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Developmental Psychobiology

RESEARCH ARTICLE

# Association of Socioeconomic Status With IQ and Attention in School Children in Poland, a Country With Relatively Low Socioeconomic Differences

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**Received:** 5 May 2025 | **Revised:** 12 May 2025 | **Accepted:** 31 May 2025

**Funding:** This work was supported by the "NeuroSmog: Determining the impact of air pollution on the developing brain" (Nr. POIR.04.04.00-1763/18 00) grant to Marcin Szwed implemented as part of the TEAM-NET programme of the Foundation for Polish Science, co-financed from EU resources obtained from the European Regional Development Fund under the Smart Growth Operational Programme. Additional funding came from a grant from the Priority Research Area ("Anthropocene") to Marcin Szwed under the Strategic Programme Excellence Initiative at Jagiellonian University, Poland. Iana Markevych's time on this publication is partially supported by the "Strategic research and innovation program for the development of Medical University–Plovdiv" N BG-RRP-2.004-0007-C01, Establishment of a network of research higher schools, National plan for recovery and resilience, financed by the European Union–NextGenerationEU.

**Keywords:** attention | children | IQ | social inequalities | socioeconomical status

## ABSTRACT

Socioeconomic inequalities affect health via multiple biological, behavioral, and social pathways. Specifically, low socioeconomic status (SES) negatively impacts children's intelligence quotient (IQ). Most data on this topic comes from high-inequality countries such as the United States. Here, we investigate the relation between SES, IQ, and attention and how it might be mediated by early-childhood factors in 10- to 13-year-old children in Poland, a country with relatively low inequality and a medium GDP level. Executive attention was measured using a go/no-go task. We found that parental education significantly influenced IQ and attention. Low SES children scored on average 3 IQ points lower than high SES children and had significantly longer reaction times and d' (discrimination accuracies). Family SES had a clear non-mediated impact on IQ and an overall effect on attention. On the other hand, smoking/alcohol during pregnancy and breastfeeding, while all correlated with SES, did not mediate its effects on IQ or attention. We conclude that the impact of SES on cognition is considerable even in a low-inequality country such as Poland, and in our population it cannot be explained by these early-life factors.

Trial Registration: Clinical Trials Identifier: NCT04574414

## 1 | Introduction

Socioeconomic status (SES) is usually understood as position in social hierarchy, measured with indicators such as income, educational level, occupational level, and place of residence (Baker 2014). Education and income are the most popular measurements of SES, followed by occupation prestige, complexity, and social position (Barone et al. 2021).

A person's SES will affect his/her life in manifold ways. Systematic reviews and meta-analyses show its association not only with health (Bridger Staatz et al. 2021; Knorst et al. 2021; Levesque et al. 2021; Pathirana and Jackson 2018) but also educational achievements (Dietrichson et al. 2017; Rodríguez-Hernández et al. 2020; Sirin 2005; Sosu et al. 2021). A recent meta-analysis by Korous et al. (2022) revealed a consistent, positive association between SES, cognitive abilities, and educational achievements. There is also ample evidence of a higher prevalence of mental health problems among children and adolescents from low SES backgrounds (Duncan et al. 1994; Goodman et al. 2003; Merikangas et al. 2010; Shanahan et al. 2008). In this study we focus on the relation between SES, intelligence, and attention. Lower SES among children and adolescents correlates with lower IQ (e.g., Duyme et al. 1999). These regularities are observed both in preschool children (Milovanović et al. 2022; Piccolo et al. 2016) and adolescents (Madhushanthi et al. 2021). In some studies, the IQ of 10-year-old children can be as much as 12.5 points lower than their higher SES counterparts (von Stumm and Plomin 2015).

SES combines different dimensions (Duncan and Magnuson 2012), which may affect children's cognitive development in different ways (Bradley and Corwyn 2002). Low SES correlates with less linguistic, social, and cognitive stimulation and more stress and adversity, two large groups of factors that affect brain and cognitive development (Brito and Noble 2014). Rosen and co-authors (Rosen et al. 2020), in particular, attribute SES-related differences to lower cognitive stimulation. SES can influence whether children will express their genetic potential for intelligence (Tucker-Drob et al. 2010; Turkheimer et al. 2003; see, however, Bates et al. 2016).

SES also affects attention and executive function in children, the second focus of our study (Hackman et al. 2010; Hackman and Farah 2009). Results indicate a positive relation of higher SES with working memory, planning tasks, cognitive flexibility, and inhibitory control (Hackman et al. 2015; Madhushanthi et al. 2021; Ming et al. 2021). This relation occurred both when attention was measured using subjective descriptive scales filled out by children (14 years old) and parents (Schmengler et al. 2023) and attentional tasks (Stumper et al. 2020). In addition, studies involving children of racial minorities in the US showed a positive correlation between SES and attention with both task-based and CBCL-based (Child-Behavior Checklist) attention measures (Assari 2020).

Specific factors explaining the effects of SES on development include, among others, genetics (Deary et al. 2006), stress and adversity levels (Rincon-Cortes and Sullivan 2014), parental and school environment (Hamre et al. 2013; Pollé et al. 2025), parental nurturing (Farah et al. 2008), and nutrition (Prado and Dewey 2014). Among the latter group of factors, some are specifically linked to early childhood environment. Here, we focus on early childhood measures available in the NeuroSmog study, i.e., breastfeeding, prenatal smoking, and alcohol drinking and low birthweight. All these are associated with SES and may influence cognitive functions in children (Rincon-Cortes and Sullivan 2014). These early-life factors have been the focus of extensive research linking them to cognitive outcomes in childhood and beyond.

A study by Stumm and Plomin (2015) indicates that breastfeeding has a small positive effect on the development of IQ from early childhood to adolescence. Horwood and Ferguson (1998), for example, suggested that breastfeeding is associated with increases in child cognitive ability and educational achievement. The authors also found that higher SES mothers breastfed for longer periods. Feeding with breast milk is positively associated with maternal verbal ability, educational attainment, SES, and home environment (Smith et al. 2003). Lopez et al. (2021) show clear benefits of breastfeeding on general cognitive ability scores. Other studies (for example, Larkby and Day 1997; Lees et al. 2020) and meta-analyses (Jacobson et al. 2021; Pyman et al. 2021) also show that any prenatal alcohol use by the mother is associated with detrimental effects on child development. Based on these studies, we hypothesized that SES effects on cognition will be mediated by the above perinatal/environmental factors.

Most studies on SES and cognition to date have been conducted in high-inequality, wealthy countries such as the United States (e.g., Hanson et al. 2013; Noble et al. 2007; Raizada et al. 2008; Kishiyama et al. 2009; Hanson et al. 2013; Hackman et al. 2015; Hair et al. 2015; Last et al. 2018; Li et al. 2022; Vrantsidis et al. 2019; Brieant et al. 2021), Australia or the UK (e.g., Butterworth et al. 2012; Noble et al. 2012; Tomalski et al. 2013; Trzaskowski et al. 2013; Cavanagh et al. 2013). This challenges the generalizability of their conclusions (Kamgang et al. 2023), as environmental stability in low-inequality countries may lead to less stressful living conditions and foster more uniform cognitive development. Here we report results from a study based in Poland, a country with relatively low socioeconomic differences and medium incomes, underrepresented in the literature. According to World Bank survey data, as assessed by the Gini index, Poland (GI = 28.5) has less income inequality than the United States (GI = 39.8) or the European Union on average (GI = 30.8). This relatively low inequality has been linked to, among other factors, good social equity in education. It results, for example, in a higher proportion of resilient students compared to the average among member states of the Organization for Economic Co-Operation and Development (OECD), i.e., a higher proportion of students who come from the 25% of families with the lowest SES but in terms of academic performance rank among the top 25% of students with similar backgrounds (OECD 2016). We hypothesized that despite relative equality, high SES will be positively related to IQ and attentional task outcomes.

In the present study we focus on the relation between SES, IQ, and attention. IQ is the general cognitive ability to solve complex tasks and it is linked with the academic and career success (Gottfredson 1997). Attention, on the other hand, is a specialized set of cognitive processes responsible for prioritization and selection of proper reaction to the outside world and it is crucial for the regulation of behavior (Posner et al. 2014). In our study we focused on specific aspect of attention–executive attention, which is responsible for resolving motor and cognitive conflicts (Posner et al. 2014). To properly resolve the conflicts and regulate behavior, executive attention amplifies the activity of the goal related processes, and inhibits conflicting processes (Posner 2012). While attention and general cognitive ability are related, they are not identical constructs. In disorders such as attention deficit hyperactivity disorder (ADHD), attentional processes are impaired, especially those related to inhibition and focusing for extended periods of time (vigilance) (Wodka et al. 2007); however, at the same time intelligence does not seem to be strongly affected by the disorder (Antshel et al. 2007).

The first aim of our study is to assess relation between socioeconomical status (SES), defined as minimum parental education and financial situation, and cognitive outcomes, namely attention operationalized as the outcomes from continuous performance test (CPT) ($d'$ and mean reaction time) and intelligence quotient (IQ). The second aim is to check whether relation between SES and cognitive outcomes is mediated by early-life factors, such as smoking and alcohol consumption during pregnancy, birthweight, and breastfeeding. We hypothesize that higher SES is linked to better cognitive outcomes in children, with the above early-life factors being on the pathway on this association.

## 2 | Methods

### 2.1 | Study Sample

The NeuroSmog study (Markevych et al. 2021) is a study of cognitive and brain development based in southern Poland, a region notorious for its high levels of air pollution. It was created to assess the associations of air pollution with cognitive measures and brain function, structure, and connectivity in both healthy children and those diagnosed with ADHD. Between October 2020 and July 2022, 714 children aged 10–13 were enrolled. Large (> 90,000 inhabitants, including Kraków, Częstochowa and the Silesian agglomeration) and small (e.g., Skawina, Zakopane, or Kłobuck) study towns were selected based on their location within 2 hours' drive to the MRI scanning center in Kraków. Children with birthweight lower than 2500 g, intellectual disability or neurodevelopmental disorders were excluded from the study and the analysis. The cohort included children with ADHD and typically developing (TD) children. For the current analysis, only the TD population is included. TD children were recruited via a random stratified sampling procedure that randomly selected schools/classes/participants (see Markevych et al. 2021). It is important to note that, despite the use of stratified random sampling, our sample does not reflect the general Polish population in terms of parental education levels. In our sample, 14% of children had parents with a low educational background, while 42% had parents with a high educational background. In contrast, national statistics indicate that 37% of the Polish population has low education, and only 23% are highly educated (Statystyczny 2023).

The raw dataset consisted of 524 children, out of which two were excluded due to low birthweight, and 60 were excluded due to lack of data on cognitive outcomes (IQ or attention), mediators, SES, or null performance in the attentional task.

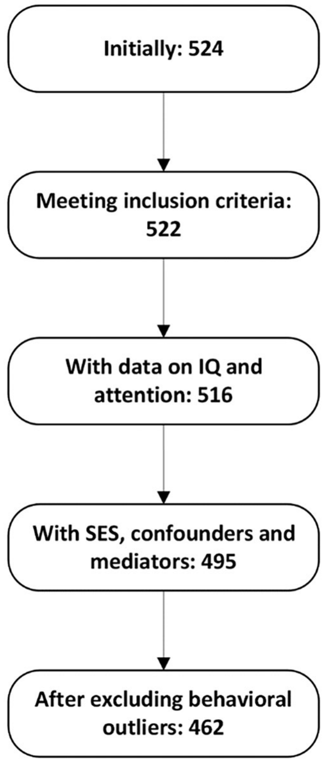


**FIGURE 1** | Flowchart representing exclusion steps and formation of the final analytic dataset.

**TABLE 1** | Descriptive statistics of numerical variables.

| **Variable** | **Mean (SD)** |
|---|---|
| Age | 11.31 (0.76) |
| Birthweight | 3418 (494) |
| IQ[a] | 104 (10) |
| CPT[b] mean reaction time (RT) | 363 (47) |
| CPT d prime | 1.53 (0.91) |
| Conners Impulsivity Scale | 12.17 (8.19) |

[a]IQ—Intelligence Quotient.
[b]CPT—Continuous Performance Test.

A total of 462 were included in the analytic sample (Figure 1 – exclusions table; Table S2). All were in the 10–13 age range (mean = 11.31; SD = 0.76), Out of 462 children, 217 were females. Detailed description of the analytic sample and its descriptive statistics are found in Tables 1 and 2. In our sample, 14% of children came from families with low parental education, 44% from families with medium education levels, and 42% from highly educated families. Regarding financial situation during the child's early years, 22% of families reported financial difficulties, 58% described their situation as "doing alright," and 20% reported living comfortably. Even though the distributions of both SES variables are skewed towards medium and high SES levels, there are enough children

TABLE 2 | Descriptive statistics of categorical variables.

| Variable | Category | *N* (%) |
|---|---|---|
| **Town-size** | Small | 231 (50) |
| | Large | 231 (50) |
| **Sex** | Female | 217 (47) |
| | Male | 245 (53) |
| **Parental education** | Low | 63 (14) |
| | Medium | 203 (44) |
| | High | 196 (42) |
| **Maternal alcohol intake during pregnancy** | No | 433 (94) |
| | Yes | 29 (6) |
| **Early-life, paternal and maternal smoking during pregnancy** | No | 259 (56) |
| | Yes | 203 (44) |
| **Maternal smoking during pregnancy** | No | 428 (93) |
| | Yes | 34 (7) |
| **Paternal smoking during pregnancy** | No | 304 (66) |
| | Yes | 153 (33) |
| | NA | 5 |
| **Household early-life smoking** | No | 328 (71) |
| | Yes | 132 (28) |
| | NA | 2 |
| **Early-life smoking** | No | 265 (57) |
| | Yes | 197 (43) |
| **Financial situation during first 5 years of child's life** | It was very difficult/it was quite difficult/we just managed to make ends meet | 100 (22) |
| | We were doing alright | 270 (58) |
| | We were living comfortably | 92 (20) |
| **Exclusive breastfeeding during first four months** | No | 71 (15) |
| | Partially | 121 (26) |
| | Yes | 270 (58) |

from less educated and poorer families in the analytic sample to estimate the associations of different SES groups.

The study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the Ethics Committee of the Institute of Psychology, Jagiellonian University, Kraków, Poland (#KE_24042019A). Written informed consent was obtained from the legal guardians and all children signed written informed assent.

## 2.2 | Socioeconomic Status

Parental education level was chosen as proxy for SES and was operationalized as a three-level categorical variable. Low education corresponds to primary school, medium education to high school and/or additional educational trainings, while high education corresponds to a bachelor's degree or higher. Due to a large gender gap in educational status in Poland (Statystyczny 2021), with mothers having on average higher education than fathers, we decided a priori to use the minimum education of the two caregivers as an SES indicator. Taking the maximum education would have deprived us of statistical power, as almost all families would then find themselves in the "medium" or "high" education categories. In addition, we decided to use the minimum parental education level to avoid overestimation of the cultural and educational resources in the family. The generation of parents of children in our sample, particularly women, experienced a radical increment in participation in tertiary education (Kwiek 2018). Therefore, the highest level of education in the family may not be a good indicator as the time to develop a new upbringing practice was very short. Moreover, research on Polish participants shows that using a lower level helps in identifying families with upbringing practices that are potentially harmful to children's development (Chłoń-Domińczak et al. 2015).

While we did not gather information on the occupation of the parents, we did gather information on the perceived financial situation of the participants' families at the time of the children's birth. However, after running models with both parental education and perceived financial situation, we found that perceived financial situation did not add much information (see Section 2). Based on that we decided that minimum parental education was a better proxy for family SES.

## 2.3 | IQ Assessment

Stanford–Binet Intelligence Scale 5th edition (SB5)—Polish adaptation by Roid et al. (2017) was used to assess the IQ of the participants. A detailed description of the validation studies can be found in the technical manual for the Polish adaptation of the test (Roid et al. 2017). The manual provides comprehensive evidence regarding reliability—both internal consistency (Full scale: Cronbach's $\alpha = 0.98$; nonverbal: $\alpha = 0.95$; verbal: $\alpha = 0.96$; factors: $\alpha = 0.88$–$0.91$) and test–retest stability—as well as validity, demonstrated by high and very high correlations with other intelligence measures (e.g., Wechsler Adult Intelligence Scale) and language proficiency tests. SB5 is based on the Cattell–Horn–Carroll (CHC) theory of intelligence and assesses five cognitive factors: fluid reasoning, quantitative reasoning, crystallized knowledge, short-term memory, and visual processing. The test was administered by trained clinical psychologists from the local psychological counseling centers. IQ was estimated as Stanford–Binet full-scale IQ. For more details on the intelligence testing in Neurosmog study, please see Buczyłowska et al. 2023.

## 2.4 | Attention Assessment–Continuous Performance Test (CPT)

The CPT is a widely used tool which measures inhibition, ability to stop ongoing motor reaction and ability to sustain attention. These abilities are linked to the efficiency of attention. In this task participants are asked to react to one set of visual shapes ("go condition"), and not to react to the other set of shapes ("no-go condition").

There were four possible types of responses: hit, correct rejection, omission, and commission error. Hit response is recorded when participant correctly reacted in a go condition, while correct rejection is when a participant successfully withdraw from reaction in a no–go condition. Two types of erroneous responses are recorded when participant did not react in go condition (omission) or reacted in no-go condition (commission error). More details on the CPT procedure used in the study, please refer to (Compa et al. 2023).

We also calculated the signal detection parameter $d'$, which is related to the ability to discriminate between targets and non-targets. It is calculated with the following formula:

$$d' = \phi^{-1}(\text{ratio of correct responses in go trials}) - \phi^{-1}(\text{ratio of correct responses in nogo trials}) \quad (1)$$

where $\Phi$ is the inverse of the cumulative normal distribution function.

After visually inspecting histograms (Figure S3) and scatterplots we decided to remove participants from the analytic sample who had more than 100 omission errors (which corresponds to 27% of all trials or 34% of all go trials) or mean reaction times faster than 100 ms, both of which indicate that the child did not understand or do the task properly.

## 2.5 | Procedure

Each of the children attended three meetings with one of 25 field clinical psychologists. All meetings were carried out in the local psychological counseling center closest to the child's place of residence. All field psychologists were trained in the study protocols and procedures before data acquisition started. CPT data was recorded on the beginning of the second meeting, while IQ testing was done at the first meeting.

CPT was done on identical 15.6-inch HP laptops that were provided to the psychologists. Acquisition of CPT data was done in a specially designated room and was supervised by the trained field psychologist. The CPT procedure lasted approximately 15 min.

While children were assessed by the field psychologist, parents were asked to fill out the questionnaire which included questions on their SES, alcohol and tobacco use and exposure, and children's habits. The detailed procedure for the overall study is described in the NeuroSmog protocol paper (Markevych et al. 2021).

## 2.6 | Confounders, Mediators, and Other Variables

The set of confounders was selected using a directed acyclic graphs (DAG), which was generated using dagitty.net software (Textor et al. 2016) (Figure S1). Sex, age, and town-size were identified as confounders.

As mediators we chose early life exposure to smoking, maternal alcohol intake during pregnancy, breastfeeding, and birthweight. A subsequent set of mediators was chosen due to their mostly biological and perinatal context of developmental influence. DAG with all paths, mediators, confounders, and dependent variables can be viewed in Figure S1. We chose sex and age as the potential confounders due to their well-established relation to cognitive and individual differences (Nichols et al. 2021). Relation between age and sex are commonly observed in the studies with children as subjects due to differences in dynamics of cognitive development between sexes and age groups (Neufang et al. 2009; Peper et al. 2009). Town size was included as a confounding variable, as children living in larger towns often have greater access to healthcare, educational, and cultural opportunities.

The pathway between alcohol and tobacco consumption during pregnancy and birthweight was included due to the potential negative association of these exposures on fetal growth and, consequently, birthweight (Patra et al. 2011; Pereira et al. 2017).

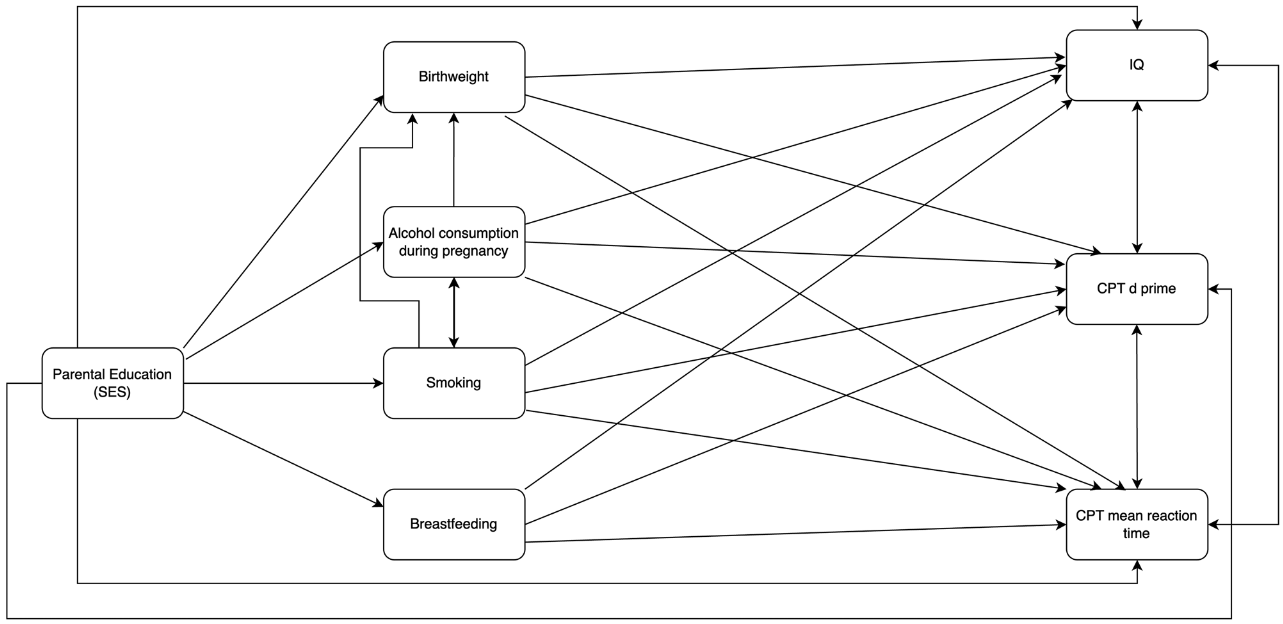


**FIGURE 2** | Hypothetical pathways between parental education and cognitive measures, attention and IQ, and mediators.

Early life exposure to smoking was defined by combining answers for the following questions: whether any of the household inhabitants smoked at home during the child's early life, whether father and/or mother smoked during pregnancy. If any answer to the questions regarding smoking was "yes", then the early life exposure to smoking variable would get the value "yes", if all of the answers were "no", then the variable took the value "no".

Information on maternal alcohol intake during pregnancy was gathered by asking the legal guardian "how often did the child's mother drink alcohol during the pregnancy?" For any answer except for "never" variable took the value "yes".

"Breastfeeding" information was acquired by asking the legal guardian whether the child was exclusively breastfed during the first 4 months of its life, with possible answers: "no", "partially", "yes".

To perform additional post hoc analysis we also used impulsivity sub-scale from the Third edition of Conners' Rating Scales Polish Adaptation (Wrocławska-Warchał and Wujcik 2018).

## 2.7 | Statistical Analyses

To explore the strength and direction of the relations between variables, we used Pearson correlation coefficients for pairs of numerical variables or ordinal variables (that were converted to numerical), point–biserial correlation coefficients for pairs of numerical and binary variables, and phi coefficients for pairs of binary variables. A structural equation modeling (SEM) approach was used to assess the network of relations between variables of interest. All of the SEM analyses were calculated using the lavaan software (Rosseel 2012), version 0.6.17. Figure 2 shows the variables of interest and the modeled relations. Data preparation was performed, and models were fitted in R statistical software (R Core Team, 2023), version 4.3.2. To keep the SEM model as simple as possible, we only chose three dependent variables: IQ, CPT $d'$, and mean reaction time. We chose $d'$ over CPT omission and commission errors since it is a measure that combines the two, showing the ability to properly detect and interpret the incoming stimuli related to the task. CPT mean reaction time and $d'$ are complementary but still distinct measures of attentional efficacy.

In the initial SEM model, we included both parental education and financial situation as SES indicators. However, consistent with the pattern seen in the correlations (Figure 3), family financial situation proved to be a worse predictor of cognitive outcomes than parental education. Then, we computed a model without financial situation, with parental education as the only SES indicator. Removing the financial situation from the model changed the estimates only slightly (Figure 4 and Figure S2, Table S3). Given its negligible effect on the estimates and the greater simplicity of the model without financial education, we decided to use parental education as the only SES proxy in the final model. The structure of the final model, set of mediators, SES, cognitive outcomes, and paths between variables are shown in Figure 2.

To run an SEM model, first we transformed the numerical variables to *Z*-scores, making their effect estimates standardized. Model parameters were estimated by diagonally weighted least squares (DWLS) estimation. Standard errors were estimated by bootstrapping with 1000 draws for all direct and indirect effects in the model. As goodness-of-fit measures, we utilized the $\chi^2$ ($p >$ 0.05), comparative fit index (CFI) > 0.98, root mean square error approximation (RMSEA) < 0.02, and standardized root mean square residual (SRMR) < 0.05.

Specific configurations of results regarding attentional outcomes can be interpreted in numerous ways. For example, a longer mean reaction time and fewer mistakes can indicate that a child is less impulsive. To test whether this interpretation is substantiated, we conducted additional post hoc analysis of the relation between impulsivity, SES, and attentional outcomes.

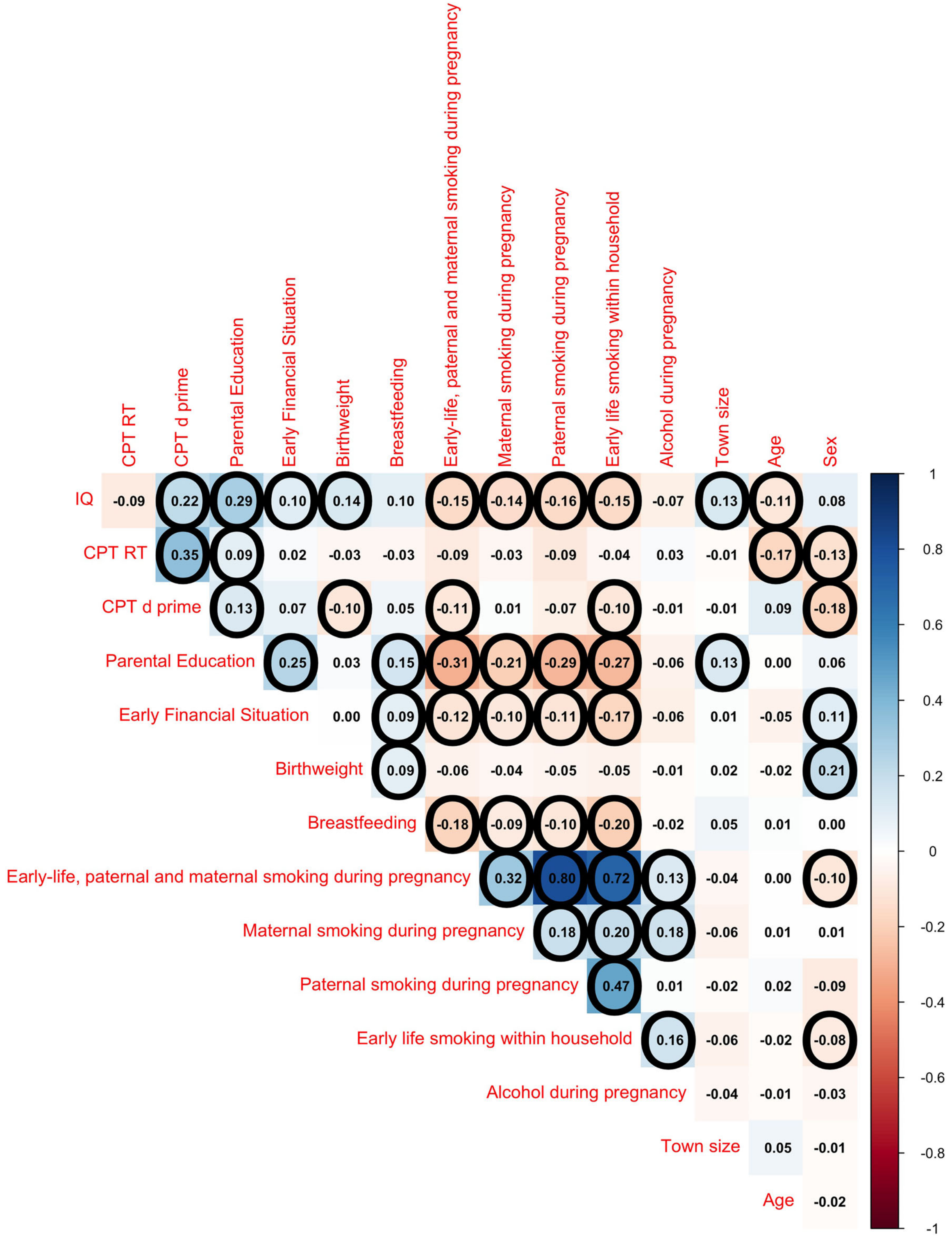


**FIGURE 3** | Pairwise correlation coefficients matrix showing the relation between variables used in the analysis. Pearson correlation coefficients were calculated for pairs of numerical variables, which included ordinal variables converted to numerical, phi coefficients for pairs of binary variables and point–biserial correlation coefficients for numerical–binary variable pairs. Encircled correlation coefficients values signify statistical significance ($p < 0.05$).

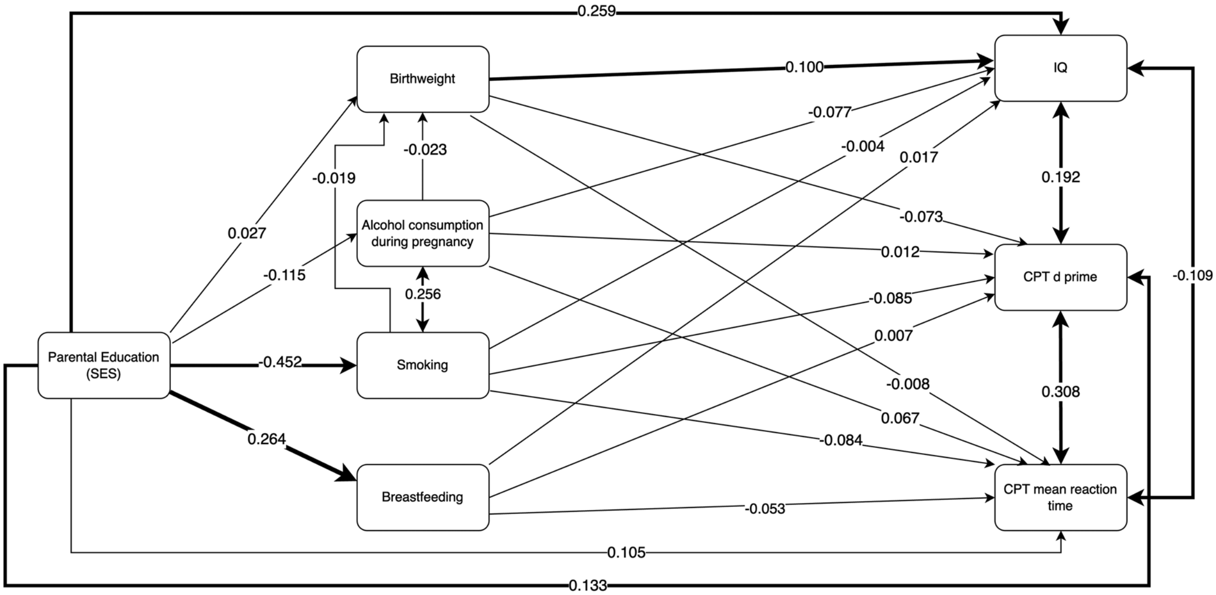


**FIGURE 4** | Structural equation model diagram used to estimate relation between SES (parental education) and cognitive outcomes (CPT d prime, CPT mean reaction time, and IQ). Mediators included birthweight, alcohol consumption during pregnancy, smoking, and breastfeeding. Numbers on the paths with single-headed arrows show standardized effect estimates. Double-headed arrows signify correlation between variables. Bolded lines and arrows mark statistically significant coefficients whose confidence intervals (95%) do not contain zero.

## 3 | Results

### 3.1 | Correlations

Figure 3 shows the correlation matrix of the variables used in the SEM model. Positive correlations between IQ and $d'$ ($R = 0.22$, $p < 0.05$), parental education ($R = 0.29$, $p < 0.05$), financial situation in early life ($R = 0.1$, $p < 0.05$), and birthweight ($R = 0.14$, $p < 0.05$) were found. IQ was also negatively, but weakly, correlated with early life exposures to smoking ($R = -0.15$, $p < 0.05$).

CPT mean reaction time was positively correlated with parental education ($R = 0.09$, $p < 0.05$); parental education was also positively correlated with CPT $d'$ ($R = 0.13$, $p < 0.05$). Negative correlations were observed for birthweight ($R = -0.1$, $p < 0.05$); and early-life exposure to tobacco smoke ($R = -0.11$, $p < 0.05$). Negative correlation was observed between parental education and parental smoking during pregnancy ($R = -0.31$, $p < 0.05$); at the same time, parental education was found to be positively correlated with breastfeeding ($R = 0.15$, $p < 0.05$) and financial situation ($R = 0.25$, $p < 0.05$).

### 3.2 | SEM Results

The SEM model ran for 27 iterations to find a stable solution, and fit indices indicated good fit: $\chi^2 = 0.23$ with 16 degrees of freedom, CFI = 0.984, RMSEA = 0.023, and SRMR = 0.032.

The total effects of parental education on IQ ($\beta = 0.28$, 2.98 IQ points), CPT mean reaction time ($\beta = 0.12$, 5.9 ms), and $d'$ ($\beta = 0.17$) were all significant (all effect sizes are for differences between low- and high-education caregivers). Note that the longer mean reaction times observed in children from better educated families were accompanied by higher $d'$, i.e., better discrimination between signal and noise. Figure 4 shows the results from the main SEM model.

A SEM analysis revealed a significant direct effect between parental education and IQ ($\beta = 0.26$, $p < 0.001$), corresponding to a difference of 2.78 IQ points between low and high education caregivers. There was also a significant effect of parental education on $d'$ ($\beta = 0.13$, $p < 0.05$). The results are summarized in Table 3. There were no significant direct effects of parental education on CPT mean reaction time. We also did not find significant indirect effects from parental education via smoking, alcohol during pregnancy, birthweight, or breastfeeding to IQ, CPT mean reaction time, or $d'$.

Indirect paths from parental education via smoking through birthweight or via alcohol during pregnancy through birthweight were also not significant

Birthweight was directly and positively associated with children's IQ ($\beta = 0.1$). Smoking, but not alcohol consumption, was negatively associated with parental education level ($\beta = -0.45$). The results also revealed that boys had faster mean reaction times than girls ($\beta = -12.89$ ms), but at the same time were worse at discriminating between go and no-go stimuli in CPT ($d'$ $\beta = -0.31$).

We also have found a significant relation between attentional measures and IQ. Children with higher IQ tended to have faster mean reaction times ($r = -0.1$) and were better at discrimination of the targets ($r = 0.19$).

We also tested the model with both financial situation and parental education; however, this addition of the financial situ-

**TABLE 3** | **SEM results**. Effect estimates and corresponding confidence intervals.

| | Effect estimate (95% confidence interval) | | |
|---|---|---|---|
| | **IQ** | **Mean reaction time** | ***d′*** |
| **Total effects** | | | |
| Parental education → | **0.28 (0.19 to 0.36)** | **0.12 (0.02 to 0.22)** | **0.17 (0.07 to 0.27)** |
| **Direct effect** | | | |
| Parental education → | **0.26 (0.13 to 0.39)** | 0.11 (−0.02 to 0.25) | **0.13 (0.01 to 0.26)** |
| **Indirect effects** | | | |
| Parental education → smoking → | 0.002 (−0.05 to 0.06) | 0.04 (−0.02 to 0.1) | 0.04 (−0.03 to 0.1) |
| Parental education → alcohol during pregnancy → | 0.009 (−0.01 to 0.03) | −0.008 (−0.03 to 0.02) | −0.001 (−0.03 to 0.03) |
| Parental education → birthweight → | 0.002 (−0.01 to 0.01) | −0.0002 (−0.003 to 0.003) | −0.002 (−0.11 to 0.008) |
| Parental education → breastfeeding → | 0.004 (−0.02 to 0.03) | −0.01 (−0.04 to 0.01) | 0.002 (−0.03 to 0.03) |
| **Specific indirect effects** | | | |
| Parental education → smoking → birthweight → | 0.001 (−0.005 to 0.007) | −0.00007 (−0.001 to 0.001) | −0.001 (−0.005 to 0.004) |
| Parental education → alcohol during pregnancy → birthweight → | 0.0002 (−0.002 to 0.003) | 0.00002 (−0.0003 to 0.0003) | −0.0002 (−0.002 to 0.002) |
| **Overall indirect effects** | | | |
| Parental education → | 0.02 (−0.05 to 0.08) | 0.02 (−0.05 to 0.08) | 0.04 (−0.03 to 0.1) |

*Note:* Statistically significant ($p < 0.05$) results are shown in **bold**.

ation as an SES variable did not prove to make much difference. Effect estimates and the SEM model with financial situation are presented in Figure S2.

### 3.3 | Additional Impulsivity Analysis

Children of parents with lower education had faster mean reaction time, but, at the same time, were worse at differentiating signal from noise (lower $d'$). This is suggestive of a more impulsive pattern of responses in low-SES children. Therefore, we decided to perform an additional post hoc analysis between impulsivity measured with the Conners' Impulsivity Scale measure and CPT attentional outcomes. We ran linear regression models with impulsivity as the dependent variable and attentional outcomes as independent variables, adjusting for sex, age, and parental education. The analysis revealed a statistically significant association between impulsivity and CPT $d'$ ($\beta = -1.99$, $p < 0.001$), while there was no association with CPT mean reaction. Full regression results are presented in the Table S1.

## 4 | Discussion

In this study we investigated the nature of the relation between children's SES, attention, and IQ. We found that minimum parental education was related to higher IQ, longer CPT mean reaction time, and higher $d'$, i.e., there were significant total effects of parental education on those three outcomes. When decomposing the total effects into direct effects and indirect effects via prenatal and early life exposure to smoking, maternal alcohol intake during pregnancy, breastfeeding, and birthweight, the direct positive effect of parental education on IQ and $d'$ was significant. None of the other direct and indirect effects were significant.

Higher parental education was related to an increase in stimulus recognizability ($d'$) combined with slower reaction times. This could potentially be interpreted in the speed/accuracy trade-off perspective, which indicates that the faster, or the more impulsive, the responses, the less accurate they get. Thus, children with highly educated parents might utilize the strategy of maximizing accuracy over the speed of the responses. To validate this hypothesis/explanation, we conducted an additional analysis of the relation between the Conners Impulsivity Scale measure, CPT $d'$ and CPT mean reaction times. We found that there was a negative and significant correlation between $d'$ and impulsivity, but not between impulsivity and mean reaction time. Impulsivity was also marginally related to SES.

### 4.1 | SES Effects in a Country With (Arguably) Low Inequalities

Despite the relatively low income inequality in Poland, our study found IQ differences of a size comparable to those in other, more unequal countries. Several explanations are possible here.

First, the effects of social differences on cognition can be reproduced via mechanisms that are not captured by the simple metrics of Gini and OECD development scores (Schneider 2019). For example, despite a low Gini index, an unusually large chasm could exist between low and high SES home environments and the level of nurturing/stimulation they provide (e.g., Lareau 2003). Fundamental inequalities that have existed in Polish society for decades could operate through many, yet undescribed, mechanisms/causes (see Clouston and Link 2021; Link and Phelan 1995). For example, higher SES households could have provided a radically better response to the COVID-19 crisis that was happening during our study by providing computers necessary for online classes and effectively supplementing inadequate school instruction by homeschooling. The COVID-19 crisis could have been much less stressful for high-income, white-collar middle-class households with large homes and the possibility to work online than for blue-collar working-class households with small homes, where adults had to risk infection every day at jobs that exposed them to COVID-19 infection.

The leveling influence of early school education may be another explanation for the lack of differences. In all the countries reporting similar effect sizes, we can also observe similar levels of the primary school completion rate (https://www.education-inequalities.org/indicators). In other words, although there are differences in internal economic inequalities between e.g., the UK and Poland, these countries are similar in their very high early education inclusiveness.

The association between SES and IQ could also arise at the micro-level, e.g., family. Specifically, it might be possible that the levels of stimulation and environmental support influence the children's IQ (Rosen et al. 2020) and that these levels vary substantially between countries. Yet, these effects cannot be fully captured by studying the macro-structures such as education or income.

Finally, it should be noted that an alternative set of data on inequality, which, unlike World Bank data, is based on tax receipts rather than surveys, paints a bleaker picture of Polish inequality. According to this data, while in 1995 Poland had a Gini index of 0.41 and was one of the EU's most equal countries, its income differences have been dramatically rising since then. By 2021, the Gini index reached 0.49, more than the EU average and several countries considered unequal, such as the UK (GI = 0.46) (Brzezinski et al. 2022; Bukowski and Novokmet 2021). This finding could also explain why the IQ gap between social strata reported here is similar to the one reported in societies more unequal than Poland.

### 4.2 | Parental Education Affects IQ and Attention

Our result shows a total effect on IQ of $\beta = 0.28$ equivalent to 2.98 IQ points between children from low-education versus high-education families. While the effect sizes are not easily comparable because different studies used different tools to assess IQ and approximate SES, we nevertheless compare this outcome to the results of similar studies.

In a sample of British twins from the Twins Early Development Study ($n = 14{,}853$), von Stumm and Plomin (2015) reported a much larger difference of 8.5 IQ points at the age of 10 and 12.5 IQ points at the age of 12 between low- and high- education families. Similarly, in an adoption study, Duyme et al. (1999) ($n$ = 65) found that at an average age of 14 years, the difference in IQ gain following adoption by either low SES or high SES families was 11.8 IQ points. However, twin/sibling/adoption studies used a very particular way of choosing participants. It should also be noted that not all twin/sibling/adoption studies give such high SES differences; a sibling study from Norway (Kendler et al. 2015) reports a much lower IQ difference between SES strata of about 4 IQ points.

Inversely, an analysis of the more recent ABCD study cohort ($n$ = 9837; United States), which used the WISC-V Matrix Reasoning Task instead of a full IQ battery and evaluated children at the age of 8.9–11.1 (mean = 9.9), reported an effect of family SES on the WISC-V Matrix Reasoning Task an order of magnitude smaller ($\beta = 0.029$) than the one reported in our study ($\beta = 0.26$) (Bignardi et al. 2024). However, their different modeling approach might explain their small effect size.

Most studies yielded effect sizes similar to ours. In a study of children aged 11–14 from Sri Lanka, a country with large inequalities (2019 Gini index (GI) = 37.7) and high poverty, Madhushanthi et al. (2021) reported an effect of SES on general IQ of Cohen's $D = 0.65$ and effects on working memory, processing speed, and perceptual reasoning components around $\beta = 0.26$–0.27. In another study from a high- inequality and medium-low-income country (Brazil), in children aged 10–12, Piccolo et al. (2016) found SES effect sizes on IQ with $\beta = 0.22$.

In Germany, another country with inequalities slightly higher than Poland, SES differences amounted to 0.65 SD ($n = 435$) in the IQ of 7 to 9-year-old children (Falk et al. 2021). Finally, in another two studies from European countries with a similar socioeconomic history (Milovanović et al. 2022) found that SES is a significant predictor of IQ for children aged 6–7 years ($n = 114$) $\beta = 0.24$ ($p < 0.01$) in Serbia, while Cermakova et al. (2023) in a study in the Czech Republic reported parental education effects of $\beta = 0.2$ in 8-year-old children ($n = 850$).

Apart from findings related to IQ, we also found that attentional measures, reaction times, and $d'$ were related to parental education. This finding is not surprising since attentional processes are closely related to IQ (Cowan et al. 2006), and there was a significant correlation between our attentional and IQ measures. Our study, with $\beta$ values of 0.12 for mean reaction time and 0.17 for $d'$, indicates a moderate effect of SES on attention and aligns with effect sizes found in the literature.

Thus, similarly to our study, Noble et al. (2005), Corso et al. (2016), and Piccolo et al. (2016) found significant and moderate relations between SES and attentional measures. Piccolo et al. (2016) used a go/no-go task in children of similar age (10–12) and reported a similar effect size ($\beta = 0.17$) to ours. For a younger group of children (6–9 years), the reported effect size was a bigger ($\beta = 0.37$). Noble et al. (2005) also reported bigger effect size ($\beta = 0.345$) in children aged 4–6 years, while Corso et al. (2016) reported slightly larger effects ($\beta = 0.3$) for 9- to 12-year-old children. In another study on preschool- age children (4.5–5.5 years), St. John et al. (2020) found a weaker but significant effect ($\beta = 0.1$) of SES on accuracy in the go/no-go task. A weak yet significant effect of SES on inhibitory task outcomes ($\beta = 0.073$) was reported in the study by Ursache et al. (2016), however, this study was conducted on a broader age group (3–21 years). In another study, Cascio et al. (2022) did not find significant effects of SES on go/no-go task outcomes ($\beta = 0.01$) in their sample of 81 teenagers (16–17 years).

Our results show that children from low parental education backgrounds scored nearly 3 IQ points lower than their peers, a moderate effect consistent with studies from similar socioeconomic contexts. While our effect is smaller than effects seen in high-inequality settings, this finding confirms that SES continues to influence cognitive development even in countries with relatively low socioeconomical disparities.

We also found moderate SES-related differences in attentional performance, aligning with prior research. These effects were observed in tasks requiring sustained attention and cognitive control, highlighting that SES can possibly influence not only general cognitive ability but also core executive functions during development.

While previous research has reported associations between SES and cognitive outcomes, these studies have primarily focused on direct relationships between variables. In contrast, the present study adopts a mediation analysis to explore potential pathways through which SES may influence cognitive outcomes. Specifically, we examined whether this relation is mediated by a set of early life factors, including smoking and alcohol consumption during pregnancy, breastfeeding, and birthweight.

### 4.3 | No Effect of Perceived Financial Situation on IQ or Attention

In addition to parental education, we incorporated perceived financial situation as a predictor of children's cognitive characteristics. However, perceived financial situation was less predictive of children's cognitive functions compared to parental education. This finding can be explained in several ways. First, pure income does not necessarily translate into increased parental care or intellectual stimulation. While children from higher-income households may experience more stable living conditions, it is the educational level of the parents, often indicative of higher intellectual engagement, that predominantly influences cognitive development.

Second, according to several reports, it is extreme poverty that affects cognitive development the most (Ball et al. 2012; Krishnadas et al. 2013; Luby et al. 2013; Noble et al. 2015). Extreme poverty might not have been adequately captured by the indicator used in our study ("What was your family's financial situation at the time of the child's birth?"), which measured relative economic position. Also, recall bias might also have obscured our results, as there was a long (10–13 years) gap between the time of participants' birth and data collection.

Finally, for several reasons, caregivers may have been reluctant to provide accurate responses to questions concerning their financial situation. First, the question could raise several emotions, including shame or embarrassment associated with disclosing their true financial situation, either when it falls below societal expectations or norms or, conversely, surpasses them. In general, though not in our study, where we did not ask for exact income, the existence of a substantial informal economy in Poland might have led individuals to underreport their earnings, fearing legal repercussions or taxation. Respondents may have also perceived little benefit or incentive in providing accurate information, particularly if they feared for their anonymity. Hence, the reliability of our perceived financial situation predictor might have been compromised.

### 4.4 | Effects of SES Not Mediated by Prenatal Alcohol, Smoking, Birthweight, or Breastfeeding

In this study, we explored mediation of SES effects by alcohol intake during pregnancy, smoking in the household during pregnancy and early life, and breastfeeding. These variables did not influence the children's IQ, even though many studies have demonstrated their influence on children's cognitive development (Alati et al. 2013; Bandoli et al. 2023; Hill et al. 2000; Horwood and Fergusson 1998; Madureira et al. 2020). We also did not observe significant indirect effects of the alcohol, smoking, and breastfeeding variables on IQ. One possible reason why no mediating effect was observed could be the small percentage of caregivers reporting smoking and/or alcohol intake during pregnancy (only 6% of respondents admitted to drinking alcohol during pregnancy, and 7% admitted to smoking during pregnancy). Possibly, some of the respondents did not reveal their use of harmful substances during pregnancy because of the social shame associated and the sensitive nature of those questions. While low education was related to smoking during pregnancy, there were no differences concerning smoking at home. Children from high SES families were more often breastfed than their poorer peers. Nevertheless, breastfeeding had no statistically significant direct and indirect effect on children's IQ or attention.

A lack of significant direct and indirect effects of the alcohol intake, smoking, birthweight, and breastfeeding suggests that these specific exposures may not play a central role in explaining SES-related differences in cognitive outcomes in this sample. One interpretation is that SES has a more direct influence on cognitive development, through mechanisms that were not captured in our model. It is also possible that the timing and intensity of early-life exposures or unmeasured protective factors modulated their influence. Another possible explanation for the lack of significant mediation is that some of the variance in cognitive outcomes attributed to SES may reflect genetic confounding. Parental education is related to the general cognitive ability (IQ), which is moderately heritable (Plomin and von Stumm 2018). This raises the possibility that the observed associations between SES and cognitive outcomes may partially reflect shared genetic influences between parents and children, rather than purely environmental mechanisms. In conclusion, other perinatal and early life factors, endocrine (stress hormone levels), immune (level of inflammatory responses, see Chapters 2 and 3 in "*The Biological Consequences of Socioeconomic Inequalities*" (Wolfe et al. 2012)), familiar, educational, and societal, e.g., Lareau (2003), could better explain how in our study population attentional capacities and IQ are influenced by caregiver SES. Suitable candidate factors include, for example, less household stress, more parental nurturing, better school education, or community ties.

### 4.5 | Conclusions

Our objective was to evaluate the influence of SES, operationalized through parental education level, on children's cognitive abilities, specifically on attention and IQ. Our analysis demonstrated that parental education exerts a significant effect on IQ and attentional outcomes and that the size of these effects is similar to other studies, including those conducted in societies that are of different wealth and/or more unequal than Poland.

**Conflicts of Interest**

The authors declare no conflicts of interests.

**Data Availability Statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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**Supporting Information**

Additional supporting information can be found online in the Supporting Information section.
Figure S1. Directed Acyclic Graph (DAG)—for SES Cognition analysis. SES—early financial situation and minimum parental education, specified as correlated cognitive outcomes—IQ, CPT d' and CPT RT mean, all correlated, smoking/alcohol—smoking by mother during pregnancy, smoking at home during pregnancy/early life and alcohol consumption by mother during pregnancy, all specified correlated. Figure S2. Structural equation model diagram used to estimate relation between SES (parental education and family financial situation) and cognitive outcomes (CPT d prime, CPT mean reaction time and IQ). Mediators included birthweight, alcohol consumption during pregnancy, smoking and breastfeeding. Numbers on the paths with single-headed arrows show standardized effect estimates. Double-headed arrows signify correlation between variables. Bolded lines and arrows mark statistically significant coefficients whose confidence intervals (95%) do not contain zero. Figure S3. Histograms showing the empirical distribution of numerical variables. Table S1. Regression table for post-hoc impulsivity analysis. Table S2. Comparison of descriptive statistics between analytic sample and excluded participants. Numerical variables were compared using independent samples t-tests, and categorical variables were compared using chi-squared tests. The results of these statistical comparisons are presented in the 'p-values' column. Table S3. Table showing fit indices for model with only parental education and model with both parental education and financial status.