Chapter 5

**Effect of Parental Age on Offspring’s Neurodevelopment**

This chapter is based on:


*These authors contributed equally to this work
Chapter 5 Effect of Parental Age on Offspring’s Neurodevelopment

Abstract

**Background.** The aim of this study was to investigate whether established detrimental effects of advanced parenthood on neurodevelopmental disorders extend to the more common neurodevelopmental outcomes: attention problems, intelligence, and educational achievement. **Methods.** We analyzed child-, father-, mother- and teacher-rated attention-problems ($N=38,024$), intelligence ($N=10,273$) and educational achievement ($N=17,522$) of children from four Dutch population-based cohorts. We used 50% of the datasets to generate hypotheses and the other 50% to evaluate support for these hypotheses. With Bayesian evidence synthesis, we combined the results over cohorts. Data were analyzed with and without inclusion of child gender and SES as covariates. **Results.** We mostly found linear relations between parental age and attention-problems as reported by fathers, mothers, and teachers. Offspring of younger parents were more disadvantaged. Maternal age was also positively and linearly related to IQ and educational achievement in offspring. Paternal age showed an inverted U-shaped relation with IQ, with younger and older fathers being disadvantaged, and an attenuating positive relation with educational achievement. After including SES, we mostly found no effects. **Conclusions.** There were hardly any harmful effects of advanced parental age on attention problems, intelligence, and educational achievement. SES had an important role in the relation between parental age and offspring neurodevelopmental outcomes.
Postponing parenthood to advanced age has been a persistent trend in all European as well as in many other developed countries during the past decades. In the Netherlands, for example, women nowadays first give birth around age 30, while in 1970 the mean age was 24 (CBS, 2019). Concerns about this postponement are understandable and growing, as a large body of research has shown that offspring of older parents are at increased risk for developing severe neurodevelopmental disorders, such as schizophrenia, Down syndrome, and autism (Merikangas, 2016; 2017). One important question is whether these effects generalize to the more common neurodevelopmental outcomes. In a recent population-based study, we found no negative effects of advanced parenthood on internalizing and externalizing problems, but observed that children of older parents tended to show fewer externalizing behavior problems than children of younger parents (Zondervan et al., in press). In the current study, we focused on attention problems and cognition and investigated whether offspring of older parents are at increased risk for more attention problems, and lower intelligence and educational achievement.

While the risk of high parental age on offspring schizophrenia, Down syndrome, and autism seems well-established, no consistent pattern exists for attention problems. Attention problems are an important component of Attention Deficit Hyperactivity Disorder (ADHD), one of the most common neurodevelopmental disorders in childhood (Faraone, Sergeant, Gillberg & Biederman, 2003). There are studies that show a reverse association, suggesting that offspring of younger parents are more at risk. Mikkelsen and colleagues (2016) found in a population-based sample (N=943,785) that offspring of mothers who gave birth to children early in their reproductive lives were more vulnerable to develop ADHD. This same outcome was also observed in a case-control (N=10,409; N=39,125) study by Chudal et al. (2015) and in population-based cohort studies (N=1,495,543; N=1,490,745) by Chang et al. (2014) and Janecka et al. (2019). The results are more diverse for fathers. While Mikkelsen et al. (2016) found no effect for fathers, D’Onofrio et al. (2014) reported, in a population-based study (N=2,615,081), that offspring of fathers 45 years and older were at higher risk for ADHD. Chudal et al. (2015), however, found that the relationship between paternal age and offspring ADHD showed high risk for young fathers (<25), lowest risk for fathers around 30, and a somewhat increased risk for fathers older than 40. Taken together, most studies point to an adverse linear effect of paternal age, but a curvilinear effect with adverse scores in both extremes of the age distribution has also been reported.
The relation between parental age and attention problems might thus differ for fathers and mothers and might also differ from those found in research on more extreme neurodevelopmental problems, such that offspring of younger parents could also be more at risk. It is therefore important to investigate not only linear effects, but curvilinear effects as well.

For intelligence, earlier studies showed mixed results. Saha et al. (2009) found in a sample of 33,437 children that intelligence at age 7 was lower for offspring of older fathers. Gajos and Beaver (2017) reported a similar finding for verbal IQ scores in daughters (N=449). McGrath, Mortensen, Pedersen, Ehrensen and Petersen (2013) found that both younger and older fathers had children with lower IQ scores than fathers aged 25-29 (i.e. an inverted U shape) (N=169,009). Gajos and Beaver (2017) reported the same effect for verbal IQ scores in sons of younger and older fathers (N=480). On the other hand, D’Onofrio et al. (2014) observed that children of fathers aged 45 or older were more vulnerable for low educational attainment and failing a grade. Regarding maternal age, some studies indicated that offspring of older mothers (and not fathers) had a higher chance of cognitive disability (Cohen, 2014), while other studies suggested that older mothers have offspring with higher IQ scores (McGrath et al., 2013). Like attention problems, effects of parental age on cognitive ability need to be further clarified.

The present study looks into the effects of parental age on neurodevelopmental outcomes. We analyzed parent-, teacher- and self-reported attention problems (N≤38,024), psychometric IQ (N=10,273) and educational achievement assessed by standardized tests (N=17,522) of children from four large population-based cohort studies. We investigated paternal age and maternal age and with and without two possible confounders: child gender and family SES. Given mixed results in previous research, we used cross-validation to generate hypotheses based on one half of our data, and subsequently evaluated how much support each of these hypotheses obtained in the other half of the data. Furthermore, Bayesian statistical methods were used to evaluate overall support.

**Method**

**Participants**

Four Dutch cohorts contributed to this study: the Netherlands Twin Register (NTR), Generation R (Gen-R), the Research on Adolescent Development and Relationships-Young cohort (RADAR-Y), and the Tracking Adolescents’ Individual Lives Survey (TRAILS). The number of participants differed over dependent variables (Supplementary Tables S1-S3).
NTR recruits newborn twins from all regions in the Netherlands. Children were excluded if they had a severe handicap that interfered with daily functioning. For attention problems, we included data on 10-year-olds who were born between 1986 and 2008. The children had a mean age of 9.95 (SD=0.51), ranging from 7.83 to 11.95. For educational achievement, data of twins and their siblings came from a nation-wide standardized test assessed around age 12. For IQ, data of twins and their siblings measured at ages 5, 7, 9, 10, 12, 17 and 18 were included. Parental age information is given in Supplementary Table S4. Parents were mostly born in the Netherlands (95.7% of fathers and 96.7% of mothers). Mother’s educational level was low (i.e., no education or primary education) for 4.6%, intermediate (i.e., secondary school, vocational training) for 67.0%, and high (i.e., bachelor’s degree, university) for 28.4%.

Gen-R recruited pregnant women in the city of Rotterdam and their partners. For attention problems, 10-year-old participants were included (born between 2002 and 2006). The age of the children ranged from 8.68 to 12.47 (M=9.73, SD=0.33). For educational achievement, Gen-R analyzed data obtained from a nation-wide standardized test assessed around age 12. IQ was measured at 6 years. Information for parental age is given in Supplementary Table S4. In the overall dataset, 58.7% of the sample was of Dutch or other European ancestry, other groups included Moroccan, Dutch Antilles, and Cape-Verdian. Mother’s educational level was low for 4.1%, intermediate for 39.4%, and high for 56.6%.

The RADAR-Y sample was recruited in the province of Utrecht and four large cities in the mid–west of the Netherlands. Because the RADAR-Y study had a focus on delinquency development, children with increased externalizing behavior problems at age 12 were oversampled. All participants from the first wave of data collection, born between 1990 and 1995, were selected for inclusion. The mean age was 13.03 (SD=0.46), ranging from 11.01-15.56. Parental age information is given in Supplementary Table S4. The sample consisted mainly of children with parents born in the Netherlands (93.3%). The other children had parents born in Surinam (1.8%), Indonesia (1%), and Dutch Antilles (0.8%). Mother’s educational level was for 3.2%, intermediate for 56.7%, and high for 40.1%.

The TRAILS sample was recruited in the Northern regions of the Netherlands. All participants from the first wave of data collection (born between 1990 and 1991) were included in all analyses. Average age of the children was 11.11 (SD=0.56) and ranged between 10.01 and 12.58. The majority of participants had parents born in the Netherlands (86.5%), with others from Surinam (2.1%), Indonesia (1.7%), Antilleas (1.7%), Morocco (0.7%), Turkey (0.5%), and other (6.9%). Mother’s educational level was low for 6.6%, intermediate for 64.3%, and high for 25.9%.
Measures

Predictors

Maternal and Paternal Age at Birth. The age of the biological parents at birth of the child was measured in years up to two decimals for each cohort (Supplementary Table S4 for descriptive statistics). Gen-R used parental age at intake (during pregnancy).

Outcomes

Attention Problems. Attention problems were measured with the ASE-BA questionnaires in Gen-R, NTR, and TRAILS, which include the child-rated Youth Self Report (YSR; Achenbach & Rescorla, 2001), the parent-rated Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2001, and Achenbach, 1991 for earlier birth cohorts), and the teacher-rated Teacher Report Form (TRF; Achenbach & Rescorla, 2001). Radar-Y measured mother-rated attention problems with a Dutch adaptation of Teacher ratings of DSM-III-R symptoms for the disruptive behavior disorders (DPD; Pelham, Gnagy, Greenslade & Milich, 1992; Oosterlaan, Scheres, Antrop, Roeyers, and Sergeant, 2000). In TRAILS, teachers rated child behavior on a five-point scale for: “fails to finish things he/she starts, can’t concentrate, can’t pay attention for long, is confused, daydreams, has learning difficulties, is clumsy or poorly coordinated, is inattentive, is easily distracted, underachieves, fails to carry out tasks”. This item was derived from the set of TRF items on attention. See Supplementary Table S1 for descriptive statistics.

IQ. In Gen-R, IQ was measured using the Snijders-Oomen nonverbal intelligence test (Tellegen, Laros & Winkel, 2005). In NTR, IQ was measured using the RAKIT, WISC-R(-III), Raven or WAIS (see Franić et al., 2014). For the children in NTR with multiple assessments, the mean over all IQ assessments was taken. In Radar-Y and TRAILS, IQ was assessed with the block design and the vocabulary subtests of the WISC-III-R (Legerstee, van der Reijden-Lakeman, Lechner-van der Noort & Ferdinand, 2004). See Supplementary Table S2 for descriptive statistics.

Educational Achievement. Educational achievement was available in two cohorts: Gen-R and NTR. Scores came from a 3-day nation-wide standardized test around age 12 (end of primary school; Citogroep, 2019). Most schools in the Netherlands take part. See Supplementary Table S3 for descriptive statistics.
Covariates

Socio-Economic Status (SES) and child gender. In Gen-R, SES was defined as a continuous variable (principal component) based on parental education and household income. In NTR, SES was a 5-level ordinal variable based on parental occupational level. In TRAILS, SES was a 3-level ordinal variable based on parental education, parental occupational status and household income. In RADAR-Y SES was a dichotomous variable based on parents’ occupational level. Child gender was coded as male = 0 and female = 1.

Missing Data and Data Imputation

The proportions of missing data per cohort and variable are provided in Supplementary Tables S5-S7. NTR used different subgroups for attention problems (only twins) and cognitive functioning (educational achievement and IQ data was also available for triplets and siblings). In addition, note that IQ data were only available in a subset (~10%), so IQ was analyzed with a subset of the cognitive functioning dataset, including only children for who at least one IQ assessment was available (to prevent introducing bias by imputing a large proportion of the data). Therefore, IQ has no missing values. For Gen-R, educational achievement data was only available for a small subset of the overall dataset (26.8%), therefore a sub-dataset was used containing participants with complete educational achievement data only.

Missing data were imputed (Schafer & Graham, 2002; Van Buuren, 2012) with the package mice (Van Buuren & Groothuis-Oudshoorn, 2011) in R (R Core Team, 2018). The imputation was conducted for attention and the cognitive functioning datasets separately, which all included variables on paternal age, maternal age, SES and child gender. Datasets were split into an exploratory and confirmatory half (see analytical strategy). Except for participant and family ID, all variables in the datasets were selected as predictors in the imputation model if the correlation was larger than .10 with the to be imputed variable. The data were imputed 100 times, and analyses results were pooled over these datasets by the mice package. The imputation for the twins of Gen-R and NTR was done per twin-pair instead of per participant, to ensure equal information within twins on parental age and SES. The (non-twin) sibling data was imputed as in the other cohorts.

Analytical Strategy

The analytical strategy consisted of four steps: (1) exploratory data analysis, (2) informative hypothesis generation, (3) Bayesian hypothesis evaluation in confirmatory data per cohort, and (4) Bayesian evidence synthesis over cohorts.
Exploratory Data Analysis

As previous research is mixed about the relations between parental age and the outcome variables, we started with exploratory data analyses. In each cohort, the datasets were randomly divided into an exploratory and a confirmatory part. In the exploratory data, linear regression analyses were conducted in R with as predictors standardized father age and father age squared, or mother age and mother age squared. The dependent variables were attention problems (reported by either child, father, mother, or teacher) child IQ, and educational achievement. The analyses were first conducted without covariates. Next, gender was added as a covariate, and thirdly, SES was added as a covariate. For the datasets including twins or siblings (i.e., Gen-R and NTR), data were split based on Family ID to create independent datasets (so that all siblings are in one dataset) and linear regression analyses were cluster-corrected based on Family ID with the R-package lavaan (Rosseel, 2012).

Informative Hypothesis Generation

Informative hypotheses are hypotheses that contain information about the parameters of interest in the model, like that a regression parameter is positive (Hoijtink, 2012). Based on the direction and significance of the exploratory regression analyses, competing informative hypotheses were composed stating that the $\beta_{age}$ and $\beta_{age2}$ parameters were either negative, equal to zero, or positive. In the set of competing hypotheses, two hypotheses were included by default: the null hypothesis: $\beta_{age}=0$, $\beta_{age2}=0$, and the unconstrained alternative hypothesis: $\beta_{age}$, $\beta_{age2}$. The unconstrained alternative hypotheses entails that ‘anything goes’, that is: $\beta_{age}$, $\beta_{age2}$ can take on any value. This alternative hypothesis is a fail-safe hypothesis that will receive most support when the informative hypotheses in the set do not represent the data well.

Bayesian Hypothesis Evaluation in Confirmatory Data per Cohort

In the confirmatory data, linear regression analyses were conducted with mean-centered father or mother age and age squared as predictors, and the same dependent variables and covariates as before. Using the statistical software Bain (Gu et al., 2017; Hoijtink, Gu, & Mulder, 2018), the relative support of each informative hypothesis versus the unconstrained alternative (i.e., $\beta_{age}$, $\beta_{age2}$) was computed. Posterior model probabilities (PMPs) represented the relative probability of each of the evaluated hypotheses in the set, summing up to 1.00.

Bayesian Evidence Synthesis over Cohorts

Next, results were updated over cohorts, meaning that we evaluated which informative hypothesis was best supported by all cohorts simultaneously. In this step we can unite results from cohorts that used different measures, because we evaluate informative hypotheses that are applicable irrespective of the operationalization of the attention and cognitive constructs.
Assessing how much the hypotheses are supported by all cohorts, evaluates support for hypotheses irrespective of the population and measurement specifics of separate cohorts.

Results

Exploratory Data Analyses

In general, the results of the exploratory analyses indicated that child-reported attention problems were not predicted by parental age (results are provided in Supplementary Tables S8-S21). For other reporters, age had a significant negative relation with attention problems, accompanied by a significant positive quadratic factor in about half of the analyses across raters and cohorts. The negative direction of the linear relation indicated that offspring of younger parents had on average more attention problems. In case of significant quadratic factors, the regression either became U-shaped, indicating that offspring of the youngest and oldest parents had most attention problems or had a steeper decline in the beginning that attenuated over time, indicating that offspring of the youngest parents had the most attention problems (see for example Figure 1a-1b). For parental age with IQ and educational achievement the linear relations were positive: offspring of younger parents had on average lower IQ or educational achievement. Also, significant quadratic factors were now negative resulting in either a bow-shape (inverse U), indicating that offspring of the youngest and oldest parents had the lowest IQ and educational achievement scores or had a steeper increase in the beginning that attenuated over time. Offspring of the youngest parents had the lowest IQ and educational achievement (see for example Figure 1c-1d). Adding gender as a covariate to the model did generally not change the patterns. When SES was added to the model about half of the significant relations between age and attention problems disappeared.

Informative Hypothesis Generation in Exploratory Data

Based on the exploratory results, the overall set of hypotheses for attention problems was:

- H1: $\beta_1=0, \beta_2=0$. Age is unrelated (i.e., the classical null model).
- H2: $\beta_1<0, \beta_2=0$. Age has a negative linear relation, there is no quadratic relation.
- H3: $\beta_1<0, \beta_2>0$. Age has a negative linear relation, and a positive quadratic relation.
- H4: $\beta_1=0, \beta_2>0$. Age has a positive quadratic relation, there is no linear relation.
- Ha: $\beta_1, \beta_2$. The relation with age can be anything.
A set of these competing hypotheses was drafted for each combination of predictor (paternal age or maternal age), dependent variable (i.e., attention rated by mother, father, teacher, child; IQ; educational achievement), and set of covariates (i.e., none or gender and SES). For example, for teacher reported attention problems regressed on maternal age, we found $H_3: \beta_1 < 0, \beta_2 > 0$ in NTR and $H_2: \beta_1 < 0, \beta_2 = 0$ in TRAILS. As a fail-safe, we always evaluate $H_1: \beta_1 = 0, \beta_2 = 0$, and $H_a: \beta_1, \beta_2$ (see Analytical Strategy section). Hence, we evaluated $H_1, H_2, H_3,$ and $H_a$ as the set of competing hypotheses with the confirmatory data in all cohorts for the regression of teacher reported attention problems on maternal age. See Supplementary Table S22 for the exact hypotheses for attention problems per rater, before and after adjustment for gender and SES. Note that we composed hypotheses and ran analyses with gender and SES in the model at once, because gender on itself hardly affected any of the relations in the model. For IQ and educational achievement, the overall set of hypotheses was:

- $H_1: \beta_1 = 0, \beta_2 = 0$. Age is unrelated (i.e., the classical null model).
- $H_1: \beta_1 > 0, \beta_2 = 0$. Age has a positive linear relation, there is no quadratic relation.
- $H_3: \beta_1 > 0, \beta_2 < 0$. Age has a positive linear relation, and a negative quadratic relation.
- $H_4: \beta_1 = 0, \beta_2 < 0$. Age has a negative quadratic relation, there is no linear relation.
- $H_a: \beta_1, \beta_2$. The relation with age can be anything.

See Supplementary Table S23 for the exact hypotheses for IQ and educational achievement before and after adjustment for gender and SES.

**Bayesian Hypothesis Evaluation and Evidence Synthesis in Confirmatory Data**

Cohort-specific and robust results are provided in Tables 1 to 6. Cohort-specific results are fully described in the Supplementary Tables S24-S32. We focus on the robust results across cohorts.

First, for attention problems, child-reported data showed no relation with parental age across cohorts. For all other informants, results without covariates supported a negative linear relation between parental age and attention problems, i.e. fewer attention problems in offspring of older parents. One exception is that overall, there was no relation between paternal age and mother-reported attention problems. When including gender and SES in the model, we found most support for no relation between attention problems and parental age. Two exceptions were the relation between father-reported attention problems and paternal age, and mother-reported problems with maternal age. Most support was found for a negative linear relation with parental age (i.e., older parents reported less attention-problems); even after including covariates. Second, for IQ, most support was found for a quadratic relation with paternal age with slightly lower scores for younger and older fathers (inverted U; see Figure 2a-2c), or a relation that attenuated with older age (see Figure 2d).
A positive linear relation between maternal age and IQ was found. After taking child gender and SES into account, the relation with IQ disappeared for paternal age, but the linear relation was still best supported for maternal age. Third, for educational achievement, the findings of the two largest cohorts (Gen-R and NTR) indicated that there was a quadratic relation with parental age, in which children of younger fathers (see Figure 3a-3b) and younger mothers (see Figure 3c-3d) were disadvantaged. Offspring of older mothers had higher educational achievement. For both parents, the effects disappeared after taking child gender and SES into account.

### Table 1. Posterior Model Probabilities for Parental Age Predicting Attention Problems

<table>
<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
<th>Age Father</th>
<th>Age Mother</th>
</tr>
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<td></td>
<td></td>
<td>H1 H2 H3 H4 H5</td>
<td>H1 H2 H3 H4 H5</td>
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<td>1.00 - - - .01</td>
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<td>TRAILS</td>
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<td>1.00 - - - .00</td>
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<td>All</td>
<td>1.00 - - - .00</td>
<td>1.00 - - - .00</td>
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<td>.30 .44 .21 - .06</td>
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*Note.* Numbers in italic font represent the highest posterior model probability per cohort. Numbers in bold font represent the highest results after Bayesian updating. Dashes indicate that the hypothesis was not among the set of evaluated hypotheses based on the exploratory analyses.
### Table 2. Posterior Model Probabilities for Parental Age Predicting Attention Problems After Correction for Covariates

<table>
<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
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<td>.96  -  -  .04  .00</td>
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*Note.* See Table 1.

### Table 3. Posterior Model Probabilities for Parental Age Predicting IQ

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<th>Age Mother</th>
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<td>Gen-R</td>
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<td>.00  .37  .51  .00  .12</td>
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<tr>
<td>NTR</td>
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<td>.53  .30  .06  .09  .02</td>
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<td>.00  .62  .31  .00  .08</td>
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<td>RADAR-Y</td>
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<td>.05  .06  .36  .43  .09</td>
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<td>All</td>
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<td>.00  .51  .48  .00  .00</td>
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*Note.* See Table 1.
### Table 4. Posterior Model Probabilities for Parental Age Predicting IQ After Correction for Covariates

| Cohort | Age Father | | | | | Age Mother | | | |
|--------|------------|---|---|---|---|---|---|---|---|---|
|        | H₁ | H₂ | H₃ | H₄ | H₅ | H₁ | H₂ | H₃ | H₄ | H₅ |
| Gen-R  | .22 | .71 | .05 | .01 | .02 | .05 | .94 | -  | -  | .01 |
| NTR    | .82 | .10 | .01 | .07 | .00 | .87 | .12 | -  | -  | .00 |
| TRAILS | .65 | .29 | .02 | .04 | .01 | .02 | .94 | -  | -  | .04 |
| RADAR-Y| .51 | .10 | .09 | .27 | .03 | .38 | .34 | -  | -  | .28 |
| All    | .97 | .03 | .00 | .00 | .00 | .01 | .99 | -  | -  | .00 |

Note. See Table 1.

### Table 5. Posterior Model Probabilities for Parental Age Predicting Educational Achievement

| Cohort | Age Father | | | | | Age Mother | | | |
|--------|------------|---|---|---|---|---|---|---|---|---|
|        | H₁ | H₂ | H₃ | H₄ | H₅ | H₁ | H₂ | H₃ | H₄ | H₅ |
| Gen-R  | .00 | .00 | .76 | -  | .24 | .00 | .06 | .76 | -  | .18 |
| NTR    | -   | -   | -   | -  | -   | -   | -   | -   | -   | -   |
| TRAILS | .00 | .31 | .52 | -  | .17 | .00 | .70 | .24 | -  | .06 |
| RADAR-Y| -   | -   | -   | -  | -   | -   | -   | -   | -   | -   |
| All    | .00 | .00 | .91 | -  | .09 | .00 | .19 | .77 | -  | .05 |

Note. See Table 1.

### Table 6. Posterior Model Probabilities for Parental Age Predicting Educational Achievement After Correction for Covariates

| Cohort | Age Father | | | | | Age Mother | | | |
|--------|------------|---|---|---|---|---|---|---|---|---|
|        | H₁ | H₂ | H₃ | H₄ | H₅ | H₁ | H₂ | H₃ | H₄ | H₅ |
| Gen-R  | .95 | .05 | -  | -  | .00 | .98 | .02 | -  | -  | .00 |
| NTR    | -   | -   | -   | -  | -   | -   | -   | -   | -   | -   |
| TRAILS | .54 | .45 | -  | -  | .01 | .09 | .89 | -  | -  | .02 |
| RADAR-Y| -   | -   | -   | -  | -   | -   | -   | -   | -   | -   |
| All    | .96 | .04 | -  | -  | .00 | .84 | .16 | -  | -  | .00 |

Note. See Table 1.
Chapter 5  Effect of Parental Age on Offspring’s Neurodevelopment

**Figure 1.** Exploratory plots

(a) *Child-reported attention by TRAILS with $\beta_1 = 0, \beta_2 = 0$*

(b) *Teacher reported Attention by NTR with $\beta_1 < 0, \beta_2 > 0$*
(c) IQ regressed on mother age by Gen-R with $\beta_1 > 0$, $\beta_2 < 0$

(d) Educational Achievement by NTR with $\beta_1 > 0$, $\beta_2 = 0$
Figure 2. Confirmatory plots for Age Father with IQ

(a) Gen-R

(b) NTR
Chapter 5  
Effect of Parental Age on Offspring’s Neurodevelopment

(c) Radar-Y

(d) TRAILS
Figure 3. Confirmatory plots for Parental Age with Educational Achievement

(a) Gen-R – Paternal age

(b) NTR – Paternal Age
Chapter 5  
Effect of Parental Age on Offspring’s Neurodevelopment

(c) Gen-R – Maternal age

(d) NTR – Maternal Age
Discussion

We found that older parents are beneficial for offspring attention, IQ, and educational achievement. In contrast to being disadvantaged from a biological point of view (e.g. Malaspina, 2001), older parents seem to provide benefits for offspring on a psychosocial or contextual level (Janecka et al., 2019). Parents who postpone parenthood are typically highly educated with higher incomes at the time they start a family. This puts them in a better position to provide their children with a more stimulating environment (e.g., more books at home; van Bergen et al., 2017), which has been positively associated with educational attainment (Mellhuish et al., 2008; Kong et al., 2018). We observed only advantageous effects of advanced parental age, and suggest that biological disadvantages appear compensated by the positive contextual factors for attention, IQ and educational achievement. This might not be the case for the more severe neurodevelopmental disorders, such as autism, where adverse effects of advanced parenthood have been found in multiple studies (reviewed by e.g. De Kluiver, Buizer-Voskamp, Dolan, & Boomsma, 2017), but is in line with the support for an advantageous relation between older age and offspring’s reduced externalizing problem behavior that we found in our earlier study (Zondervan-Zwijnenburg et al., in press). The effects of parental age on child outcomes were highly similar for paternal and maternal age. This corroborates the major influence of level of SES.

Most of the statistically significant associations between parental age and child attention problems, IQ, and educational achievement disappeared when SES was taken into account. Associations that attenuate after taking SES into account suggest that most of the effect of parental age on offspring development is due to genetic and environmental effects from parent SES to child outcome. Because it is not clear which genetic and environmental effects SES captures, we argue that it is important to present results both with and without controlling for SES. Furthermore, we know that low SES tends to be associated with young parenthood, parental ADHD and lower IQ, and that low SES may reflect a more general genetic liability that influences both age at having offspring and offspring outcome. Alternatively, SES could influence parental age which, in turn, influences offspring outcome. In that case, adjusting for SES could introduce bias (Janecka et al., 2019). Hence, we conclude that older parents tend to have offspring with better attention and cognition, but the effects are small and mostly explained by higher SES.

Besides environmental transmission, parent and child characteristics are also associated due to genetic transmission. Both ADHD and intelligence are heritable phenotypes.
Individuals with ADHD and/or low IQ have an increased risk of impulsive behavior, which could result in early pregnancies (Østergaard, Dalsgaard, Faroone, Munk-Olsen & Laursen. 2017). Offspring of these young parents may thus have a genetic predisposition to develop ADHD and low IQ. Support for this hypothesis was also reported by Chung et al. (2014) and Mikkelsen et al. (2016). Individuals who become parents at later ages tend to have higher educational attainment, and these parents pass on favorable education-related genetic variants. Likewise, Swagerman et al. (2017), for example, found resemblance between parents and children in reading ability was solely due to genetic transmission.

In the exploratory phase, the four cohorts consistently showed associations in the same direction (offspring of older parents performed better), but these associations did not consistently reach significance despite large samples, suggesting that the associations tended to be small. Our cross-cohort differences may relate to birth-cohorts differences. For example, Goisis (2017) found that the association between advanced maternal age and children’s cognitive ability changed from negative to positive in different birth-cohorts because of changing parental characteristics. RADAR-Y and TRAILS have an early nineties cohort, and Gen-R a cohort from after 2000. Our largest cohort, NTR, included children from the 80’s, 90’s, and 2000’s. It is unclear, however, whether there is a birth-cohort effect within this range of twenty years. Other reasons for cross-cohort differences may be structural differences between the populations, and reliability and validity of measures. Although the cohorts had some different properties and results sometimes differed, the cohorts did not yield contradictory findings. Moreover, our analytical strategy enabled us to summarize the evidence per hypothesis over cohorts.

Previous studies regarding attention problems, IQ, and educational achievement showed mixed results, but these studies used different populations, measures, covariates, etcetera. A strength of our study is that we applied Bayesian evidence synthesis, allowing us to combine evidence from multiple cohort studies that possibly used different measures. As a result, we were able to identify consistent effects and hypotheses that received the most support over cohorts. The overall results pointed towards robust effects, as they were supported by all cohorts, irrespective of the characteristics of the populations or specifics of the measurements used. Furthermore, we included large population-based samples, handled missing data by means of multiple imputation, and used cross-validation.

In conclusion, we found support for older parents having offspring with better attention, IQ and educational achievement scores and younger parents having offspring with worse attention, IQ and educational achievement scores. Only paternal age had a clear inverted U-shaped relation with educational achievement, with both offspring of younger and older fathers being disadvantaged.
More resources and more education-elevating genetic variants in older parents
may compensate for possible biological disadvantages. Genetic effects in which
ADHD, cognitive functioning, and young parenthood come together may explain
why lower parental age goes together with more offspring problems. After includ-
ing SES in the model, most of the associations with parental age disappeared.
Hence, we can be certain that SES takes on an important role which may be due
to genetic sharing of SES with parental age and outcomes or SES may influence
parental age, which, in turn, influences offspring outcome. Based on this popula-
tion-based multi-cohort study, we conclude that offspring of older parents are not
disadvantaged with respect to the investigated cognitive constructs, at least where
this pertains to mild outcomes as studied in the general population.
References


Chapter 5  
Effect of Parental Age on Offspring’s Neurodevelopment


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Chapter 5 Supplement

Effect of Parental Age on Offspring’s Neurodevelopment

IQ Bullying Perpetration Internalizing Parental age
ADHD CITO Bullying Victimization Externalizing
Table S1. Mean, SD and Sample Size for Attention Problems

<table>
<thead>
<tr>
<th>Variable Informant</th>
<th>Gen-R (N = 9,901)</th>
<th>NTR (N = 25,396)</th>
<th>RADAR-Y (N = 497)</th>
<th>TRAILS (N = 2,230)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD) N</td>
<td>Mean (SD) N</td>
<td>Mean (SD) N</td>
<td>Mean (SD) N</td>
</tr>
<tr>
<td>Attention Problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child</td>
<td>3.41 (2.49) 4,357</td>
<td>-</td>
<td>-</td>
<td>4.33 (2.74) 2,197</td>
</tr>
<tr>
<td>Mother</td>
<td>3.25 (3.20) 4,920</td>
<td>2.95 (3.05) 22,045</td>
<td>8.94 (8.37) 489</td>
<td>4.36 (3.47) 1,964</td>
</tr>
<tr>
<td>Father</td>
<td>3.29 (3.08) 3,555</td>
<td>2.62 (2.88) 14,725</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Teacher</td>
<td>-</td>
<td>6.74 (7.87) 12,573</td>
<td>-</td>
<td>0.53 (0.58) 1,927</td>
</tr>
</tbody>
</table>

Note. The total sample size is presented between brackets. The sample size for each outcome variable is presented below to provide insight in the amount of missing values. Unless otherwise specified, Gen-R, NTR and TRAILS used the ASEBA questionnaires (YSR, CBCL, and TRF) to measure attention problems (Achenbach, 1991; Achenbach & Rescorla, 2001).

1 Radar-Y measured mother-rated attention problems with a Dutch adaptation of Teacher ratings of DSM-III-R symptoms for the disruptive behavior disorders (DPD; Pelham, Gnagy, Greenslade & Milich, 1992), by Oosterlaan, Scheres, Antrop, Roeyers, and Sergeant, (2000).

2 TRAILS uses a 1-item adapted version of the TRF (scale and range = 0-2), see Measures section for more information.

Table S2. Mean, SD and Sample Size for IQ

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Mean (SD) N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R (N=6,111)</td>
<td>100.71 (15.18) 6,111</td>
</tr>
<tr>
<td>NTR (N=1,495)</td>
<td>103.44 (14.21) 1,495</td>
</tr>
<tr>
<td>TRAILS (N=2,230)</td>
<td>97.19 (15.00) 2,221</td>
</tr>
<tr>
<td>RADAR (N=497)</td>
<td>102.05 (11.80) 446</td>
</tr>
</tbody>
</table>

Note. The total sample size is presented between brackets. The sample size for each outcome variable is presented below to provide insight in the amount of missing values. In TRAILS and Radar-Y, IQ was assessed with the block design and the vocabulary subtests of the WISC-III-R.

1 Snijders-Oomen nonverbal intelligence test (Tellegen, Laros & Winkel, 2005)

2 IQ was measured at ages 5, 7, 9, 10, 12, 17 and 18 using the RAKIT, WISC-R(-III), Raven or WAIS (see Franči et al., 2014). For the children in NTR with multiple assessments, the mean over all IQ assessments was taken.
Table S3. Mean, SD and Sample Size for IQ

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Mean (SD)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R (N=2,655)</td>
<td>538.4 (9.44)</td>
<td>2,655</td>
</tr>
<tr>
<td>NTR (N=15,693)</td>
<td>538 (8.55)</td>
<td>14,867</td>
</tr>
<tr>
<td>TRAILS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RADAR</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. The total sample size is presented between brackets. The sample size for each outcome variable is presented below to provide insight in the amount of missing values. Educational achievement was assessed by the CITO End of Primary Education Test.

Table S4. Parental Age at Offspring Birth

<table>
<thead>
<tr>
<th>Variable</th>
<th>Maternal age at birth child</th>
<th>Paternal age at birth child</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>M (SD)</td>
</tr>
<tr>
<td><strong>Attention Problems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gen-R</td>
<td>15.27-46.34</td>
<td>29.92 (5.37)</td>
</tr>
<tr>
<td>NTR</td>
<td>17.36-47.09</td>
<td>31.35 (3.95)</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>17.80-48.61</td>
<td>31.38 (4.43)</td>
</tr>
<tr>
<td>TRAILS</td>
<td>16.34-44.88</td>
<td>29.32 (4.58)</td>
</tr>
<tr>
<td><strong>IQ</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gen-R</td>
<td>15.27-34.14</td>
<td>29.92 (5.37)</td>
</tr>
<tr>
<td>NTR</td>
<td>19.26-45.63</td>
<td>30.18 (3.81)</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>17.80-48.61</td>
<td>31.38 (4.43)</td>
</tr>
<tr>
<td>TRAILS</td>
<td>16.34-44.88</td>
<td>29.32 (4.58)</td>
</tr>
<tr>
<td><strong>Educational Achievement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gen-R</td>
<td>16.85-46.34</td>
<td>32.25 (4.71)</td>
</tr>
<tr>
<td>NTR</td>
<td>17.15-45.63</td>
<td>31.02 (3.80)</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TRAILS</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. Gen-R and NTR had different datasets for attention problems, IQ, and EA, therefore all descriptive statistics for parental age are given, since these are key variables in our study.
### Table S5. Attention Problems

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Child Age N(%)</th>
<th>Maternal Age N(%)</th>
<th>Paternal Age N(%)</th>
<th>Gender N(%)</th>
<th>SES N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R*</td>
<td>31 (0.6)</td>
<td>0 (0)</td>
<td>645 (13.11)</td>
<td>0 (0)</td>
<td>1020 (20.73)</td>
</tr>
<tr>
<td>NTR</td>
<td>3,233 (12.73)</td>
<td>76 (.30)</td>
<td>332 (1.31)</td>
<td>0 (0)</td>
<td>751 (2.96)</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>0 (0)</td>
<td>2 (.40)</td>
<td>48 (9.66)</td>
<td>0 (0)</td>
<td>8 (1.61)</td>
</tr>
<tr>
<td>TRAILS</td>
<td>0 (0)</td>
<td>114 (5.11)</td>
<td>558 (25.02)</td>
<td>0 (0)</td>
<td>42 (1.88)</td>
</tr>
</tbody>
</table>

*This are the missing in the dataset that have mother’s attention (N= 4920)*

### Table S6. CITO / Educational Achievement

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Child Age N(%)</th>
<th>Maternal Age N(%)</th>
<th>Paternal Age N(%)</th>
<th>Gender N(%)</th>
<th>SES N(%)</th>
<th>CITO / SP N(%)</th>
<th>IQ N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R*</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>372 (14.01)</td>
<td>0 (0)</td>
<td>575 (21.66)</td>
<td>0(0)</td>
<td>375 (14.12)</td>
</tr>
<tr>
<td>NTR</td>
<td>Exact Age is not available. Groep 8</td>
<td>26 (.17)</td>
<td>136 (.87)</td>
<td>0</td>
<td>1,046 (6.67)</td>
<td>826 (5.26)</td>
<td>14,198 (90.47)</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TRAILS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*This are the missing in the dataset that have information on CITO (N= 2655)*
Table S7. IQ

<table>
<thead>
<tr>
<th></th>
<th>Maternal Age</th>
<th>Paternal Age</th>
<th>Gender</th>
<th>SES</th>
<th>CITO / SP</th>
<th>IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N(%)</td>
<td>N(%)</td>
<td>N(%)</td>
<td>N(%)</td>
<td>N(%)</td>
<td>N(%)</td>
</tr>
<tr>
<td>Gen-R*</td>
<td>0 (0)</td>
<td>1,104 (18.07)</td>
<td>0 (0)</td>
<td>1,672 (27.36)</td>
<td>3,831 (62.69)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>NTR</td>
<td>1 (.07)</td>
<td>11 (.74)</td>
<td>0</td>
<td>30 (2.00)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>2 (.40)</td>
<td>48 (9.66)</td>
<td>0 (0)</td>
<td>8 (1.61)</td>
<td>7 (1.41)</td>
<td>51 (10.26)</td>
</tr>
<tr>
<td>TRAILS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* This are the missing in the dataset that have information on IQ (N= 6111)

Additional Remarks/Information

- **NTR (CITO + IQ):** For families with more than one twin-pair, the ‘second’ twin-pairs were excluded.
- **NTR (IQ):** there were no missings, since children were selected to have IQ present due to large proportion of missing + CITO was not included in the imputation (since there were no missings for IQ)
- **Radar:** Separate imputations (with varying aux variables) were conducted for attention and IQ/Educational Achievement, but the imputation was all on the same dataset (no subset selections), because the largest percentage of missing data is ≈ 10%.
- **GenR:** The datasets were created and imputed separately (with the same aux variables) for attention, IQ and CITO, due to large proportion of missings.
- **TRAILS:** Same as Radar: Separate imputations (with varying aux variables) were conducted for attention and IQ, but the imputation was all on the same dataset (no subset selections).
### Tables for Exploratory Data

#### Attention Problems

**Table S8. Parental Age Predicting Attention Problems from Exploratory Results**

<table>
<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
<th>Age F. β (p-value)</th>
<th>Age² F. β (p-value)</th>
<th>$r^2$</th>
<th>Age M. β (p-value)</th>
<th>Age² M. β (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
<td>Gen-R</td>
<td>.00 (.77)</td>
<td>.03 (.08)</td>
<td>.001</td>
<td>-.01 (.72)</td>
<td>.02 (.16)</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>.02 (.59)</td>
<td>-.01 (.81)</td>
<td>.001</td>
<td>-.00 (.95)</td>
<td>.03 (.30)</td>
<td>.001</td>
</tr>
<tr>
<td>Mother</td>
<td>Gen-R</td>
<td>- .05 (.003)</td>
<td>.03 (.03)</td>
<td>.002</td>
<td>- .03 (.03)</td>
<td>.04 (.01)</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.05 (&lt;.001)</td>
<td>.02 (.04)</td>
<td>.002</td>
<td>-.05 (&lt;.001)</td>
<td>.02 (.13)</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.07 (.07)</td>
<td>.08 (.03)</td>
<td>.009</td>
<td>-.14 (&lt;.001)</td>
<td>.05 (.16)</td>
<td>.021</td>
</tr>
<tr>
<td></td>
<td>RADAR-Y</td>
<td>-.12 (.114)</td>
<td>.20 (.006)</td>
<td>.035</td>
<td>-.13 (.041)</td>
<td>.20 (.002)</td>
<td>.045</td>
</tr>
<tr>
<td>Father</td>
<td>Gen-R</td>
<td>-.06 (&lt;.001)</td>
<td>.03 (.046)</td>
<td>.003</td>
<td>-.03 (.03)</td>
<td>.03 (.04)</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.05 (&lt;.001)</td>
<td>.02 (.11)</td>
<td>.003</td>
<td>-.05 (&lt;.001)</td>
<td>.01 (.20)</td>
<td>.002</td>
</tr>
<tr>
<td>Teacher</td>
<td>NTR</td>
<td>-.04 (.002)</td>
<td>.01 (.40)</td>
<td>.001</td>
<td>-.03 (.01)</td>
<td>.02 (.03)</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.09 (.014)</td>
<td>.07 (.068)</td>
<td>.010</td>
<td>-.11 (&lt;.001)</td>
<td>.02 (.527)</td>
<td>.013</td>
</tr>
</tbody>
</table>

*Note. F. = Father. M. = Mother.*

**Table S9. Age Father and Gender Child Predicting Attention Problems from Exploratory Results**

<table>
<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
<th>Age β (p-value)</th>
<th>Age² β (p-value)</th>
<th>Gender Child β (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
<td>Gen-R</td>
<td>.01 (.76)</td>
<td>.03 (.07)</td>
<td>-.09 (&lt;.001)</td>
<td>.009</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>.02 (.581)</td>
<td>-.01 (.82)</td>
<td>.03 (.460)</td>
<td>.001</td>
</tr>
<tr>
<td>Mother</td>
<td>Gen-R</td>
<td>-.05 (.002)</td>
<td>.03 (.02)</td>
<td>-.14 (&lt;.001)</td>
<td>.022</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.06 (&lt;.001)</td>
<td>.03 (.02)</td>
<td>-.15 (&lt;.001)</td>
<td>.024</td>
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<tr>
<td></td>
<td>TRAILS</td>
<td>-.07 (.055)</td>
<td>.08 (.036)</td>
<td>-.16 (&lt;.001)</td>
<td>.034</td>
</tr>
<tr>
<td></td>
<td>RADAR-Y</td>
<td>-.12 (.100)</td>
<td>.20 (.007)</td>
<td>-.11 (.075)</td>
<td>.047</td>
</tr>
<tr>
<td>Father</td>
<td>Gen-R</td>
<td>-.06 (&lt;.001)</td>
<td>.03 (.04)</td>
<td>-.13 (&lt;.001)</td>
<td>.02</td>
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<tr>
<td></td>
<td>NTR</td>
<td>-.06 (&lt;.001)</td>
<td>.02 (.08)</td>
<td>-.15 (&lt;.001)</td>
<td>.024</td>
</tr>
<tr>
<td>Teacher</td>
<td>NTR</td>
<td>-.04 (&lt;.001)</td>
<td>.01 (.25)</td>
<td>-.26 (&lt;.001)</td>
<td>.066</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.09 (.009)</td>
<td>.06 (.076)</td>
<td>-.17 (&lt;.001)</td>
<td>.038</td>
</tr>
</tbody>
</table>
**Table S10. Age Father and Covariates Predicting Attention Problems from Exploratory Results**

<table>
<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
<th>Age</th>
<th>Age²</th>
<th>SES</th>
<th>Gender Child</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\beta$ (p-value)</td>
<td>$\beta$ (p-value)</td>
<td>$\beta$ (p-value)</td>
<td>$\beta$ (p-value)</td>
<td></td>
</tr>
<tr>
<td>Child</td>
<td>Gen-R</td>
<td>.02 (.14)</td>
<td>.01 (.39)</td>
<td>-.07 (&lt;.001)</td>
<td>-.09 (&lt;.001)</td>
<td>.013</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>.02 (.613)</td>
<td>-.01 (.294)</td>
<td>.01 (.871)</td>
<td>.02 (.463)</td>
<td>.001</td>
</tr>
<tr>
<td>Mother</td>
<td>Gen-R</td>
<td>-.01 (.07)</td>
<td>.01 (.56)</td>
<td>-.12 (&lt;.001)</td>
<td>-.14 (&lt;.001)</td>
<td>.035</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.04 (&lt;.001)</td>
<td>.02 (.11)</td>
<td>-.09 (&lt;.001)</td>
<td>-.15 (&lt;.001)</td>
<td>.033</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.03 (.490)</td>
<td>.05 (.156)</td>
<td>-.20 (&lt;.001)</td>
<td>-.15 (&lt;.001)</td>
<td>.072</td>
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<tr>
<td></td>
<td>RADAR-Y</td>
<td>-.12 (.111)</td>
<td>.20 (.007)</td>
<td>.04 (.545)</td>
<td>-.12 (.067)</td>
<td>.052</td>
</tr>
<tr>
<td>Father</td>
<td>Gen-R</td>
<td>-.04 (.03)</td>
<td>.01 (.36)</td>
<td>-.08 (&lt;.001)</td>
<td>-.13 (&lt;.001)</td>
<td>.027</td>
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<tr>
<td></td>
<td>NTR</td>
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<td>.01 (.24)</td>
<td>-.08 (&lt;.001)</td>
<td>-.15 (&lt;.001)</td>
<td>.030</td>
</tr>
<tr>
<td>Teacher</td>
<td>NTR</td>
<td>-.02 (.08)</td>
<td>.00 (.88)</td>
<td>-.14 (&lt;.001)</td>
<td>-.26 (&lt;.001)</td>
<td>.085</td>
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<tr>
<td></td>
<td>TRAILS</td>
<td>-.05 (.186)</td>
<td>.04 (.294)</td>
<td>-.21 (&lt;.001)</td>
<td>-.16 (&lt;.001)</td>
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**Table S11. Age Mother and Gender Child Predicting Attention Problems from Exploratory Results**

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<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
<th>Age</th>
<th>Age²</th>
<th>Gender Child</th>
<th>$r^2$</th>
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</thead>
<tbody>
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<td></td>
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<td>$\beta$ (p-value)</td>
<td>$\beta$ (p-value)</td>
<td></td>
</tr>
<tr>
<td>Child</td>
<td>Gen-R</td>
<td>-.01 (.66)</td>
<td>.02 (.18)</td>
<td>-.09 (&lt;.001)</td>
<td>.009</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.00 (.946)</td>
<td>.03 (.310)</td>
<td>.02 (.489)</td>
<td>.002</td>
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<td>Mother</td>
<td>Gen-R</td>
<td>-.03 (.02)</td>
<td>.04 (.01)</td>
<td>-.14 (&lt;.001)</td>
<td>.022</td>
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<tr>
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<td>NTR</td>
<td>-.05 (&lt;.001)</td>
<td>.02 (.06)</td>
<td>-.15 (&lt;.001)</td>
<td>.025</td>
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<tr>
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<td>TRAILS</td>
<td>-.14 (&lt;.001)</td>
<td>.05 (.109)</td>
<td>-.16 (&lt;.001)</td>
<td>.047</td>
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<tr>
<td></td>
<td>RADAR-Y</td>
<td>-.14 (.038)</td>
<td>.19 (.004)</td>
<td>-.10 (.135)</td>
<td>.054</td>
</tr>
<tr>
<td>Father</td>
<td>Gen-R</td>
<td>-.03 (.02)</td>
<td>.03 (.045)</td>
<td>-.13 (&lt;.001)</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.05 (&lt;.001)</td>
<td>.02 (.10)</td>
<td>-.15 (&lt;.001)</td>
<td>.023</td>
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<tr>
<td>Teacher</td>
<td>NTR</td>
<td>-.04 (&lt;.001)</td>
<td>.03 (.004)</td>
<td>-.26 (&lt;.001)</td>
<td>.067</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.11 (&lt;.001)</td>
<td>.03 (.408)</td>
<td>-.17 (&lt;.001)</td>
<td>.041</td>
</tr>
</tbody>
</table>
Table S12. Age Mother and Covariates Predicting Attention Problems from Exploratory results

<table>
<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
<th>Age</th>
<th>Age$^2$</th>
<th>SES</th>
<th>Gender Child</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
<td>Gen-R</td>
<td>.02 (.15)</td>
<td>.01 (.47)</td>
<td>-.07 (&lt;.001)</td>
<td>-.09 (&lt;.001)</td>
<td>.013</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.01 (.849)</td>
<td>.03 (.271)</td>
<td>.01 (.665)</td>
<td>.02 (.496)</td>
<td>.002</td>
</tr>
<tr>
<td>Mother</td>
<td>Gen-R</td>
<td>.02 (.22)</td>
<td>.02 (.16)</td>
<td>-.13 (&lt;.001)</td>
<td>-.14 (&lt;.001)</td>
<td>.036</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.03 (.002)</td>
<td>.02 (.16)</td>
<td>-.09 (&lt;.001)</td>
<td>-.15 (&lt;.001)</td>
<td>.033</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.08 (.017)</td>
<td>.04 (.271)</td>
<td>-.18 (&lt;.001)</td>
<td>-.16 (&lt;.001)</td>
<td>.076</td>
</tr>
<tr>
<td></td>
<td>RADAR-Y</td>
<td>-.13 (.045)</td>
<td>.19 (.004)</td>
<td>.03 (.590)</td>
<td>-.10 (.123)</td>
<td>.056</td>
</tr>
<tr>
<td>Father</td>
<td>Gen-R</td>
<td>.00 (.83)</td>
<td>.02 (.23)</td>
<td>-.09 (&lt;.001)</td>
<td>-.13 (&lt;.001)</td>
<td>.026</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.03 (.002)</td>
<td>.01 (.23)</td>
<td>-.08 (&lt;.001)</td>
<td>-.15 (&lt;.001)</td>
<td>.030</td>
</tr>
<tr>
<td>Teacher</td>
<td>NTR</td>
<td>-.01 (.34)</td>
<td>.02 (.03)</td>
<td>-.14 (&lt;.001)</td>
<td>-.26 (&lt;.001)</td>
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<tr>
<td></td>
<td>TRAILS</td>
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<td>-.20 (&lt;.001)</td>
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<td>.078</td>
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</table>

IQ

Table S13. Parental Age Predicting IQ from Exploratory Results

<table>
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<tr>
<th>Cohort</th>
<th>Age F.</th>
<th>Age$^2$ F.</th>
<th>$r^2$</th>
<th>Age M.</th>
<th>Age$^2$ M.</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.14 (&lt;.001)</td>
<td>-.09 (&lt;.001)</td>
<td>.02</td>
<td>.18 (&lt;.001)</td>
<td>-.06 (&lt;.001)</td>
<td>.039</td>
</tr>
<tr>
<td>TRAILS</td>
<td>.17 (&lt;.001)</td>
<td>-.12 (&lt;.001)</td>
<td>.033</td>
<td>.21 (&lt;.001)</td>
<td>-.05 (.130)</td>
<td>.045</td>
</tr>
<tr>
<td>NTR</td>
<td>.02 (.68)</td>
<td>-.08 (.29)</td>
<td>.005</td>
<td>-.00 (.95)</td>
<td>-.09 (.12)</td>
<td>.009</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>.14 (.060)</td>
<td>-.02 (.781)</td>
<td>.019</td>
<td>.11 (.114)</td>
<td>-.08 (.316)</td>
<td>.015</td>
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</table>

Table S14. Age Father and Gender Child Predicting IQ from Exploratory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age</th>
<th>Age$^2$</th>
<th>Gender Child</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.14 (&lt;.001)</td>
<td>-.09 (&lt;.001)</td>
<td>-.00 (.88)</td>
<td>.02</td>
</tr>
<tr>
<td>TRAILS</td>
<td>.17 (&lt;.001)</td>
<td>-.12 (&lt;.001)</td>
<td>-.10 (.001)</td>
<td>.042</td>
</tr>
<tr>
<td>NTR</td>
<td>.02 (.68)</td>
<td>-.08 (.29)</td>
<td>.00 (.95)</td>
<td>.005</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>.14 (.067)</td>
<td>-.02 (.757)</td>
<td>-.09 (.167)</td>
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</table>
Table S15. Age Father and Covariates Predicting IQ from Exploratory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age</th>
<th>Age²</th>
<th>SES</th>
<th>Gender Child</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.05</td>
<td>-.02</td>
<td>.37</td>
<td>-.00</td>
<td>.146</td>
</tr>
<tr>
<td>TRAILS</td>
<td>.09</td>
<td>-.08</td>
<td>.35</td>
<td>-.11</td>
<td>.146</td>
</tr>
<tr>
<td>NTR</td>
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<td>-.04</td>
<td>.24</td>
<td>-.00</td>
<td>.062</td>
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<tr>
<td>RADAR-Y</td>
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<td>-.02</td>
<td>-.07</td>
<td>-.08</td>
<td>.033</td>
</tr>
</tbody>
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Table S16. Age Mother and Gender Child Predicting IQ from Exploratory Results

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<th>Cohort</th>
<th>Age</th>
<th>Age²</th>
<th>Gender Child</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.18</td>
<td>-.06</td>
<td>-.00</td>
<td>.039</td>
</tr>
<tr>
<td>TRAILS</td>
<td>.21</td>
<td>-.04</td>
<td>-.10</td>
<td>.054</td>
</tr>
<tr>
<td>NTR</td>
<td>-.00</td>
<td>-.09</td>
<td>-.00</td>
<td>.009</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>.11</td>
<td>-.09</td>
<td>-.09</td>
<td>.027</td>
</tr>
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</table>

Table S17. Age Mother and Covariates Predicting IQ from Exploratory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age</th>
<th>Age²</th>
<th>SES</th>
<th>Gender Child</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.05</td>
<td>-.01</td>
<td>.36</td>
<td>-.00</td>
<td>.146</td>
</tr>
<tr>
<td>TRAILS</td>
<td>.10</td>
<td>-.01</td>
<td>.34</td>
<td>-.10</td>
<td>.161</td>
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<tr>
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<td>-.06</td>
<td>.25</td>
<td>-.01</td>
<td>.065</td>
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<td>-.07</td>
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</table>

Educational Achievement

Table S18. Parental Age Predicting Educational Achievement from Exploratory Results

<table>
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<tr>
<th>Cohort</th>
<th>Age F</th>
<th>Age² F</th>
<th>r²</th>
<th>Age M</th>
<th>Age² M</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.15</td>
<td>-.16</td>
<td>.033</td>
<td>.16</td>
<td>-.11</td>
<td>.043</td>
</tr>
<tr>
<td>NTR</td>
<td>.10</td>
<td>-.01</td>
<td>.009</td>
<td>.11</td>
<td>-.02</td>
<td>.013</td>
</tr>
</tbody>
</table>
### Table S19. Age Father and Gender Child Predicting Educational Achievement from Exploratory Results

<table>
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<tr>
<th>Cohort</th>
<th>Age $\beta$ (p-value)</th>
<th>Age$^2$ $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.15 (&lt;.001)</td>
<td>-.17 (&lt;.001)</td>
<td>.06 (.04)</td>
<td>.036</td>
</tr>
<tr>
<td>NTR</td>
<td>.09 (&lt;.001)</td>
<td>-.01 (.45)</td>
<td>-.05 (&lt;.001)</td>
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</table>

### Table S20. Age Mother and Covariates Predicting IQ from Exploratory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age $\beta$ (p-value)</th>
<th>Age$^2$ $\beta$ (p-value)</th>
<th>SES $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.04 (.19)</td>
<td>-.04 (.16)</td>
<td>.47 (&lt;.001)</td>
<td>.05 (.03)</td>
<td>.233</td>
</tr>
<tr>
<td>NTR</td>
<td>.05 (.001)</td>
<td>.01 (.28)</td>
<td>.29 (&lt;.001)</td>
<td>-.05 (&lt;.001)</td>
<td>.091</td>
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</table>

### Table S21. Age Mother and Gender Child Predicting Educational Achievement from Exploratory Results

<table>
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<th>Cohort</th>
<th>Age $\beta$ (p-value)</th>
<th>Age$^2$ $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.17 (&lt;.001)</td>
<td>-.11 (.001)</td>
<td>.06 (.02)</td>
<td>.047</td>
</tr>
<tr>
<td>NTR</td>
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<td>-.02 (.22)</td>
<td>-.05 (&lt;.001)</td>
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</table>

### Table S22. Age Mother and Covariates Predicting Educational Achievement from Exploratory Results

<table>
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<th>Cohort</th>
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<th>Age$^2$ $\beta$ (p-value)</th>
<th>SES $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.01 (.66)</td>
<td>-.02 (.68)</td>
<td>.47 (&lt;.001)</td>
<td>.05 (.03)</td>
<td>.232</td>
</tr>
<tr>
<td>NTR</td>
<td>.05 (.001)</td>
<td>-.00 (.89)</td>
<td>.28 (&lt;.001)</td>
<td>-.05 (&lt;.001)</td>
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### Table S23. Hypotheses for Attention Problems per Rater before and after adjustment for the Covariates Gender and SES.

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<th>Age Mother</th>
<th></th>
<th></th>
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<th></th>
<th></th>
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<td>(H_2)</td>
<td>(H_3)</td>
<td>(H_4)</td>
<td>(H_a)</td>
<td>(H_1)</td>
<td>(H_2)</td>
<td>(H_3)</td>
<td>(H_4)</td>
<td>(H_a)</td>
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<tr>
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<td>(\beta_1 &lt; 0)</td>
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<td>(\beta_1 = 0)</td>
<td>(\beta_2 = 0)</td>
<td>(\beta_2 = 0)</td>
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<td>(\beta_2 &gt; 0)</td>
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#### Before Adjusting

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<td></td>
<td></td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Mother</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
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<td>x</td>
<td>x</td>
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<tr>
<td>Father</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Teacher</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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</table>

#### After Adjusting

<table>
<thead>
<tr>
<th>Att. Problems</th>
<th></th>
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<th>Att. Problems</th>
<th></th>
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</tr>
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<tbody>
<tr>
<td>Child</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Mother</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Father</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Teacher</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

**Note.** These hypotheses are based on the results of the exploratory analyses.

### Table S24. Hypotheses for IQ and EA before and after adjustment for the Covariates Gender and SES.

<table>
<thead>
<tr>
<th>Age Father</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Age Mother</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(H_1)</td>
<td>(H_2)</td>
<td>(H_3)</td>
<td>(H_4)</td>
<td>(H_a)</td>
<td>(H_1)</td>
<td>(H_2)</td>
<td>(H_3)</td>
<td>(H_4)</td>
<td>(H_a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\beta_1 = 0)</td>
<td>(\beta_1 &lt; 0)</td>
<td>(\beta_1 &lt; 0)</td>
<td>(\beta_1 = 0)</td>
<td>(\beta_1 = 0)</td>
<td>(\beta_2 = 0)</td>
<td>(\beta_2 = 0)</td>
<td>(\beta_2 &gt; 0)</td>
<td>(\beta_2 &gt; 0)</td>
<td>(\beta_2 = 0)</td>
<td>(\beta_2 = 0)</td>
<td>(\beta_2 &gt; 0)</td>
<td>(\beta_2 &gt; 0)</td>
</tr>
</tbody>
</table>

#### Before Adjusting

| IQ | x | x | x | x | x | x | x | x | x | x | x | x |
| EA | x | x | x | x | x | x | x | x | x | x | x | x |

#### After Adjusting

| IQ | x | x | x | x | x | x | x | x | x | x | x | x |
| EA | x | x | x | x | x | x | x | x | x | x | x | x |

**Note.** These hypotheses are based on the results of the exploratory analyses.
Tables for Confirmatory Data

Attention Problems

Table S25. Parental Age Predicting Attention Problems from Confirmatory Results

<table>
<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
<th>Age F. $\beta$ (p-value)</th>
<th>Age$^2$ F. $\beta$ (p-value)</th>
<th>$r^2$</th>
<th>Age M. $\beta$ (p-value)</th>
<th>Age$^2$ M. $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
<td>Gen-R</td>
<td>-.02 (.01)</td>
<td>.00 (.05)</td>
<td>.002</td>
<td>-.02 (.002)</td>
<td>.00 (.40)</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.04 (.68)</td>
<td>-.02 (.85)</td>
<td>.001</td>
<td>-.01 (.90)</td>
<td>-.02 (.81)</td>
<td>.0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>Gen-R</td>
<td>-.04 (&lt;.001)</td>
<td>.00 (.001)</td>
<td>.006</td>
<td>-.04 (&lt;.001)</td>
<td>.00 (.01)</td>
<td>.007</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.04 (&lt;.001)</td>
<td>.00 (.02)</td>
<td>.003</td>
<td>-.05 (&lt;.001)</td>
<td>.00 (.01)</td>
<td>.004</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.29 (.01)</td>
<td>.10 (.42)</td>
<td>.008</td>
<td>-.42 (&lt;.001)</td>
<td>.15 (.17)</td>
<td>.017</td>
</tr>
<tr>
<td></td>
<td>RADAR-Y</td>
<td>-.20 (.079)</td>
<td>.01 (.276)</td>
<td>.018</td>
<td>-.32 (&lt;.001)</td>
<td>.03 (.13)</td>
<td>.040</td>
</tr>
<tr>
<td>Father</td>
<td>Gen-R</td>
<td>-.05 (&lt;.001)</td>
<td>.00 (.04)</td>
<td>.01</td>
<td>-.04 (&lt;.001)</td>
<td>.00 (.02)</td>
<td>.005</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.03 (&lt;.001)</td>
<td>.00 (.03)</td>
<td>.002</td>
<td>-.04 (&lt;.001)</td>
<td>.00 (.04)</td>
<td>.003</td>
</tr>
<tr>
<td>Teacher</td>
<td>NTR</td>
<td>-.04 (.06)</td>
<td>.00 (.15)</td>
<td>.000</td>
<td>-.04 (.04)</td>
<td>.01 (.11)</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.08 (&lt;.001)</td>
<td>.02 (.27)</td>
<td>.018</td>
<td>-.09 (&lt;.001)</td>
<td>.04 (.03)</td>
<td>.031</td>
</tr>
</tbody>
</table>

Note. F. = Father. M. = Mother.

Table S26. Age Father and Covariates Predicting Attention Problems from Confirmatory Results

<table>
<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
<th>Age $\beta$ (p-value)</th>
<th>Age$^2$ $\beta$ (p-value)</th>
<th>SES $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
<td>Gen-R</td>
<td>-.01 (.07)</td>
<td>.00 (.13)</td>
<td>-.10 (.01)</td>
<td>-.44 (&lt;.001)</td>
<td>.011</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.05 (.58)</td>
<td>-.01 (.91)</td>
<td>.07 (.56)</td>
<td>.06 (.72)</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>Gen-R</td>
<td>-.02 (.01)</td>
<td>.00 (.08)</td>
<td>-.38 (&lt;.001)</td>
<td>-.97 (&lt;.001)</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.03 (.001)</td>
<td>.00 (.12)</td>
<td>-.36 (&lt;.001)</td>
<td>-1.07 (&lt;.001)</td>
<td>.046</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.17 (.18)</td>
<td>.09 (.45)</td>
<td>-.66 (&lt;.001)</td>
<td>1.22 (&lt;.001)</td>
<td>.058</td>
</tr>
<tr>
<td></td>
<td>RADAR-Y</td>
<td>-.18 (.10)</td>
<td>.01 (.47)</td>
<td>4.40 (.018)</td>
<td>-1.72 (.118)</td>
<td>.049</td>
</tr>
<tr>
<td>Father</td>
<td>Gen-R</td>
<td>-.04 (&lt;.001)</td>
<td>.00 (.16)</td>
<td>-.20 (&lt;.001)</td>
<td>-1.10 (&lt;.001)</td>
<td>.042</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.02 (.003)</td>
<td>.00 (.16)</td>
<td>-.35 (&lt;.001)</td>
<td>-1.00 (&lt;.001)</td>
<td>.043</td>
</tr>
<tr>
<td>Teacher</td>
<td>NTR</td>
<td>-.03 (.18)</td>
<td>.00 (.41)</td>
<td>-.59 (&lt;.001)</td>
<td>-4.51 (&lt;.001)</td>
<td>.086</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.04 (.04)</td>
<td>.02 (.36)</td>
<td>-.17 (&lt;.001)</td>
<td>.24 (&lt;.001)</td>
<td>.108</td>
</tr>
</tbody>
</table>
### Table S27. Age Mother and Covariates Predicting Attention Problems from Confirmatory Results

<table>
<thead>
<tr>
<th>Rater</th>
<th>Cohort</th>
<th>Age $\beta$ (p-value)</th>
<th>Age$^2$ $\beta$ (p-value)</th>
<th>SES $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
<td>Gen-R</td>
<td>-.02 (.04)</td>
<td>.00 (.66)</td>
<td>-.09 (.04)</td>
<td>-.44 (&lt;.001)</td>
<td>.011</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.03 (.77)</td>
<td>-.01 (.87)</td>
<td>.06 (.61)</td>
<td>.06 (.73)</td>
<td>.001</td>
</tr>
<tr>
<td>Mother</td>
<td>Gen-R</td>
<td>-.01 (.14)</td>
<td>.00 (.16)</td>
<td>-.37 (&lt;.001)</td>
<td>-.97 (&lt;.001)</td>
<td>.039</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.04 (&lt;.001)</td>
<td>.00 (.06)</td>
<td>-.344 (&lt;.001)</td>
<td>-1.08 (&lt;.001)</td>
<td>.047</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.27 (.021)</td>
<td>.17 (.12)</td>
<td>-.58 (&lt;.001)</td>
<td>1.24 (&lt;.001)</td>
<td>.063</td>
</tr>
<tr>
<td></td>
<td>RADAR-Y</td>
<td>-.30 (.01)</td>
<td>.02 (.252)</td>
<td>3.90 (.034)</td>
<td>-1.72 (.12)</td>
<td>.067</td>
</tr>
<tr>
<td>Father</td>
<td>Gen-R</td>
<td>-.02 (.03)</td>
<td>.00 (10)</td>
<td>-.21 (&lt;.001)</td>
<td>-1.10 (&lt;.001)</td>
<td>.037</td>
</tr>
<tr>
<td></td>
<td>NTR</td>
<td>-.03 (.001)</td>
<td>.00 (.18)</td>
<td>-.34 (&lt;.001)</td>
<td>-1.00 (&lt;.001)</td>
<td>.043</td>
</tr>
<tr>
<td>Teacher</td>
<td>NTR</td>
<td>-.03 (.12)</td>
<td>.00 (.27)</td>
<td>-.58 (&lt;.001)</td>
<td>-4.51 (&lt;.001)</td>
<td>.086</td>
</tr>
<tr>
<td></td>
<td>TRAILS</td>
<td>-.05 (.008)</td>
<td>.04 (.017)</td>
<td>-.16 (&lt;.001)</td>
<td>.24 (&lt;.001)</td>
<td>.114</td>
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</table>

### IQ

### Table S28. Parental Age Predicting IQ from Confirmatory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age F. $\beta$ (p-value)</th>
<th>Age$^2$ F. $\beta$ (p-value)</th>
<th>$r^2$</th>
<th>Age M. $\beta$ (p-value)</th>
<th>Age$^2$ M. $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.36 (&lt;.001)</td>
<td>-.02 (&lt;.001)</td>
<td>.023</td>
<td>.53 (&lt;.001)</td>
<td>-.02 (.002)</td>
<td>.04</td>
</tr>
<tr>
<td>TRAILS</td>
<td>2.38 (&lt;.001)</td>
<td>-.79 (.114)</td>
<td>.025</td>
<td>3.25 (&lt;.001)</td>
<td>-.83 (.07)</td>
<td>.049</td>
</tr>
<tr>
<td>NTR</td>
<td>.31 (.06)</td>
<td>-.04 (.18)</td>
<td>.011</td>
<td>.37 (.05)</td>
<td>-.04 (.20)</td>
<td>.013</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>.21 (.161)</td>
<td>-.04 (.043)</td>
<td>.023</td>
<td>.29 (.086)</td>
<td>-.07 (.01)</td>
<td>.044</td>
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</table>
Table S29. Age Father and Covariates Predicting IQ from Confirmatory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age $\beta$ (p-value)</th>
<th>Age$^2$ $\beta$ (p-value)</th>
<th>SES $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.16 (.001)</td>
<td>-.00 (.16)</td>
<td>5.25 (.001)</td>
<td>.09 (.82)</td>
<td>.136</td>
</tr>
<tr>
<td>TRAILS</td>
<td>.95 (.06)</td>
<td>-.28 (.56)</td>
<td>6.874 (.001)</td>
<td>-.91 (.29)</td>
<td>.122</td>
</tr>
<tr>
<td>NTR</td>
<td>.16 (.36)</td>
<td>-.02 (.58)</td>
<td>3.923 (.001)</td>
<td>-1.71 (.17)</td>
<td>.078</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>.19 (.213)</td>
<td>-.03 (.079)</td>
<td>-3.78 (.154)</td>
<td>1.078 (.495)</td>
<td>.034</td>
</tr>
</tbody>
</table>

Table S30. Age Mother and Covariates Predicting IQ from Confirmatory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age $\beta$ (p-value)</th>
<th>Age$^2$ $\beta$ (p-value)</th>
<th>SES $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.19 (.001)</td>
<td>-.00 (.68)</td>
<td>5.07 (.001)</td>
<td>.12 (.77)</td>
<td>.136</td>
</tr>
<tr>
<td>TRAILS</td>
<td>1.64 (.001)</td>
<td>-.47 (.28)</td>
<td>6.41 (.001)</td>
<td>.90 (.29)</td>
<td>.129</td>
</tr>
<tr>
<td>NTR</td>
<td>.19 (.32)</td>
<td>-.02 (.70)</td>
<td>3.91 (.001)</td>
<td>-1.68 (.18)</td>
<td>.078</td>
</tr>
<tr>
<td>RADAR-Y</td>
<td>.27 (.115)</td>
<td>-.06 (.018)</td>
<td>-3.25 (.216)</td>
<td>1.13 (.471)</td>
<td>.053</td>
</tr>
</tbody>
</table>

Educational Achievement

Table S31. Parental Age Predicting Educational Achievement from Confirmatory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age F. $\beta$ (p-value)</th>
<th>Age$^2$ F. $\beta$ (p-value)</th>
<th>$r^2$</th>
<th>Age M. $\beta$ (p-value)</th>
<th>Age$^2$ M. $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.20 (.001)</td>
<td>-.02 (&lt;.001)</td>
<td>.022</td>
<td>.28 (.001)</td>
<td>-.03 (.002)</td>
<td>.033</td>
</tr>
<tr>
<td>NTR</td>
<td>.17 (&lt;.001)</td>
<td>-.01 (.003)</td>
<td>.007</td>
<td>.23 (&lt;.001)</td>
<td>-.01 (.02)</td>
<td>.011</td>
</tr>
</tbody>
</table>

Table S32. Age Father and Covariates Predicting Educational Achievement from Confirmatory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age $\beta$ (p-value)</th>
<th>Age$^2$ $\beta$ (p-value)</th>
<th>SES $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>.02 (.70)</td>
<td>-.00 (.74)</td>
<td>4.83 (.53)</td>
<td>.29 (.53)</td>
<td>.000</td>
</tr>
<tr>
<td>NTR</td>
<td>.08 (.003)</td>
<td>-.00 (.19)</td>
<td>2.41 (&lt;.001)</td>
<td>-.97 (&lt;.001)</td>
<td>.076</td>
</tr>
</tbody>
</table>
Table S33. Age Mother and Covariates Predicting Educational Achievement from Confirmatory Results

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Age $\beta$ (p-value)</th>
<th>Age$^2$ $\beta$ (p-value)</th>
<th>SES $\beta$ (p-value)</th>
<th>Gender Child $\beta$ (p-value)</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-R</td>
<td>-.06 (.28)</td>
<td>-.00 (.71)</td>
<td>4.97 (&lt;.001)</td>
<td>.25 (.58)</td>
<td>.214</td>
</tr>
<tr>
<td>NTR</td>
<td>.11 (&lt;.001)</td>
<td>-.01 (.15)</td>
<td>2.37 (&lt;.001)</td>
<td>-.96 (&lt;.001)</td>
<td>.077</td>
</tr>
</tbody>
</table>

Bayesian Hypothesis Evaluation and Evidence Synthesis in Confirmatory Data

Attention Problems Regressed on Paternal Age

Both Gen-R and TRAILS strongly supported $H_1$, the absence of a relation between paternal age and child-reported attention problems. This was found both before and after adding child gender and SES as covariates.

For mother-rated attention problems, Gen-R, TRAILS, and Radar-Y best supported $H_1$. That is, the absence of a relation between paternal age and mother-rated attention problems. NTR, on the other hand, preferred $H_3$: a negative linear relation with age with a positive quadratic factor. The NTR plot of this relation showed a wide inverted-U curve, implying that younger and older fathers had children with more attention problems. The Bayesian evidence synthesis showed that over all cohorts, $H_1$ received most support. Adding covariates did not change the preferred hypotheses. Over all cohorts, age was not associated with mother-reported attention problems when taking the covariates into account.

For father-rated attention problems both Gen-R and NTR best supported $H_2$, the negative linear relation. After including covariates, Gen-R still supported $H_2$ best, but NTR now supported the absence of an effect, i.e., $H_1$. Overall, the negative linear hypothesis was still best supported.

For teacher-rated attention problems, NTR supported the absence of an effect, $H_1$, whereas TRAILS best supported $H_2$, the negative linear relation. Overall, the negative linear hypothesis was best supported. After correction for covariates, the null hypothesis was preferred by both cohorts.

Attention Problems Regressed on Maternal Age

Both Gen-R and TRAILS strongly supported $H_1$ for the relation between maternal age and child-reported attention problems. That is, there is no relation between maternal age and child-reported attention problems before and after adding the covariates.
Without covariates in the model, the preferred hypothesis by all cohorts for mother-reported attention problems was $H_2$, a negative linear relation with age. After including covariates, Gen-R preferred $H_1$ best, that is, no relation between maternal age and mother reported problems. NTR and Radar-Y still found most support for $H_2$, the negative linear relation with mother-reported attention problems, whereas TRAILS found substantial support for both $H_1$ and $H_2$. Evidence synthesis over the cohorts resulted in most support for $H_2$, a negative linear relation between maternal age and mother-reported attention problems when taking the covariates into account.

For father-rated attention problems without covariates in the model, Gen-R preferred $H_1$, whereas NTR preferred $H_2$, the negative linear hypothesis. Overall, the negative linear relation between maternal age and father-reported attention problems was best supported. After including covariates, Gen-R still preferred $H_1$, and NTR still $H_2$, but the best supported hypothesis by both cohorts simultaneously then became $H_1$: there is no relation between maternal age and father-reported attention problems when taking into account the covariates.

For teacher-reported attention problems, NTR preferred $H_1$, while TRAILS supported a negative linear relation either with or without a quadratic trend (PMP = .47 and .41 for $H_3$ and $H_2$ respectively). Over both cohorts, the best supported hypothesis was $H_2$, a negative linear relation with maternal age. With covariates in the model, TRAILS was ambiguous about the best hypothesis, but NTR preferred the null hypothesis. Hence, over cohorts the null hypothesis was best supported.

**IQ Regressed on Paternal Age**

Findings across cohorts were mixed. Gen-R found most support for $H_3$, a positive linear relation with a negative quadratic factor, NTR and Radar-Y found most support for $H_3$, and TRAILS best supported $H_2$, a positive linear relation. Over the cohorts, $H_3$, a positive linear relation with a quadratic effect was best supported. In Gen-R, NTR, and RADAR-Y the form of the quadratic relation was that of a wide inverted U, with slightly lower scores for younger and older fathers (see Figure 2a-2c). TRAILS showed a positive relation that attenuated with older age (see Figure 2d). After including child gender and SES in the model, NTR, TRAILS and Radar-Y best supported $H_1$, whereas Gen-R found most support for $H_2$, a positive linear effect. Over cohorts, $H_1$ was preferred: there is no relation between paternal age and IQ after the covariates in the model.
**IQ Regressed on Maternal Age**

For maternal age, findings were also mixed over cohorts. Gen-R found most support for $H_3$, a positive linear effect with a negative quadratic factor. RADAR-Y preferred $H_4$, a negative quadratic factor but no linear effect. The Gen-R plot showed a positive effect of age that attenuated over time, whereas the RADAR-Y plot showed an inverse-U curve with younger and older parents having children with lower IQ scores. NTR preferred $H_1$, and TRAILS found most support for $H_5$, a positive linear relation. Over the cohorts, $H_2$ and $H_3$ were best supported ($PMP H_2 = .51, PMP H_3 = .48$). After including covariates in the model, Gen-R and TRAILS found most support for $H_2$, a linear relation with maternal age, whereas NTR found most support for $H_1$, and Radar-Y supported both $H_1$ ($PMP = .38$) and $H_2$ ($PMP = .34$). Overall, $H_2$, the positive linear relation between maternal age and IQ was best supported by all cohorts.

**Educational Achievement Regressed on Paternal Age**

Both Gen-R and NTR best supported $H_3$, a positive linear relation with a negative quadratic factor between paternal age and EA. Plots of this relation (see Figure 3a-3b) showed a wide inverted-U curve, implying that younger and older fathers had children with lower EA scores. After including child gender and SES in the model, Gen-R preferred $H_1$, whereas NTR found support for both $H_1$, no relation between paternal age and EA, and $H_2$, a positive linear relation between paternal age and EA. Over cohorts, the null hypothesis of no relation between paternal age and EA was best supported when including the covariates in the model.

**Educational Achievement Regressed on Maternal Age**

For maternal age, Gen-R found most support for $H_3$, a positive linear relation with a negative quadratic trend. The Gen-R plot showed a positive effect of age that attenuated over time (see Figure 3c). NTR, on the other hand, found most support for $H_5$, a positive linear relation. Overall, most support was found for $H_3$ (see Figure 3d for the NTR plot). After correction for covariates, Gen-R preferred $H_1$, whereas NTR preferred the positive linear relation. Overall, most support was found for $H_1$, there is no support for a relation between maternal age and EA after including child gender and SES in the model.