Sibling Effects on School Achievement: Evidence From Two Large French Cohorts

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Sibling Effects on School Achievement: Evidence from Two Large French Cohorts

Lay abstract

This study emphasizes the negative association between the number of siblings and school achievement, independent of socio-economic status. This effect is found for siblings of both genders, but is more negative for older siblings than younger ones. Interestingly, this association is less negative in wealthier families. This could be taken into account for public policies to ensure that all their children benefit from equal opportunities, and to design interventions to support larger families, especially from lower-income backgrounds, to ensure that all children have access to the resources and support they need to succeed academically.

Abstract

We studied the effect of the number and characteristics of siblings (sex, age) on school achievement in several grades (kindergarten, 1th grade and 5th grade), in two large French cohorts, with more than 16,000 children. Running linear mixed-effects models, we find that, independently of socio-economic status, having more siblings is negatively associated with school achievement. We found a stronger negative association between the number of siblings and the achievement in older compared to younger siblings. This finding is in line with the resource dilution model, where families with more children have fewer resources available per child, but contradicts the confluence model (i.e., a child's intellectual ability is influenced by the average intellectual ability in the family). The negative association between the number of siblings and achievement was moderated by family income, with weaker effects in wealthier families.

Keywords: siblings, school achievement, resource dilution, confluence

Highlights:

- Having more siblings is negatively associated with school achievement in France
- The negative effect is seen for older and younger siblings, and brothers and sisters
- Our results support the resource dilution model, but not the confluence model
- Income moderates the association between siblings' number and achievement score

Various factors determine a child’s cognitive development and academic achievement, and among them, family environment is one of the main ones, especially at an early age. More specifically, siblings seem to be a significant part of a child's social environment and can influence various aspects of their cognitive development. Indeed, the number of siblings and more generally various aspects of the sibship structure seem to be related to various child cognitive outcomes.

Two theoretical models have often been used to explain the negative effect of sibship size: the resource-dilution hypothesis, and the confluence model. Blake’s resource-dilution model (Blake, 1981) states that families have limited resources (time, energy, financial resources…) to distribute among children, so the more children there are, the fewer resources should be available per child. The confluence model (Zajonc & Markus, 1975) states that a child’s intellectual environment is made up of the average absolute intellectual ability of all members of the immediate family, and, as children have lower intellectual abilities than adults, having more children in the family brings the average down. While both models predict an overall negative effect of the sibship size, they also entail predictions specific to each model. For instance, the resource dilution model predicts that the negative sibling effect should be mediated by the amount of parental resources dedicated to the target child, whereas the confluence model makes no such prediction. On the other hand, the confluence model predicts that the siblings’ age matters, and thus younger siblings should have a larger negative effect than older ones, because their absolute intelligence level is lower. Regarding sibling’s age, the resource dilution model would rather predict a more negative effect of the number of older rather than younger siblings, because having older siblings means that the target child had to compete for parental resources since birth, and even more so if they have several older siblings. It is important to note that the number of older siblings is equivalent to birth rank, which has often been used to measure sibship effects, and is independent from the number of younger siblings. As presented above, to test the confluence model we are interested in both the number of older and younger siblings.

In line with these models, previous studies have shown a negative association between the number of siblings and language development of children, even when controlling for confounding factors such as socioeconomic status (Gurgand et al., 2022; Havron et al., 2019; Karwath et al., 2014; Peyre et al., 2016). This is also true more generally for intellectual development (Breland, 1974; Mercy & Steelman, 1982; Steelman & Mercy, 1983; Wolter, 2003) and some studies suggest that it is also the case at a later developmental stage, for school achievement (Australian Institute of Family Studies, 2011; Bodovski & Youn, 2011; Siegler et al., 2012). Finally, this negative impact of sibship size has also been found with longer-term outcomes such as academic achievement and even adult earnings (Black et al., 2005; Booth & Kee, 2009).

Other predictions specific to the resource-dilution model have been empirically supported, such as the mediation of the sibship structure effect by parental interactions, one aspect of parental resources (Gurgand et al., 2022; Lehmann et al., 2018).

However, some predictions of the confluence model have found mixed support: first, the confluence model predicts that the age difference between the target child and older siblings should be positively correlated with cognitive outcomes (older siblings bring the average intellectual ability up). This has been found in some studies (Buckles & Munnich, 2012; Karwath et al., 2014), but opposite patterns have also been reported, with the age gap being negatively correlated to cognitive outcomes (Gurgand et al., 2022; ; non-significant trend in Havron et al., 2019). Mixed findings have also been reported in a systematic review (Dhamrait et al., 2022). Second, since girls tend to have better language than boys, the confluence model would also predict that having older sisters should be better for language development than having older brothers. This was found in several studies (Havron et al., 2019; Jakiela et al., 2020) but not in others (Gurgand et al., 2022; Havron et al., 2021).

In this study, we examine school achievement data in literacy and numeracy which enables us to further test the various predictions made by the two models, at a later stage of development than a previous study on the Elfe cohort (Gurgand et al., 2022). For instance, girls tend to have higher language levels than boys, whereas from first grade (Conseil scientifique de l'education nationale (CSEN), 2021; Fischer & Thierry, 2022), French boys tend to have better mathematics level than girls. According to the confluence model, having brothers should bring the average mathematics ability of the family up, and thus the child's mathematics score up, whereas having sisters should bring the average language ability of the family up, and thus the child's language scores up.

Finally, we investigate to what extent the language spoken by the parents moderates the relation between the number of siblings and school achievement. This question does not contribute to teasing apart the two models (i.e., resource dilution model and confluence model), but still is of interest to better understand the effect of siblings on development, as a previous study at 2 years of age suggested that the effect of the number of older siblings was less negative in foreign speaking families than in French speaking families, suggesting that older siblings might partly compensate for the effect of having foreign-speaking parents (Gurgand et al., 2022). Indeed, previous studies have suggested that siblings might have a positive effect on language development and literacy in the special case where parents do not speak the local language at home. In this context, siblings may help each other and speak the local language (Sorenson Duncan & Paradis, 2020). In fact, some studies showed an advantage in the language (of the country of residence) for toddlers with siblings compared to those without siblings in bilingual families (Bridges & Hoff, 2012; Gurgand et al., 2022; Tsinivits & Unsworth, 2021). However, this effect might be restricted to young children (who were not older than 2.5 years old in the cited studies). Indeed, their main source of language input is within the family (with parents and siblings), whereas the effect might disappear in older children who have more interactions outside of the family (at school with teachers and other students for example). Therefore, we want to examine whether this parental language influence on the relation between number of siblings and language also extents to school scores.

Using school data collected in two different French cohorts of children, in pre-school and first grade for the Elfe cohort, and in first and fifth grade for the DEPP cohort, we investigate the effect of siblings (number, age, sex) on literacy and numeracy skills. To the best of our knowledge, this is the first time that such a wide range of siblings' characteristics are studied in relation to early school achievement. This is especially important as the first elementary school years lay the foundation for subsequent academic progress.

<u>More specifically, we aim to test the following predictions:</u>

1. There is an overall negative association between both the number of older and younger siblings and school achievement, as predicted by the confluence and resource dilution models.
2. There is an overall negative association between the number of both sisters and brothers and school achievement, as predicted by the confluence and resource dilution models.
3. The association between the number of siblings and school achievement is more negative for younger than older siblings, as predicted by the confluence model.
4. Literacy achievement should be more negatively associated with the number of brothers than with the number of sisters, while numeracy achievement should be more negatively associated with the number of sisters than brothers, as predicted by the confluence model.

5. The language spoken by the parents may moderate the association between the number of siblings and school achievement (less negative number of siblings' effect when the parents do not speak French).
6. The parents' income may moderate the association between the number of siblings and school achievement (post-hoc hypothesis motivated by the results of analysis 5 and predicted by the resource dilution model) (stronger negative effect of the number of siblings' when the parents have lower income).
7. The association between the number of siblings and the school achievement scores is partly mediated by parental investment (one aspect of parental resources), as predicted by the resource dilution model (negative correlation between the number of siblings and parental interactions, and positive correlation between parental interactions and school achievement scores).

Material and methods

Study design

We used data from two datasets of children, the Elfe cohort, and the DEPP 2011 panel, enabling us to have a larger sample size.

Elfe cohort

ELFE (*Étude Longitudinale Française depuis l'Enfance*, French Longitudinal Study since Childhood) is a nationwide French longitudinal birth cohort launched in 2011 (Charles et al., 2019). The study and each wave of data collection were approved by either the national advisory committee on information processing in health research (CCTIRS) or the National Statistics Council and the Committee for the protection of persons engaged in research

(CPP). Written informed consent was obtained from parents both for themselves and for the child at inclusion.

DEPP panel

The 2011 Panel of the Direction de l'Evaluation, la Prospective et la Performance (DEPP) of the French Ministry of National Education and Youth is a study following French children from first until fifth grade. The sample was constituted in such a way as to be representative of the French population of middle school students, with a slight over-representation of students in schools belonging to schools in disadvantaged areas. Participation was compulsory as part of national statistical collection and approved by the National Council for Statistical Information (CNIS).

Participants

Elfe cohort

A total of 18,329 newborns were included in the cohort, with a participation rate of 51% at birth, and with additional attrition over the years. The analysis is restricted to children with enough data to create the achievement scores (as detailed in the next section) and if they were in the grade corresponding to their age (second year of kindergarten at 4-5 years, and first grade at 6-7 years). At 4-5 years, 5071 children met this criterion for numeracy scores and 5033 for literacy scores; at 6-7 years, 4415 children met it for numeracy and 4406 for literacy scores.

DEPP panel

15,188 children were recruited at the beginning of first grade with an attrition of maximum 88% in fifth grade. The analysis is restricted to children with enough data to create the achievement score (see next section), and who were not placed in social care. This corresponds to 10,094 children for the analysis of numeracy and 10,088 for the analysis of literacy in first grade, 9,551 children for the analysis of numeracy, and 9,555 for the analysis of literacy in fifth grade.

Measures

The Elfe cohort

Sibship composition. The number of older and younger sisters and brothers, coded as 0, 1, 2, 3 or more, as reported by the parents in the questionnaires, at 3 and 5 years.

School achievement. School data collected in spring of preschool and 1st grade (at age 4-5 and 6-7), for numeracy (based on 26 questions in preschool, and on 32 in 1st grade) and literacy (based on 35 questions in preschool, and on 45 in 1st grade) (for more information see supplement S1). The tests were administered by the teacher of the child's class. Note that, given the national sampling method, there usually was only one Elfe participant per class. In 1st grade in numeracy, due to the high number of missing values for some of the exercises that were associated with low performance on other items, we assumed that these missing values reflected the fact that the children were unable to answer a question that was too difficult at the time and recoded them accordingly.

For each age, a literacy score was computed when at least 10 questions were answered. The score was computed by averaging responses (0: incorrect response, 1: correct response), within a category (example for literacy: comprehension, reading…), and then averaging them and z-scoring the result.

The same method was used for numeracy score.

Cronbach's alpha for questions within each score were all equal to or above 0.8, indicating good reliability (preschool numeracy: 0.80, preschool literacy: 0.84, first grade numeracy: 0.91, first grade literacy: 0.84).

This means that each child has between 1 and 4 measures of school achievement (preschool numeracy, preschool literacy, 1st grade numeracy, 1st grade literacy).

Mediator: parental interactions. We created a score of parental interactions between parents and the target child, as a mean of the z-scored various variables measuring parental investment (as reported by the parents in the questionnaires, at 3 and 5 years, see supplement S2 for details), when at least one was available, coded such that a higher value means a higher parental investment. As suggested by a factor analysis, 2 separate scores were computed, one score for parent-child interactions (including activities done with the child: painting, playing games, reading stories…), and one score for parents' participation in school life (including information about participation in school related meetings, or coming to outdoor school trips…).

Language spoken at home. Language spoken by the parents (as reported by the parents in the questionnaires) was coded as either both parents mostly speak French, one mostly speaks French and one mostly speaks a Foreign language, or both parents mostly speak a Foreign language.

Adjustment variables. In order to control for potentially confounding factors, our models were adjusted on the following variables, that were also available in the Depp panel: Sex of the target child, Parental education (highest diploma), mean Household income (k€/month at 3 and 5 years, log scale). We also adjust our analyses for the grade of each child's achievement score.

In the preregistered analyses that are reported in the supplements S10-17, and that did not include Depp panel children, control variables also included Alcohol during pregnancy (units/week), Tobacco during pregnancy (%), Birth weight (kg), Gestational age (weeks), Maternal age at delivery (years), Paternal age at delivery (years) and Breastfeeding initiation (y/n).

After a visual inspection of the monthly income of the family at 3.5 and 5.5 years, some values were outliers at one time point and were very different at the other time point, so we assumed that they were entry errors. We thus discarded values of monthly income at 3.5 years when the value was larger than 4 times the standard deviation. We used the same cutoff for the monthly income at 5.5 years. These missing values were then imputed like all other missing values of the covariates.

The DEPP panel

Sibship composition. The number of older and younger sisters and brothers, coded as 0, 1, 2, 3 or more, as reported by the parents in the questionnaires, in 1st grade and 5th grade.

School achievement. School data collected in September of first and in spring of fifth grade, for numeracy (based on 18 questions in 1st grade, and on 50 in 5th grade) and literacy (based on 67 questions in 1st grade, and on 244 in 5th grade) (for more information see supplement S3). The tests were administered by the teacher, with all of the students of the class participating.

The literacy score was computed for children with a value for at least one category, by averaging scaled categories when at least one category was available. The results were then z-scored. The same method was used for the numeracy score.

Cronbach's alpha could not be calculated because scores were already calculated in the data that we obtained, and no information was provided about reliability.

This means that each child has between 1 and 4 measures of school achievement (1st grade numeracy, 1st grade literacy, 5th grade numeracy, 5th grade literacy).

Mediator: parental interactions. We created a score of parental interactions between parents and the target child (as reported by the parents in the questionnaires, see supplement S4 for details), as a mean of various variables measuring parental investment, when at least one was available, coded such that a high value meant a higher parental investment. As before, 2 separate scores were computed, one score for parent-child interactions (including activities done with the child: painting, playing games, reading stories…), and one score for parent-child school-related activities (including assistance in school work, checking the backpack…).

Language spoken at home. Language spoken by the parents (as reported by the parents in the questionnaires) was coded as either both parents mostly speak French, one mostly speaks French and one mostly speaks a Foreign language, or both parents mostly speak a Foreign language.

Adjustment variables. In order to control for potentially confounding factors, our models were adjusted on the following variables: sex of the child, parental education (highest diploma), and mean household income (k€/month in 1st and 5th grade, log scale). We also adjust our analyses for the grade of each child's achievement score.

Statistical analyses

Software and packages

All analyses were performed using RStudio (Version 2022.02.0+443) and R (Version 4.0.3). We used the *lme4* package (version 1.1-28) to run the linear mixed-effects regression models. Multiple imputations of the covariates were implemented using the *MICE* (Multivariate Imputation via Chained Equations) package (version 3.14.0), with 20 data sets. We pooled adjusted estimates and 95% confidence intervals.

Linear Mixed Effect Models

Contrary to what was preregistered (https://osf.io/f6mqu?view_only=60b777b6e7054a8da4d17b04d055e0c2 for the Elfe cohort and https://osf.io/uafr8/?view_only=c2205ac99a074b689c13317c1917e914 for the DEPP panel), in which we had planned to run separate regressions for each grade and for each domain (numeracy or literacy), and for the sake of simplicity and clarity, for each hypothesis, we ran a linear mixed effect model on the entire dataset instead of running 8 different linear models (for cohort (Elfe and DEPP), domain (numeracy and literacy), and grade (preschool and 1st grade for the Elfe cohort, 1st grade and 5th grade for the DEPP panel)). The identity of the child was fitted as a random intercept. The results of the preregistered analyses are provided in Tables S6-21 and although they vary across grade, domain and cohort, they overall go in the same direction as the models presented here.

For this joint analysis, the models were adjusted on the covariates available for both cohorts, i.e., grade, child sex, household income and education level of the mother and father.

Test of prediction 1. (effect of older and younger siblings on school achievement)

Model (1): $Score_i = \beta_0 + \beta_{0i} + \beta_1\ Number\_Older\_Siblings_i + \beta_2\ Number\_Younger\_Siblings_i + \beta_3\ Domain_i + \beta_4\ Grade_i + \beta_5\ Cohort_i + \beta_{6\text{-}9}\ Covariates_i + \varepsilon_i$

With i being the identity of the child, and ε the error term.

In the supplements 27 and 28, we ran two similar models with additional interaction terms, first Number_Older_Siblings x Domain and Number_Younger_Siblings x Domain, second with Number_Older_Siblings x Grade and Number_Younger_Siblings x Grade. This was to check whether the results vary by domain or grade.

Test of prediction 2. (effect of sisters and brothers on school achievement)

Model (2): $Score_i = \beta_0 + \beta_{0i} + \beta_1\ Number\_Sisters_i + \beta_2\ Number\_Brothers_i + \beta_3\ Domain_i + \beta_4\ Grade_i + \beta_5\ Cohort_i + \beta_{6\text{-}9}\ Covariates_i + \varepsilon_i$

Test of prediction 3. (difference between the effects of older and younger siblings , using the same reasoning as Kalmijn & van de Werfhorst (2016))

Model (3): $Score_i = a_0 + a_{0i} + a_1\ (Number\_Older\_Siblings + Number\_Younger\_Siblings)_i + a_2\ (Number\_Older\_Siblings - Number\_Younger\_Siblings)/2_i + a_3\ Domain_i + a_4\ Grade_i + a_5\ Cohort_i + a_{6\text{-}9}\ Covariates_i + \varepsilon_i$

Indeed, this is the same model as Model (1), with $\beta_1 = a_1 + ½\, a_2$ and $\beta_2 = a_1 - ½\, a_2$. Thus, $a_2 = \beta_1 - \beta_2$ tests the difference in the effect of the number of older and of younger siblings.

Test of prediction 4. (difference between the number of brothers and sisters, separately for literacy and numeracy, since the effects are predicted to be of opposite direction, with an analogous reasoning as in the previous analysis)

Model (4a): $Score\_Literacy_i = a_0 + a_{0i} + a_1\,(Number\_Sisters + Number\_Brothers)_i + a_2\,(Number\_Sisters - Number\_Brothers)/2_{\,i} + a_3\,Grade_i + a_4\,Cohort_i + a_{5\text{-}8}\,Covariates_i + \varepsilon_i$

Model (4b): $Score\_Numeracy_i = a_0 + a_{0i} + a_1\,(Number\_Sisters + Number\_Brothers)_i + a_2\,(Number\_Sisters - Number\_Brothers)/2_{\,i} + a_3\,Grade_i + a_4\,Cohort_i + a_{5\text{-}8}\,Covariates_i + \varepsilon_i$

Test of prediction 5. (moderating effect of the primary language spoken by the parents on the association between the number of siblings and school scores)

Model (5): $Score_i = \beta_0 + \beta_{0i} + \beta_1\,Number\_Older\_Siblings_i + \beta_2\,Number\_Younger\_Siblings_i + \beta_3\,Language_i + \beta_4\,Number\_Older\_Siblings_{ic}\ x\ Language + \beta_5\,Number\_Younger\_Siblings_{ic}\ x\ Language + \beta_6\,Domain_i + \beta_7\,Grade_i + \beta_8\,Cohort_i + \beta_{9\text{-}12}\,Covariates_i + \varepsilon_i$

If β_4 or β_5 was significant, we then ranpost-hoc analyses separately for each value of the Language factor. The interacted terms (Language, Number_Younger_Siblings, Number_Older_Siblings) were centered.

Test of prediction 6 (post-hoc analysis motivated by the results of analysis 5). (moderating effect of the parents' income on the association between the number of siblings and school achievement)

Model (6): $Score_i = \beta_0 + \beta_{0i} + \beta_1\,Number\_Older\_Siblings_i + \beta_2\,Number\_Younger\_Siblings_i + \beta_3\,Income + \beta_4\,Number\_Older\_Siblings_{ic}\ x\ Income + \beta_5\,Number\_Younger\_Siblings_{ic}\ x\ Income + \beta_6\,Domain_i + \beta_7\,Grade_i + \beta_8\,Cohort_i + \beta_{9\text{-}12}\,Covariates_i + \varepsilon_i$

The interacted terms (Income, Number_Younger_Siblings, Number_Older_Siblings) were centered. If β_4 or β_5 was significant, we then ran post-hoc analyses separately for the higher and lower incomes (median split).

Mediation analyses

Test of prediction 7. In order to test whether the effect of the number of older and younger siblings was mediated by parent-child interactions and/or school involvement, we conducted mediation analyses, using the Sibel test to calculate the significance of the indirect path. The first mediation was run with the score of parent-child interactions (see Figure 1). Then, because parent's involvement in the school was measured differently in the two cohorts, we ran the second mediation analysis separately for the Elfe and DEPP samples (school involvement was a measure of the parent's participation in school life for the Elfe cohort (investment in associations…), and was a measure of the parent's school related interactions with the child (homework help…) in the Depp panel).

Inference criteria for the preregistered analyses

For the linear mixed effect models, since we tested many associations, we corrected for multiple tests. Indeed, we have 11 predictors of interest, Number_older_siblings and Number_younger_siblings in model 1, Number_sisters and Number_brothers in model 2, (Number_older_siblings - Number_younger_siblings)/2 in model 3, (Number_sisters - Number_brothers)/2 for the literacy and the numeracy analyses in model 4a and 4b, the interaction terms Number_older_siblings x Language and Number_younger_siblings x Language in model 5 and the interaction terms Number_older_siblings x Income and Number_younger_siblings x Income in model 6. Therefore, we controlled for the false discovery rate using the Benjamini-Hochberg procedure.

Results

Descriptive results

Descriptive results are presented in Tables S1-4 and score distributions in Figure 2 for both cohorts at both time points. Significance tests of the different hypotheses, controlling for false discovery rate (Benjamini-Hochberg procedure, Benjamini & Hochberg, 1995), are presented in Table S5. All the results significant at the 5% threshold were also significant after controlling for false discovery rate.

Figure S1 shows the distributions of the number of older and younger siblings in each grade and cohort.

As can be seen in Figure 2, most of the distributions are left-skewed, particularly so for numeracy scores, reflecting a choice of relatively easy tests for most students (skewness coefficients ranged from -0.7 to -0.4 for literacy and from -1.2 to -0.2 for numeracy). The correlations between literacy and numeracy scores with each cohort and grade all ranged between 0.51 and 0.66.

Model 1. We found a negative association between the number of older siblings and achievement scores, with each additional older sibling associated with a decrease of 8.7% of an achievement score standard deviation (β=-0.087, SE=0.006, p<0.001). Similarly, we found a negative association as well between the number of younger siblings and the achievement score, with one additional younger sibling being correlated with a decrease of 4.1% of an achievement score standard deviation (β=-0.041, SE=0.007, p<0.001). See Figure 3 and Table S22.

The results of model 1 with Domain and Grade interactions are reported in Tables S23 and S24. To sum up, we found that the relation between the number of older siblings and achievement scores was more negative for literacy than for numeracy (β=0.020, SE=0.006, p=0.002), while there was no significant difference for younger siblings' number (β=-0.013, SE=0.007, p=0.08). We found that the relation between the number of older siblings and achievement scores was more negative when grade increased (both ps<0.02). The relation between the number of younger siblings and achievement scores was more negative in 1st grade than in 5th grade (β=0.031, SE=0.009, p<0.001), but no difference was found between preschool and 1st grade (β=0.019, SE=0.022, p=0.39). The plot for model 1 with the Domain interaction is presented in Figure S2.

Model 2. We found a negative association between the number of sisters and the achievement score, with each additional sister associated with a decrease of 7.5% of the achievement score standard deviation (β=-0.075, SE=0.007, p<0.001). Similarly, we found a negative association as well between the number of brothers and the achievement score, with one additional brother being correlated with a decrease of 6.1% of a school score standard deviation (β=-0.061, SE=0.007, p<0.001). See Table S25.

Model 3. The term (Number_Older_Siblings- Number_Younger_Siblings)/2 was significantly negative (β=-0.046, SE=0.008, p<0.001), meaning that there was a significant difference between the effect of the number of older and younger siblings. More specifically, it meant that the effect of the older siblings was significantly more negative than the effect of the younger siblings. See Table S26.

Model 4a. The term (Number_Sisters- Number_Brothers)/2 was not significant (β=-0.012, SE=0.010, p=0.25), which means that we found no significant difference between the effect of the number of sisters and brothers in literacy. See Table S27.

Model 4b. The term (Number_Sisters- Number_Brothers)/2 was not significant (β=-0.017, SE=0.010, p=0.080), which means that we found no significant difference between the effect of the number of sisters and brothers in numeracy. See Table S28.

Model 5. While hypothesis 5 predicted a relation between the number of siblings and school scores to be less negative in non-French speaking families, we found no significant interaction between the number of older siblings and the language spoken at home (β=-0.008, SE=0.016, p=0.62). Again, contrary to hypothesis 5, we found no significant interaction between the number of younger siblings and the language spoken at home (β=-0.013, SE=0.016, p=0.41). The main effect of the language spoken at home was significant (β=-0.171, SE=0.018, p<0.001), showing a negative effect of foreign language, so was the main effect of the number of older siblings (β=-0.085, SE=0.007, p=<0.001) and the main effect of the number of younger siblings (β=-0.036, SE=0.007, p<0.001). See Figure 4 and Table S29.

Model 6. Since the previous interaction terms were not statistically significant, this led to an additional hypothesis, that maybe parent-child interactions are of smaller importance for school achievement, and that material resources matter more. Thus, this analysis investigates to what extent the parents' income moderates the relation between the number of siblings and school achievement

We found a significant interaction between the number of older siblings and the parent's income (β=0.079, SE=0.014, $p<0.001$) as well as between the number of younger siblings and the parent's income (β=0.136, SE=0.014, $p<0.001$). The main effect of parents' income was significant (β=0.382, SE=0.015, $p<0.001$), so was the main effect of the number of older (β=-0.077, SE=0.007, $p<0.001$) and younger (β=-0.022, SE=0.007, p=0.002) siblings. See Figure 5 (income was a continuous variable in the analyses but was dichotomized in the plot (median split) for better data visualization) and Table S30.

After separating the sample by higher and lower income (median split) we found that in the lower incomes, the association between the achievement score and the number of older siblings was significantly negative (β=-0.095, SE=0.009, $p<0.001$), as for the number of younger siblings (β=-0.048, SE=0.009, $p<0.001$). In the higher incomes, the associations were weaker: the association between the achievement score and the number of older siblings was significantly negative (β=-0.049, SE=0.010, $p<0.001$), and the association with the number of younger siblings was not significant anymore (β=0.002, SE=0.011, p=0.83). See Tables S31-S32.

Mediation analyses

We conducted the mediation analyses using the Sibel test to calculate the significance of the indirect path. The indirect path for the effect of the number of older siblings on score through parental interactions was -0.006 (95%CI [-0.008, -0.005], $p<0.001$), thus the parental interactions score mediated 7.0% of the negative effect of the number of older siblings on achievement scores. The indirect path for the effect of the number of younger siblings on score through parental interactions was -0.002 (95%CI [-0.003, -0.001], $p<0.001$), thus the parental interactions score mediated 4.5% of the negative effect of the number of younger siblings on achievement scores.

Because questionnaires didn't measure exactly the same school involvement in our two samples, we ran the mediation analysis separately for the Elfe cohort and the DEPP panel, using all the questions available in each cohort. In the Elfe cohort, the score reflecting parent's participation in school life did not significantly mediate the effect of older nor younger siblings on school scores ($p>0.05$ for older and younger siblings). In the DEPP panel, the score reflecting parents' school-related interactions with the child (homework help…) showed a significant negative mediation (for older siblings, 0.006, 95%CI [0.004, 0.007], $p<0.001$, -5.6% mediated, for younger siblings, 0.001, 95%CI [0.0004, 0.0018], $p=0.002$, -3.1% mediated).

The complete results of the mediation models are reported in Tables S33-35.

Discussion

The main objective of this study was to test the various predictions made by the confluence and the resource-dilution models, by investigating the effect of siblings (number, age, sex) on school achievement, at a later developmental stage than previous studies.

Although there were variations across grades, domains, and samples, we found that each additional older sibling was associated on average with a decrease of 8.7% SD of academic achievement scores, controlling for socio-economic status. Each additional younger sibling was associated on average with a decrease of 4.1 % SD of achievement scores. Each additional sister was associated with a decrease of 7.5 % SD, and each additional brother was associated with a decrease of 6.1% SD of achievement scores. Thus, regardless of the characteristics of the siblings that we focus on, having more was always negatively associated with school achievement, and this effect was not confounded by the covariates. The covariates included socioeconomic factors (education of both parents and income) and the sex of the child of interest, as well as the grade, domain and cohort.

These effects are in line with the well-known negative effect of the overall number of siblings and with the resource dilution model (Breland, 1974; Havron et al., 2019; Mercy & Steelman, 1982; Steelman & Mercy, 1983; Wolter, 2003). However, our analyses do not support the confluence model which states that the intellectual ability of a child depends on the average intellectual ability of the family: as younger children have lower intellectual abilities, they should have a more negative impact than older children. In this study, the association between school achievement and the number of younger siblings was quantitatively less negative than with the number of older siblings, thus going in the opposite direction as predicted by the model, but in the direction consistent with the resource dilution model. In addition, the results of model 4 also fail to support the confluence model. Indeed, since boys tend to have higher mathematics achievement than girls, and girls higher language achievement than boys, the confluence model would predict that in numeracy, the brothers would bring the average numeracy score of the family up, as would the sisters in language. Yet predictions of less negative associations between the number of brothers and numeracy scores, and between the number of sisters and literacy scores, were not confirmed.

In addition, we found that, in line with the resource-dilution hypothesis, parental interactions partly mediated the negative effect of the number of siblings on achievement scores. We used parental interactions with the target child as one measure of parental resources allocated to the child. In the resource dilution model, resources also encompass financial resources. However, in this study, it was not possible to estimate the share of global financial resources allocated to the target child. The mediation that was found was small (7.0 and 4.5% of the effect), much smaller than the 50% mediation that was found at 2 years of age in the Elfe cohort between number of siblings and vocabulary development (Gurgand et al., 2022). Various hypotheses may be proposed to explain the small mediation. First, our measures of parental interactions have limited detail and precision, as parents were only asked about specific activities that they engage with the child (going to the museum, reading stories…), but not more generally about how much they interact with their children. Having more siblings may decreases more the frequency of informal talk than of formal activities, which can easily be shared between siblings and thus not be as exclusive to one child as informal talk would be. In addition, the measures of parental activities were only on a scale of 2 or 3 (yes/no in the Elfe cohort, never/sometimes/often in the DEPP Panel), thus leading to imprecise and noisy measures.

When investigating the moderating effect of the language spoken by the parents on the relation between the number of siblings and the achievement scores, we found no significant difference between French and foreign speaking families, contrary to previous studies at an earlier age (Bridges & Hoff, 2012; Gurgand et al., 2022; Tsinivits & Unsworth, 2021). This could be due to school-aged children benefiting from external language exposure (classmates, teachers…) or already being fluent in French, thus minimizing the impact of siblings at home. Moreover, in this later developmental stage, parental financial resources may matter more than parent-child or sibling-child interactions, for example in the form of private teachers or buying of school-related books. And indeed, we found that the number of siblings was less negatively related to achievement scores in higher-income families. This underscores the need for strategies supporting children from larger families, especially those from lower socio-economic backgrounds.

It is important to note that the effects that we find are small (less than 10% of a SD), so although they are consistent with the scientific literature, siblings can only account for a small share of the variability in school achievement.

A key limitation is the challenge in distinguishing correlation from causation: indeed, parents with higher intellectual abilities may at the same time have fewer children and impart a genetic advantage to their children (since cognitive traits have been shown to have quite high levels of heritability, between 20 and 80% (Plomin, 1994; Polderman et al., 2015)). Parents with fewer children may also be more invested in their children's development and school achievement, and thus that it is not directly the number of siblings that impacts the achievement scores. The best way to disentangle causation from correlation would be to run a randomized controlled trial of the number of children, but this is impossible for obvious ethical reasons. Another way is to add covariates such as socio-economic status to help controlling for confounding factors, and this is what we do in the analyses. However, bias may persist if the measures that we have are not perfect, or if other confounding variables exist, which is very probably the case. Using a dynamic modelling approach, Guo & VanWey (1999) tried to examine the causal interpretation of the negative effect of family size on intellectual development, but failed to find such an effect. This suggests that genetic and/or environmental effects may partially confound these much-studied relations. Nethertheless, in our analyses, we did control for the most obvious environmental confound (socio-economic status, as measured by parents' education and income). In case the number of children is associated with parental characteristics that are not captured by socioeconomic status, future studies may want to also account for genetic confounding, for example by adjusting analyses on an Educational attainment polygenic score.

Finally, most of the articles that we cited in this work studied the effect of siblings in Western, Educated, Industrialized, Rich, and Democratic (WEIRD) countries, and thus this effect might not be generalizable to other countries. However, given the moderating effect of income, we could predict that the number of sibling effect might be stronger in developing countries, where financial resources to be divided between children are scarcer. Thus, future research should focus on the sibship effects in non-WEIRD countries. And even within WEIRD countries, the results may vary: a study comparing 20 OECD countries showed that countries with stronger public support for childcare, universal child benefits, and larger public expenditures on education and family showed a much less negative effect of growing up in large families (Park, 2008). When compared to other WEIRD countries, France falls within the mid-range or slightly above average on most indicators. This suggests a moderate level of public investment in education and family support, along with an intermediate position in terms of the availability of childcare and universal child benefits.

Conclusion

To conclude, our results support the resource dilution model and do not support the confluence model. Parental interactions with their child mediated in (a small) part the negative effect of the number of younger and older siblings on the achievement scores. The associations between the number of older and younger siblings and achievement scores seem to be moderated by the household’s income but not by the parent’s main language.

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Figure 1

Mediation Model for Parental Interactions.

The same model is used for school involvement. Each relation is adjusted on the covariates described in the methods.

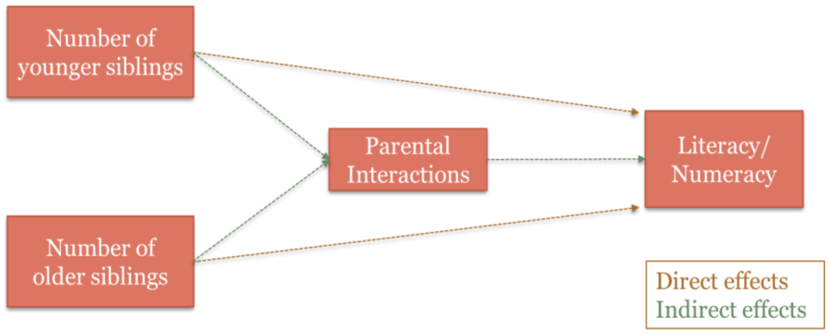


Figure 2

Distribution of Literacy and Numeracy Scores in Both Grades in the Elfe and DEPP Samples

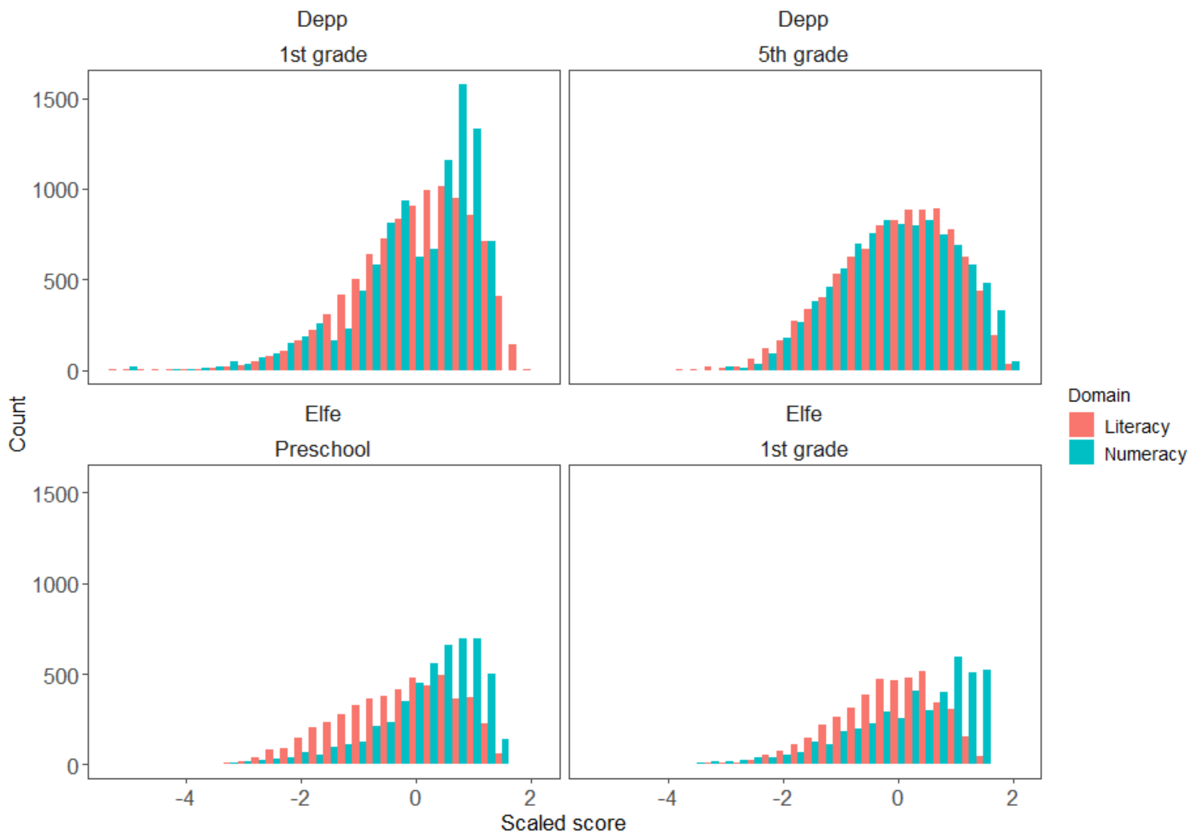
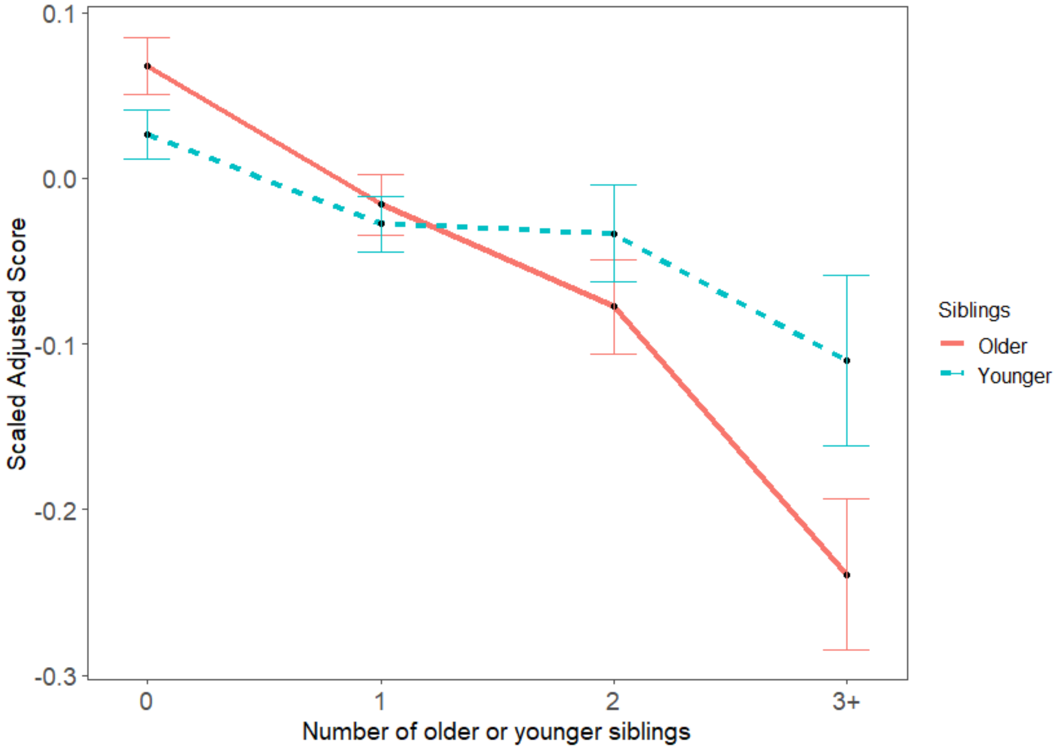


Figure 3

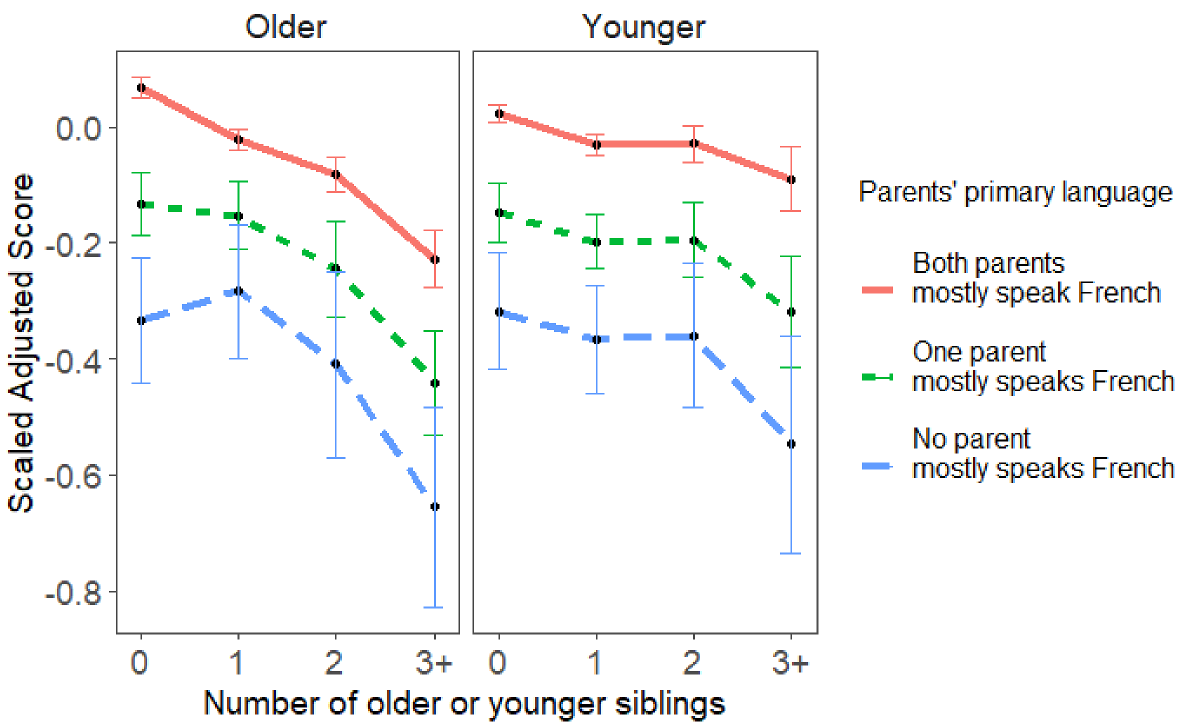
Achievement Score as a Function of the Number of Older and Younger Siblings.



Note. The achievement score is adjusted for the covariates (domain, grade, cohort, income, education of the father and of the mother, sex of the child, and number of younger siblings for the “Older” line, and number of older siblings for the “Younger” line). Error bars represent 95% confidence intervals.

Figure 4.

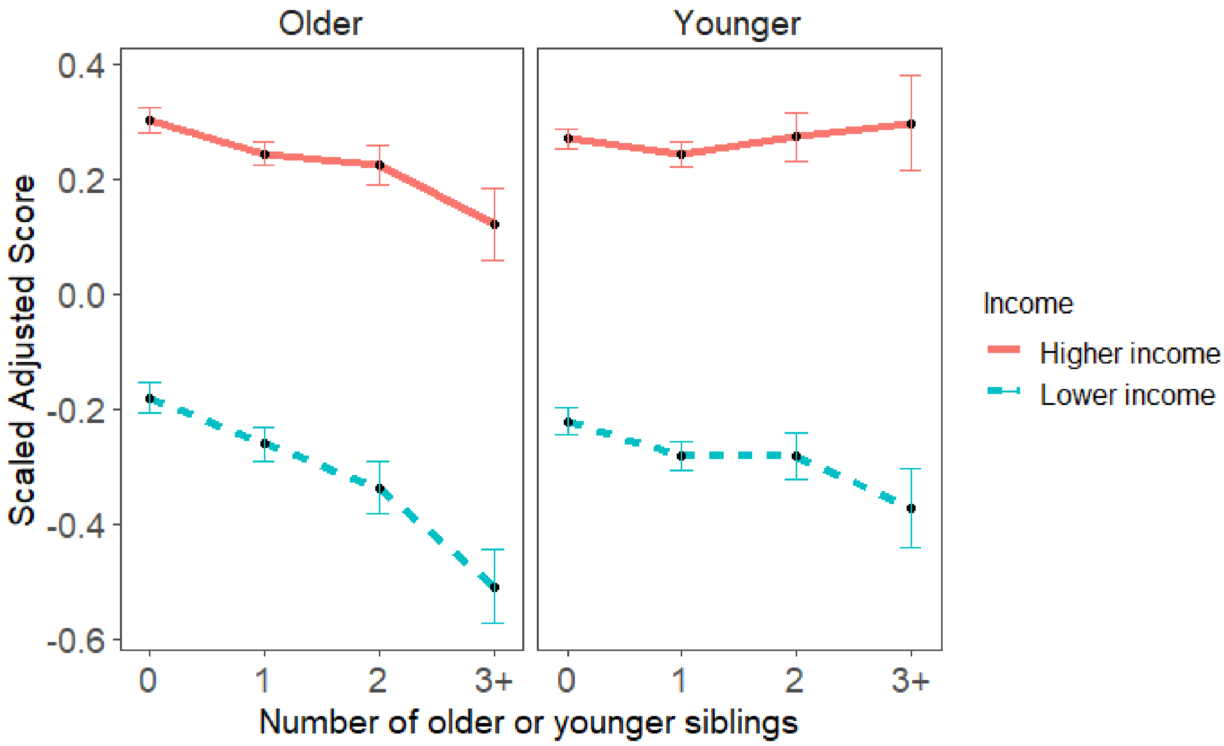
Achievement Score as a Function of the Number of Older and Younger Siblings and of the Primary Language Spoken by the Parents.



Note. The achievement score is adjusted for the covariates (domain, grade, cohort, income, education of the father and of the mother, sex of the child, and number of younger siblings for the "Older" lines, and number of older siblings for the "Younger" lines). Error bars represent 95% confidence intervals.

Figure 5

Achievement Score as a Function of the Number of Older and Younger Siblings and of the Parents' Income (Median Split).



Note. The achievement score is adjusted for the covariates (domain, grade, cohort, education of the father and of the mother, sex of the child, and number of younger siblings for the "Older" lines, and number of older siblings for the "Younger" lines). Error bars represent 95% confidence intervals.