ability to produce words within a certain time period and within a particular category, improves mainly through education. The level of education is associated with age during early adolescence. In schools (also in Poland), there is a change in teaching methods between the early school period and later years. More diverse and autonomy-demanding tasks contribute to children taking on greater responsibility for their learning, which contributes to enhancing memory efficiency and fostering conscious control of cognitive processes (Dźwierzyńska, 2019). This, in turn, is essential for the development of verbal fluency, especially in complex tasks such as creating semantic categories (Aki et al., 2022).

An interesting finding is the observed relationship between parental education and categorical fluency. This aligns with the research deliberations on the bio-psycho-social basis of psychological functioning, including EF, in contemporary children (Sitnik-Warchulska et al., 2023; Walenista et al., 2023). The level of parental education may be associated with the home environment that shapes early problem-solving skills or EF tasks. Ardila et al. (2005) suggest that parents with a college education may have a value system that correlates with a more intellectually stimulating environment. This effect may be reflected in higher scores achieved in verbal tests, especially those assessing categorical fluency. It is worth highlighting that the current study was conducted during the coronavirus disease 2019 (COVID-19) pandemic, which provided a specific context for the development of psychopathology. Studies have shown that

internalising symptoms increased significantly during the COVID-19 pandemic, with factors such as social isolation, school closures, and parental financial problems influencing children's mental health (Crescentini et al., 2020; Feinberg et al., 2022). The pandemic has had a significant impact on the mental health of children and adolescents, particularly in relation to depression and anxiety (Marques de Miranda et al., 2020; Nearchou et al., 2020). Previous studies have shown that parental stress (associated with unemployment and financial problems) can also negatively influence childhood well-being (Frasquilho et al., 2016). Additionally, the lack of direct interactions with peers causes loneliness; children spend more time on screens, their physical activity level is lower, and their sleep patterns are more irregular (Nearchou et al., 2020). The pandemic has created a state of chronic stress that affects children and adolescents' emotional life, which might affect cognitive functioning. Interestingly, contrary to our expectations, the internalising behaviour scores in our study were relatively low.

LIMITATIONS, STRENGTHS, AND FUTURE DIRECTIONS

The failure to find an association may stem from the limitations of this study. First, the study was based on well-functioning children from a nonclinical population; therefore, the internalising scores were relatively low. The study group was selected through randomisation. Strict inclusion and exclusion criteria, as well as random selection, meant that the analysis focused on children without any other psychopathological symptoms and with average or above-average IQ. Agnes Brunnekreef et al. (2007) indicated that the level of working memory is related to the severity of problem behaviours rather than to the type of maladaptive behaviour (internalising or externalising), suggesting that the association might not be linear and could emerge only at some point. It is possible that if our sample had more severe internalising problems, the association with EF would become apparent. In light of the biopsychosocial context of EF development in childhood and adolescence, it would be beneficial to include moderators from the family environment (e.g. family bonding) or environmental characteristics (e.g. features of the physical environment) in future analyses.

Second, data on internalising problems were based on a self-report questionnaire. However, the validity of the YSR is well-established, and self-reporting is considered a relevant and valid measure for the assessment of internalising problems because of its subjectivity. In particular, the components of EF were measured using performance-based tasks that provide guidelines for expected behavioural responses and are strongly structured. Formal testing may introduce anxiety, which reduces EF performance (Horwitz and McCaffrey, 2008). A strong link between internalising symptoms and EF in a nonclinical population was found in a study that used self-reported evaluation of EF (Mullin et al.,

2020). The obvious disadvantage of this method is reporter bias, but it offers insight into how EF manifests in everyday situations that might be full of emotions and uncertainties, which is an important aspect for youths with psychopathology. The perfect way to understand the relationship between psychological problems and EF is to use both performance-based and self-reported measures of EF. Another approach to increasing the reliability of the study would be to employ several measures for EF components, instead of just one for each.

The strengths of this study should be highlighted as well. The study population was homogeneous, and the adolescents were recruited under strict sample selection conditions from similar communities. This approach is important in terms of controlling for unmeasured and unknown risk factors for outcomes and the generalizability of the results. Internalising behaviours and traits are also common in nonclinical populations (Szejka, 2014; Wolańczyk, 2002), so this study aimed to explore their relationship in a healthy population of adolescents. Many previous studies have encompassed a wide age range, but specific developmental aspects are critical in both executive functioning and internalising behaviours. To address this problem, the age range of our participants was narrow, from 10 to 13 years. While some previous studies on this topic utilised entire batteries of EF tests, with many subtests, and reported significant results for certain measures. To address specific hypotheses about the relationship between internalising behaviours and EF, the present study did not rely on the entire battery of cognitive functioning, but on specific tasks.

The issues of internalising problems and EF deficits will remain important for clinical and developmental psychologists for the foreseeable future, especially during a pandemic. Future studies should focus on the influence of internalising problems on other domains of EF, as well as on other aspects of the cognitive and emotional functioning in early adolescence. Our results show that some of the EF components can be explained by age and parental education, suggesting that these factors are worth considering from the perspective of general cognitive development and family conditions. Incorporating this knowledge into therapeutic programmes and prevention strategies may provide practical benefits for young adolescents.

CONCLUSIONS

This study did not find evidence that internalising behaviours predicted deficits in specific EF domains, nor was any moderating effect of sex or age observed. However, it was found that some EF components could be explained by age and parental education. Both internalising symptoms and cognitive functioning are important during adolescence; therefore, this topic will remain relevant for clinical and developmental psychologists in the future, especially in cases involving the consequences of the pandemic for youth functioning.

Conflict of interest

The authors declare that they have no competing interests.

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Author contribution

Original concept of study: KB, KSW, ML, BI. Collection, recording and/or compilation of data: KSW, ML, IM, CB, YM, DB, MS, BI. Analysis and interpretation of data: KB, KSW, IM, CB. Writing of manuscript: KB, KSW. Critical review of manuscript: KSW, ML. Final approval of manuscript: KB, KSW, ML, IM, CB, YM, DB, MS, BI.

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