

I II SFB 882

From Heterogeneities to Inequalities

Effect of Maternal Educational Level on Offspring's Educational Attainment: Role of Prenatal Exposures

Manuela Pfinder

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SFB 882 Working Paper Series, No. 52
DFG Research Center (SFB) 882 From Heterogeneities to Inequalities
Research Project A6
Bielefeld, March 2015

SFB 882 Working Paper Series
General Editors: Martin Diewald, Thomas Faist and Stefan Liebig
ISSN 2193-9624

This publication has been funded by the German Research Foundation (DFG).

SFB 882 Working Papers are refereed scholarly papers. Submissions are reviewed by peers in a two-stage SFB 882 internal and external refereeing process before a final decision on publication is made.

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DFG Research Center (SFB) “From Heterogeneities to Inequalities”

Whether fat or thin, male or female, young or old – people are different. Alongside their physical features, they also differ in terms of nationality and ethnicity; in their cultural preferences, lifestyles, attitudes, orientations, and philosophies; in their competencies, qualifications, and traits; and in their professions. But how do such heterogeneities lead to social inequalities? What are the social mechanisms that underlie this process? These are the questions pursued by the DFG Research Center (Sonderforschungsbereich (SFB)) “From Heterogeneities to Inequalities” at Bielefeld University, which was approved by the German Research Foundation (DFG) as “SFB 882” on May 25, 2011.

In the social sciences, research on inequality is dispersed across different research fields such as education, the labor market, equality, migration, health, or gender. One goal of the SFB is to integrate these fields, searching for common mechanisms in the emergence of inequality that can be compiled into a typology. More than fifty senior and junior researchers and the Bielefeld University Library are involved in the SFB. Along with sociologists, it brings together scholars from the Bielefeld University faculties of Business Administration and Economics, Educational Science, Health Science, and Law, as well as from the German Institute for Economic Research (DIW) in Berlin and the University of Erlangen-Nuremberg. In addition to carrying out research, the SFB is concerned to nurture new academic talent, and therefore provides doctoral training in its own integrated Research Training Group. A data infrastructure project has also been launched to archive, prepare, and disseminate the data gathered.

Research Project A6 “The Legitimation of Inequalities – Structural Conditions of Justice Attitudes over the Life-span”

This project investigates (a) the conditions under which inequalities are perceived as problems of justice and (b) how embedment in different social contexts influences the formation of attitudes to justice across the life course.

We assume that individuals evaluate inequalities in terms of whether they consider them just, and that they hold particular attitudes toward justice because, and as long as, these help them to attain their fundamental goals and to solve, especially, the problems that arise through cooperation with other people (cooperative relations). As a result, attitudes on justice are not viewed either as rigidly stable orientations across the life span or as “Sunday best beliefs” i.e. short-lived opinions that are adjusted continuously to fit situational interests. Instead, they are regarded as being shaped by the opportunities for learning and making comparisons in different phases of the life course and different social contexts.

The goal of the project is to use longitudinal survey data to explain why individuals have particular notions of justice. The key aspect is taken to be changes in the social context – particularly households, social networks, or workplaces – in which individuals are embedded across their life course. This is because social contexts offer opportunities to make social comparisons and engage in social learning, processes that are decisive in the formation of particular attitudes to justice. The project will test this empirically by setting up a special longitudinal panel in which the same individuals will be interviewed three times over an 11-year period.

The results of the project will permit conclusions to be drawn on the consequences of changes in a society's social and economic structure for its members' ideas about justice. The project therefore supplements the analysis of the mechanisms that produce inequality, which is the focus of SFB 882 as a whole, by looking at subjective evaluations, and it complements that focus by addressing the mechanisms of attitude formation.

Research goals

- (1) Analysis of the conditions in which justice is used as a criterion for evaluating inequalities.
- (2) Explanation of attitudes toward justice as the outcome of comparison and learning processes mediated by the social context.
- (3) Longitudinal observation of the individual development of attitudes to justice over the life course.

Research design

- (1) Continuation and expansion of the longitudinal survey of evaluations of justice conducted by the German Socio-Economic Panel Study (SOEP).
- (2) Commencement of an independent longitudinal panel with ties to the process-generated individual data of the German Institute for Employment Research (IAB) and information on companies and households (the plan is to carry out three survey waves over an 11-year period).

The Authors

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Abstract

The mechanisms involved in the reproduction of educational inequalities are not yet fully understood, and therefore, this study aims to go beyond the scope of postnatal mechanisms. This study examines the role of prenatal exposures in the reproduction of educational differences. It is argued that health behaviors during pregnancy are associated with levels of maternal education and that prenatal exposures affect educational attainment. Thus, prenatal exposures might contribute to our understanding of educational inequalities. Using data from the German Health Interview and Examination Survey for Children and Adolescents (N=5,670), evidence is found that the risk of lower educational attainment is increased in offspring exposed to tobacco, or to both alcohol and tobacco, during pregnancy. Additionally, prenatal exposures mediate the effect of maternal educational level on offspring's school attainment. These results emphasize the need to include prenatal exposures when conducting research on both social origins and educational attainment.

Keywords: Reproduction of educational inequalities, alcohol, tobacco, pregnancy, maternal health-related behaviors, prenatal exposures

Effect of Maternal Educational Level on Offspring's Educational Attainment: Role of Prenatal Exposures

Manuela Pfänder

1. Background

It is well established that social origin affects offspring's educational attainment (Breen and Jonsson 2005). Theories of social inequalities in education offer a broad spectrum of possible explanations to help understand the mechanisms behind the link between social background and educational success. In this respect, mainstream approaches focus on the diversity of resources provided in the family of origin, such as cultural and social capital theories (Bourdieu 1982; Coleman 1988; Israel, Beaulieu, and Hartless, 2001), and rational choice theories (Boudon 1974; Breen and Goldthorpe 1997; Mare 1981). Nevertheless, the causal mechanisms between social origin and educational attainment that generate and reproduce educational inequalities are not yet clearly understood and there are still gaps in the research. Until now, the explanation of the causal mechanisms focuses mainly on postnatal conditions, disregarding conditions before birth, although the inclusion of genes into social science research has proven useful.

Studies on genetic-environmental research have shown that taking the time window before birth into account is necessary for a better understanding of educational differences (Jaffee and Price 2007; Shanahan et al. 2008). Studies on the fetal origins of adult diseases (FOAD) are more rigorous than the genetic-environmental approach (which encompasses gene modifications by environmental conditions), as the FOAD theory suggests irreversible and persisting effects of prenatal exposures, resulting in an increased risk of diseases over the life course (Lynch and Smith 2005). Toxic exposures during pregnancy, such as intrauterine tobacco smoke exposure and prenatal alcohol exposure (PAE), were found to cause various irreversible developmental disorders and malformations (including cognitive impairments) resulting in lower levels of educational attainment (Howell et al. 2006; Huizink and Mulder 2006; Sexton, Fox, and Hebel 1990; Willford et al. 2004). Therefore, as prenatal exposures

are likely to be linked to offspring's educational attainment, it seems essential to include prenatal exposures in research on educational stratification.

Regarding the effect of the mother's educational level on health-related behaviors during pregnancy, it is reported that adverse health behaviors during pregnancy are more prevalent in less well-educated women (Adler and Ostrove 1999; Bergen and Caprosa 1999; Mullen et al. 1999). Smoking during pregnancy was found to be more prevalent in women with lower levels of education and a lower socioeconomic status (Cnattingius 2004). Although there is conflicting evidence as to whether alcohol intake during pregnancy occurs mostly among well-educated and well-situated women (Ethen et al. 2009; Jaddoe et al. 2007; Pfänder et al. 2014; Pfänder, Feldmann, and Liebig 2013), the combination of drinking and smoking during pregnancy is expected to be more prevalent in lower educated women (Prager et al. 1984).

Based on the above, prenatal exposures and conditions are assumed to be influenced by the mother's level of education and to have an impact on the offspring over the life course. Therefore, prenatal exposures may well be the mechanisms involved in the generation and reproduction of social inequalities; from this viewpoint, prenatal exposures should be included in research on social stratification. Just as the inclusion of genetics in social science research has proven useful, the inclusion of prenatal exposures in social sciences might serve to broaden our view and help elucidate specific social phenomena.

The following questions are addressed: 1) Are maternal health-related behaviors during pregnancy associated with the mother's educational level? 2) Are prenatal exposures, in terms of smoking and drinking (or both together) during pregnancy, associated with offspring's educational attainment? 3) Do prenatal exposures mediate the association between the mother's level of education and offspring's educational attainment?

Educational differences in offspring educational attainment

Social origin (generally measured by mother's or parents' level of education) affects offspring's educational attainment and there is general consensus that academic success is subject to intergenerational transmission. Mother's educational level has both a direct and indirect effect on offspring's educational attainment. The direct effects can be attributed to

biological aspects, suggesting that the intergenerational transmission of educational success is based on genetic inheritance (Bouchard and McGue 1981; Plomin 1999). 50-65% of educational performance can be attributed to genetic endowments (Miller, Mulvey, and Martin 2001; Plug and Vijverberg 2003).

However, there is also evidence that a large part of the explanatory mechanisms can be attributed to the indirect effects of maternal educational level on offspring's level of educational attainment. These mechanisms are related to specific incorporated characteristics and behaviors that differ according to maternal level of education, in the sense of Bourdieu's (1982) concept of 'habitus'. Persons from the same social class share a class-specific habitus that finds its expression in one's lifestyle, attitudes, (health-related) behaviors, thoughts and taste. Integrating Bourdieu's concepts of 'habitus' and 'cultural capital' into epidemiological and social medicine research resulted in the 'cultural-behavioral approach' which serves as an explanation for class-specific morbidities and mortality (Abel 2008; Veenstra 2007). From this viewpoint, social inequalities in educational attainment evolve because lower educated people adopt more disadvantageous health behaviors (which are relevant for educational success) than individuals with higher educational levels. The effects of class-specific postnatal health behaviors and their association with educational success are well established (Rampersaud et al. 2005), but the effects of class-specific health behaviors during pregnancy on offspring's educational success have not yet been investigated. Therefore, the following section outlines the role of prenatal exposures in the reproduction of educational differences by describing the association between mother's level of education on health-related behaviors during pregnancy, as well as the effects of educationally determined health-behaviors during pregnancy, on the level of offspring's educational attainment.

Prenatal exposures in the explanation of educational differences in offspring's educational attainment

Risky and adverse health behaviors during pregnancy mostly occur in low educated women, as these women are reported to have less knowledge about the risks and benefits of various health behaviors during pregnancy (Adler and Ostrove 1999; Bergen and Caprosa 1999; Mullen et al. 1999), such as smoking during pregnancy (Cnattingius 2004). The smallest decline and the highest prevalence of smokers during pregnancy are still found among low

educated women (U.S. Department of Health and Human Services 2002). In contrast to what might be expected, alcohol consumption during pregnancy is most prevalent among well-educated and well-situated women (Ethen et al. 2009; Jaddoe et al. 2007; Pfänder et al. 2014; Pfänder, Feldmann and, Liebig 2013). This ambivalent phenomenon has been studied in the Netherlands; it was found that the increased risk of continuing drinking during pregnancy in higher educated women (as compared with mid-low educated women) can partly be attributed to physical and psychological mechanisms (Pfänder et al. 2014). Higher educated women are at a lower risk of nausea/vomiting during pregnancy, and birth-related anxiety and tiredness, as compared with lower educated women; therefore, higher educated women proved to be more likely to drink during pregnancy (Pfänder et al. 2014). Although there are numerous reports on the higher prevalence of alcohol intake during pregnancy among well-educated and well-situated women (Ethen et al. 2009; Jaddoe et al. 2007; Pfänder et al. 2014; Pfänder, Feldmann, and Liebig 2013; Prager et al. 1984) some studies report the opposite (Croxford and Viljoen 1999; Godel et al. 1992; May et al. 2005; Viljoen et al. 2002). Therefore, it cannot be regarded as a universal fact that drinking during pregnancy is more prevalent among better educated women. However, the prevalence of both drinking and smoking during pregnancy is reported to decrease with increasing levels of education (Prager et al. 1984). The underlying mechanism of multiple substance use, such as smoking and drinking during pregnancy, is likely to be an addiction problem (Bien and Burge 1990) and, in turn, addictive substance use is more prevalent in lower educated women (Compton et al. 2007). Based on these reports, the mother's level of education appears to have an influence on prenatal exposures. Therefore, adverse prenatal exposures are expected to be more prevalent in lower educated pregnant women.

According to the FOAD theory, prenatal exposures cause an intrauterine biological programming, resulting in durable changes of the organs and cells (Barker and Osmond 1986). This specifically applies to intrauterine alcohol exposure and tobacco smoke exposure, as these are toxic substances with teratogenic effects. Both substances are reported to be risk factors for cognitive development, school performance and educational attainment (Howell et al. 2006; Huizink and Mulder 2006; Willford et al. 2004).

Intrauterine tobacco smoke exposure is highly associated with physical and neurobehavioral disorders (Fried, Watkinson, and Gray 2003; Huizink and Mulder 2006; Thapar et al. 2003;). A review on the effect of fetal tobacco smoke exposure on cognitive achievements and school

performance showed that the offspring of smokers, as compared with non-smokers, are at higher risk of learning difficulties, decreased reading/writing abilities, slower language development, lower visual/spatial abilities, lower cognitive functioning, lower intellectual functioning and retardation in mathematics attainment (Lassen and Oei 1998).

PAE is very harmful for the developing embryo and fetus, as alcohol passes the placenta and affects the unborn directly through its teratogenic effect on the organs, tissues and cells. PAE causes necrotic and apoptotic cell death, and millions of neurons are destroyed in the developing brain (Ikonomidou et al. 2000). This results in reduced head circumference and brain mass, as well as neurobehavioral disorders such as hyperactivity/inattention, emotional disorders, conduct problems, and reduced cognitive and intellectual abilities. These disorders and impairments have a negative impact on school performance and educational attainment (Howell et al. 2006; Willford et al. 2004).

During pregnancy, exposure to both alcohol and tobacco might be even more harmful than the effect of one exposure alone, as the adverse effect of one toxin is enhanced by a further toxin (Aliyu et al. 2009).

Theoretical framework and hypotheses

The first hypothesis stems from integration of the cultural capital theory (Bourdieu 1992; Bourdieu and Passeron 1990) into epidemiological/medico-sociological research on the increased risk of adverse health-related behaviors in women with a lower education level as compared with higher educated women (Abel 2008; Veenstra 2007) and states that: *The prevalence of prenatal exposures increases with decreasing levels of maternal education (Hypothesis 1)*. The second hypothesis is embedded in the FOAD theory which suggests that adverse prenatal exposures cause irreversible effects in the embryo and fetus, leading to diseases and unfavorable health conditions over the life course (Barker and Osmond 1986; Lynch and Smith 2005). Research on the effects of PAE and fetal tobacco smoke exposure support the FOAD theory (Howell et al. 2006; Lassen and Oei 1998; Willford et al. 2004) and lead to the assumption that *Children with adverse prenatal exposures are at higher risk of lower educational attainment (Hypothesis 2)*. Finally, I focus on an indirect mechanism that is expected to contribute to the explanation of why the offspring of higher educated mothers possess a higher level of educational attainment. Hypotheses 1 and 2 lead to the expectation that there is an indirect effect between the mother's level of education and the offspring's level of educational attainment through prenatal exposures. Therefore, the final hypothesis is that *The association between mother's level of education and offspring's level of educational attainment is mediated by prenatal exposures (Hypothesis 3)*.

2. Data and Methods

Data for this study are derived from the German Health Interview and Examination Survey for Children and Adolescents (the KiGGS Study). In 1998, the German Federal Ministry of Health commissioned the Robert Koch Institute to design the first nationwide survey in Germany on the health of children and adolescents; the KiGGS Study was conducted between May 2003 and May 2006. Details on the survey design, sampling, recruitment and data collection are already published (Kurth et al. 2008).

Briefly, 28,299 children and adolescents in the age range 0-17 years born in Germany between 1985 and 2006 were approached. A total of 17,641 eligible subjects and their parents were surveyed (response rate 66.6%). Age-appropriate self-report (from age 11 years onwards) and parent-reported questionnaires were filled in by the participants. Children and adolescents underwent physical examinations and various tests.

The baseline sample consists of secondary school children with information on educational attainment, mother's level of education, prenatal exposures and whether the information was provided by the biological parents; the final study population consisted of 5,670 individuals. The survey was approved by the Ethics Committee of the Charité Berlin and the Federal Office for the Protection of Data on 20 February 2003. Written informed consent according to the Helsinki Declaration was obtained from the participants and their parents or guardians before the individuals entered the study.

Dependent variable: Educational attainment

The dependent variable indicates whether a secondary school pupil obtains a lower or higher educational attainment. Educational attainment is measured in secondary school pupils by means of parents' information on the current school type. If parents' information on the current school type is missing, information on the current school type is derived from the adolescents' self-report questionnaires (age \geq 11 years). Possible answers for the current school type are the following categories: school for children with learning difficulties; secondary modern school; integrated comprehensive school; comprehensive school; grammar school. Analyses showed that it is reasonable to create a dummy variable on higher

educational attainment (grammar school) and lower educational attainment (other school types).

Independent variable: Mother's educational level

Mother's educational level is measured by combining information on school qualification and vocational qualification. The classification is based on an adapted version of the Comparative Analysis of Social Mobility in Industrial Nations (CASMIN) for the German educational system (Müller, Steinmann, and Ell 1998). The classification allows categorization into low, middle and high levels of education (Braun and Müller 1997). A low level of maternal education refers to women with an inadequately completed school education, a secondary modern school education, and a secondary modern school education with a basic or an advanced vocational qualification (CASMIN categories: 1a, 1b and 1c). A middle level of maternal education refers to women with an intermediate school qualification, an intermediate school qualification with a vocational qualification or full maturity certificates with and without a vocational qualification (CASMIN categories: 2a, 2b, 2c_gen and 2c_voc). A high level of maternal education refers to women with lower and higher tertiary education (CASMIN categories: 3a and 3b).

Potential mediator: Prenatal exposures

Prenatal exposures are measured by combining information on maternal alcohol intake during pregnancy and maternal smoking during pregnancy. Alcohol intake during pregnancy and smoking during pregnancy are measured by retrospective parental self-report questionnaires. Possible answer categories were 'no, moderately or regularly'. As the number of self-reported regular drinkers is very low and the quantities on 'moderate' and 'regular' are based on the respondents' subjective evaluation of the quantities 'moderate' and 'regular', the variable was categorized into 'no PEs; tobacco smoke exposure; alcohol exposure; alcohol and tobacco smoke exposure'.

Control variables

The control variables include socio-demographic, and mother and child characteristics (Table 1). Household net income (in euros) is measured using 13 categories (in euros): <500, 500-<750, 750-<1000, 1000-<1250, 1250-<1500, 1500-<1750, 1750-<2000, 2000-<2250, 2250-<2500, 2500-<3000, 3000-<4000, 4000-<5000, ≥ 5000 . The variable is treated as a continuous variable with scores ranging from 1-13; higher scores indicate a higher household net income. The 'migrant' variable is based on information on: a) the child's country of birth, b) the country of birth of the mother and the father, and c) the citizenship of the mother and the father. A child is defined as a migrant if he/she immigrated to Germany and if at least one parent was born abroad, or if both parents immigrated to Germany or do not hold the German citizenship. A child with a one-sided migrant background (born in Germany, but mother or father is born abroad and/or holds a non-German citizenship) is classified as non-migrant (Schenk, Ellert and, Neuhauser 2007). As a proxy of mother's ethnicity, her country of birth was used and classified into German, Turkish, Slavic and others.

The spatial classification on the size of the living area (urban/rural) was derived from a variable on the city size. Cities with $\geq 100,000$ inhabitants are defined as urban ones, and cities with fewer inhabitants are classified as rural ones. Total difficulties are measured by parents' evaluation of the child's behavior, using the parental version of the Strengths and Difficulties Questionnaire (SDQ) (Goodman 1997). The SDQ is a screening questionnaire comprising five scales with five items each, designed to assess possible cases of behavioral disorders in children. The five scales include measurements on emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems and prosocial behavior. The SDQ shows satisfactory psychometric properties (Goodman 2001). Items (excluding those from the prosocial behavior scale) are summed to construct a total difficulties score. Scores range from 0-40. To increase statistical power the scores were divided by 10 resulting in scores ranging from 0-4; higher scores indicate a higher level of problems. Child's gender (male/female), age of the child (continuous), mother's age at birth of the child (continuous) and previous births (0 and >0) are also included in the analyses as control variables.

Method

To establish whether prenatal exposures mediate the effect of mother's educational level on offspring's educational attainment, the Baron and Kenny (1986) criteria were applied: Prenatal exposures are accepted as a mediator: 1) if the variable is affected by the independent variable, 2) if the independent variable affects the dependent variable, 3) if the mediator affects the dependent variable, and 4) if the effect of the independent variable on the dependent variable is significantly decreased after adjustment for the mediator. A factor should cause a decrease in the odds ratio (OR) of at least 10% (Rothman, Greenland, and Lash 2008).

Descriptive statistics are applied to analyze the sample characteristics according to levels of maternal education, and to examine whether prenatal exposures are associated with mother's level of education. Educational differences in dichotomous or categorical variables are tested with the chi-squared test, while differences in continuous variables are tested with the one-way analysis of variance (ANOVA). P-values for a trend are derived from the chi-squared test for trend (categorical variables) and from the linear trend test of the ANOVA (continuous variables). In addition, multinomial logistic regressions are applied to test whether maternal level of education predicts prenatal exposures (first criterion).

Multivariate logistic regressions are applied to examine the association between mother's educational level and offspring's educational attainment (model 1, second criterion). In the next step, the variable on prenatal exposures is added to model 1 (model 2), to examine its relation with educational attainment (criterion 3) and its effect on the relation between mother's educational level and offspring's educational attainment (criterion 4). The decrease in the ORs for mother's educational level was calculated using the formula $100 \times (\text{OR}_{(\text{model1})} - \text{OR}_{(\text{model2})} / (\text{OR}_{(\text{model1})} - 1)$ (MacKinnon, Krull and, Lockwood 2000).

3. Results

Table 1 presents results on maternal educational differences in demographic, and mother and child, characteristics. Of the 5,670 participants ($M_{\text{age}} = 14.5$ years, $SD=1.9$; age range 11.0-18.0 years), 25.6% have a mother with a low education level, 58.0% have a mother with a middle education level, and 16.4% have a mother with a high education level. The household net income is highest in those with higher levels of maternal education and lowest in those with lower levels of maternal education. Of the children from women with a lower education level, 18.4% are migrants; of the children from women with a middle education level, 9.3% are migrants; and of the children from women with a higher level of education, 11.6% are migrants. Of the higher educated women 30.7% live in urban areas compared with 20.0% of the middle educated women and 23.0% of the low educated women. Higher educated women are older at birth of their child (28.8 years) compared with middle (26.5 years) and low (27.1 years) educated women. The offspring of lower educated women show higher levels of total difficulties (p for all < 0.001). Of the low educated women, 65.7% have previously given birth compared with 60.3% of the middle educated women and 61.9% of the high educated women ($p=0.005$). Of the offspring of high educated women, 75.3% have not been exposed to alcohol or tobacco compared with 74.9% of the offspring of middle educated women and 65.5% of the offspring of low educated women. Prenatal exposures are associated with the mother's level of education: the prevalence of smoking during pregnancy is highest, i.e. 23.7%, in low educated women compared with 10.6% of middle educated women and 3.3% of high educated women. The prevalence of alcohol intake during pregnancy is higher in the high educated group (19.3%) than in the middle (11.8%) and low (6.7%) educated groups. The prevalence of using both alcohol and tobacco together during pregnancy is higher in the low educated group (4.0%) than in the middle (2.6%) and high (2.0%) educated groups ($p < 0.001$).

Table 2 shows the associations between prenatal exposures and mother's educational level expressed in terms of ORs, with 'no prenatal exposures' as the reference group. Model 1 describes the unadjusted association between prenatal exposures and mother's level of education: the risk of tobacco intake is increased in middle (OR 3.19) and low (OR 8.18) educated women as compared with high educated women. The risk of drinking alcohol during pregnancy is decreased in middle (OR 0.62) and low (OR 0.40) educated women. The risk of both drinking and smoking during pregnancy is increased in low educated women (OR 2.25).

Table 1: Descriptive statistics of sample characteristics according to mother's educational level.

Mother's educational level (CASMIN)	Low	Middle	High	p for trend
Total N=5670	N=1453 (25.6%)	N=3288 (58.0%)	N=929 (16.4%)	
Household net income	7.4 (2.8)	8.5 (2.8)	9.6 (2.6)	<0.001
Migrant				<0.001
No	81.6	90.7	88.4	
Yes	18.4	9.3	11.6	
Area				<0.001
Urban	23.0	20.0	30.7	
Rural	77.0	80.0	69.3	
Sex				0.454
Female	48.1	49.9	48.2	
Male	51.9	50.1	51.8	
Age (years) of the child	14.5 (1.9)	14.4 (1.9)	14.6 (1.9)	0.156
Mother's age (years) at birth of the child	27.1 (5.2)	26.5 (4.6)	28.8 (4.6)	<0.001
Mother's ethnicity				<0.001
German	80.4	89.5	86.1	
Turkish	9.4	2.1	2.1	
Slavic	4.5	5.2	5.6	
Others	5.7	3.2	6.3	
Child's total difficulties score	0.9 (0.5)	0.8 (0.5)	0.7 (0.5)	<0.001
Previous births				0.005
0	34.3	39.7	38.8	
>0	65.7	60.3	61.9	
Prenatal exposures				<0.001
No	65.5	74.9	75.3	
Tobacco	23.7	10.6	3.3	
Alcohol	6.7	11.8	19.3	
Alcohol and tobacco	4.0	2.6	2.0	

Note. P-values for trend are derived from the chi-squared test for trend (categorical variables) and from the linear trend test of the one-way analysis of variance (continuous variables); values are means with standard deviations in parentheses (continuous variables) and percentages (categorical variables). Data: KiGGS Study.

After adjustment for control variables (household net income, mother's ethnicity, mother's age at birth of the child, and area) in model 2, the associations emerging from model 1 still hold. Univariate and multivariate analyses (Tables 1 and 2) show that prenatal exposures are associated with mother's level of education and, therefore, the first criterion according to Baron and Kenny (1986) is fulfilled.

Table 3 shows the associations between offspring's educational attainment and mother's educational level and prenatal exposures in terms of ORs, with 'higher educational attainment' as the reference group. Model 1 shows a significant association between mother's educational level and offspring's educational attainment: The risk of lower educational attainment is increased in the offspring of middle (OR 2.74) and low (OR 7.70) educated women. Thus, the second criterion according to Baron and Kenny (1986) is fulfilled.

In the next step, the potential mediator is added to model 1 (model 2) to examine whether prenatal exposures are associated with educational attainment. From the results presented in model 2 it can be seen that the risk of lower educational attainment is increased in those who were exposed to tobacco smoke during pregnancy (OR 1.68). The association is even stronger when the mother consumed both alcohol and tobacco during pregnancy (OR 2.17).

Exposure to alcohol alone during pregnancy does not result in a significant association with educational attainment. Prenatal exposures are associated with the risk of lower educational attainment and, thus, the third criterion according to Baron and Kenny (1986) is fulfilled. Including prenatal exposures into the model affects the association between mother's educational level and offspring's educational attainment. The decrease in the ORs ranges from 5.2% (middle level of maternal education) to 10.4% (low level of maternal education). Therefore, also the fourth criterion according to Baron and Kenny (1986) is fulfilled and the variable is accepted as a mediator in the link between mother's educational level and offspring's educational attainment.

Table 2: Multinomial logistic models of the odds of prenatal exposure to tobacco, alcohol and both alcohol and tobacco (vs. no prenatal exposures).

	Model 1 Tobacco β (SE)	Model 1 Alcohol β (SE)	Model 1 Alcohol and tobacco β (SE)	Model 2 Tobacco β (SE)	Model 2 Alcohol β (SE)	Model 2 Alcohol and tobacco β (SE)
Mother's level of education (Reference: High)						
Middle	3.19*** (0.192)	0.62*** (0.100)	1.30 (0.257)	2.60*** (0.199)	0.73*** (0.108)	1.13 (0.272)
Low	8.18*** (0.194)	0.40*** (0.135)	2.25** (0.269)	6.97*** (0.202)	0.50*** (0.146)	2.14** (0.289)
Household net income				0.91*** (0.015)	1.06** (0.017)	0.93* (0.030)
Mother's ethnicity (Reference: German)						
Turkish				0.43*** (0.218)	0.28** (0.423)	0.07** (1.013)
Slavic				0.75 (0.198)	0.65 (0.227)	0.35* (0.516)
Others				0.48** (0.244)	0.57* (0.248)	0.19* (0.720)
Mother's age at birth of the child				0.97** (0.009)	1.03** (0.009)	0.98 (0.018)
Area (Reference: Rural)						
Urban				1.43*** (0.101)	1.06 (0.105)	1.77*** (0.186)
Log Likelihood	57.906			8626.490		
N	5670			5370		
Nagelkerkes R ²	0.065			0.103		

Note. High maternal educational level and no prenatal exposures were set to reference (odds ratios=1.00).

Significance key: * p<0.05, ** p<0.01, *** p<0.001; values are odds ratios with standard errors in parentheses. Data: KiGGS Study.

Table 3: Logistic models of the odds of lower educational attainment (vs. grammar school).

	Model 1	Model 2
	β (SE)	β (SE)
Mother's educational level (CASMIN) (Reference: High)		
Middle	2.74*** (0.098)	2.65*** (0.099)
Low	7.70*** (0.121)	7.00*** (0.123)
Household net income	0.86*** (0.014)	0.87*** (0.014)
Sex (Reference: Female)		
Male	1.58*** (0.070)	1.58*** (0.071)
Area (Reference: Urban)		
Rural	1.29*** (0.087)	1.34*** (0.088)
Age of the child	1.00 (0.018)	1.00 (0.018)
Migrant (Reference: No)		
Yes	1.06 (0.118)	1.09 (0.119)
Mother's age at birth of the child	0.93*** (0.008)	0.93*** (0.009)
Previous births (Reference: 0)		
>0	1.92*** (0.079)	1.95*** (0.080)
Child's total difficulties score	2.50*** (0.079)	2.41*** (0.080)
Prenatal exposures (Reference: No)		
Tobacco		1.68*** (0.126)
Alcohol		0.84 (0.104)
Alcohol and tobacco		2.17** (0.260)
Log Likelihood	4910.882	4879.501
N	4521	4521
Nagelkerke R ²	0.296	0.303

Note. Significance key: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; values are odds ratios with standard errors in parentheses. Data: KiGGS Study.

5. Discussion and conclusions

The main findings of the present study can be summarized as follows. First, the study shows that the risk of lower educational attainment increases with decreasing levels of mothers' educational level. Second, smoking and multiple substance use during pregnancy were more prevalent in lower educated women. However, in contrast, alcohol intake during pregnancy was more prevalent in higher educated women. Third, the risk of lower educational attainment was significantly increased in children and adolescents with fetal tobacco smoke exposure and in those with exposure to both alcohol and tobacco. PAE did not result in a significant association with offspring's educational attainment. Fourth, this study shows that prenatal exposures are mediators in the explanation of educational differences in offspring's educational attainment: prenatal exposures explain 5.2-10.4% of the educational differences in offspring's educational attainment.

The results regarding an intergenerational transmission of educational performance are similar to those reported by others (Breen and Jonsson 2005). However, in the present study, the effect of mother's educational level on offspring's educational attainment was considerably higher; this provides support for the argument that we need to further examine the causal factors involved in order to address the important issue of educational stratification.

The results related to complete abstinence from smoking/drinking alcohol during pregnancy, and to smoking prevalence, and to the prevalence of using both alcohol and tobacco during pregnancy, are in agreement with the second hypothesis. The prevalence of complete abstinence from smoking and alcohol intake during pregnancy was greatest in higher educated women. As expected, and in line with others (Cnattingius 2004; Prager et al. 1984), the prevalence and the risk of smoking during pregnancy and using both substances was highest in low educated women. These results provide support for the cultural-behavioral approach and suggest that higher educated women have a better understanding of the adverse health-related behaviors during pregnancy. In contrast to the preliminary hypothesis, results on educational differences in alcohol intake during pregnancy indicate a higher prevalence and a greater risk in better educated women. However, these results are similar to other studies reporting an increased risk of alcohol intake during pregnancy in higher educated and well-situated women (Ethen et al. 2009; Jaddoe et al. 2007; Pfinder et al. 2014; Pfinder, Feldmann and, Liebig 2013; Prager et al. 1984). It seems that better educated women have a lifestyle

with a higher cultural and social capital to maintain, and in this respect alcohol intake might represent a more essential part of their prestigious and wealthy lifestyle (Pfunder et al. 2014).

Results on the effects of prenatal exposures on educational attainment confirm the third hypothesis of an increased risk of lower educational attainment in children/adolescents with harmful prenatal exposures. In agreement with the FOAD theory, prenatal tobacco smoke exposure resulted in an increased risk of lower educational attainment; this result is similar to those reported in the review of Lassen and Oei (1998). An explanation could be that the ingredients of tobacco smoke cause a reduction of oxygen content, blood flow, nutrient availability, an increase of blood lead levels, and facilitate the formation of free radicals which, in turn, promote teratogenesis (Abel 1998). Smoke exposure during pregnancy leads to a reduction of fetal head circumference, lower growth of the biparietal diameter, smaller atrial width of the lateral ventricle and a smaller transcerebellar diameter, all of which might be responsible for neurobehavioral disorders, such as cognitive deficits and intellectual deficiencies, resulting in lower levels of educational attainment (Roza et al. 2007). Prenatal exposure to both alcohol and tobacco resulted in an even stronger effect on lower educational attainment than the effect of smoking alone. This is the first study to demonstrate the effect of both these substances on educational attainment. The results are in line with studies indicating that the adverse effect of one toxin is aggravated by exposure to a further toxin (Aliyu et al. 2009; Verkerk et al. 1993). For a better understanding of the biomedical mechanisms involved, future research should explore the mechanisms in the chain between multiple substance use and cognitive abilities. In contrast to the third hypothesis, and also to what might be expected from earlier research (Howell et al. 2006; Willford et al. 2004), PAE did not result in a significant association with offspring's educational attainment. Results of the present study do not support the hypothesis that the effect of PAE alone leads to an increased risk of lower educational attainment. A cohort study from the UK reported positive effects of low levels of PAE on cognitive abilities in children aged 3 and 5 years (Kelly et al. 2009, 2012). Dose-response relationships and the timing of alcohol intake during pregnancy could be relevant for the understanding of the association between PAE and educational attainment, as animal models and human studies suggest that the quantity and timing of alcohol exposure are associated with the level of brain damage (Goodlett, Horn, and Zhou 2005).

Another explanation for the association between prenatal tobacco smoke exposure and prenatal exposure to both alcohol and tobacco smoke with offspring's educational attainment

may have a socio-cultural origin. The adverse health-related behaviors of smoking, or drinking and smoking, during pregnancy could be proxies for a range of unfavorable behaviors that negatively affect offspring's educational level. Women who smoke, or smoke and drink, during pregnancy might share a specific culture, inherit specific characteristics and/or act differently compared with women who do not smoke, or do not drink and smoke, during pregnancy. If this is the case, and if these socio-cultural specificities are negatively associated with offspring's education, then prenatal exposures do not weigh as much as the results from the present study suggest. In an effort to explain the reproduction of educational differences, it was found that prenatal exposures play a role in the causal pathway between mother's level of education and offspring's educational attainment. These results indicate that the underlying mechanisms go beyond the scope of merely postnatal conditions.

This study has some limitations that should be considered in the interpretation of the results. Some misclassification with respect to prenatal exposures might have occurred, as information on smoking and alcohol intake during pregnancy was derived from self-reports. Although some studies suggest that retrospective information on alcohol intake during pregnancy is more reliable than information obtained during pregnancy (Alvik et al. 2006; Jacobson et al. 1991), there is a possibility that self-reports on drinking and smoking during pregnancy result in some underreporting. Therefore, we have to take into account that the non-exposure group may also include individuals with PAE and fetal smoke exposure. If underreporting and misclassification have affected the results, this will cause underestimation of the 'real' effect on educational attainment and underestimation of the power to explain the educational differences in offspring's educational attainment.

If reports on smoking and alcohol intake during pregnancy are related to levels of maternal education, the estimations of educational differences in educational attainment may be biased in unknown ways.

In the present study, the number of explanatory adverse prenatal exposures was limited to alcohol and smoking. However, maternal caffeine intake during pregnancy, and exposure to stress and anxieties, could also contribute to our understanding of educational differences in offspring's educational attainment. Moreover, these latter factors are more prevalent in lower educated women (Paarlberg et al. 1996; Pfänder et al. 2014; Rofé, Blittner, and Lewin 1993) and are associated with adverse pregnancy outcomes (Watkinson and Fried 1985) and

offspring's cognitive abilities (Bergh et al. 2005; Buitelaar et al. 2003; Davis and Sandman 2010). More studies are needed to investigate the role of various prenatal exposures in the pathway between mother's level of education and offspring's educational attainment.

In conclusion: prenatal exposures are relevant mechanisms in the explanation of the reproduction of educational differences and contribute to our understanding of the existence of an educational gradient. As this study indicates that it is justified to include prenatal exposures in social science research, future studies should consider including the role of prenatal exposures in relevant protocols. The present results imply that preventive actions regarding social inequalities of education should start from the very beginning (i.e. before birth) by informing (especially) pregnant women with a low education level about the adverse effects of prenatal exposures.

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