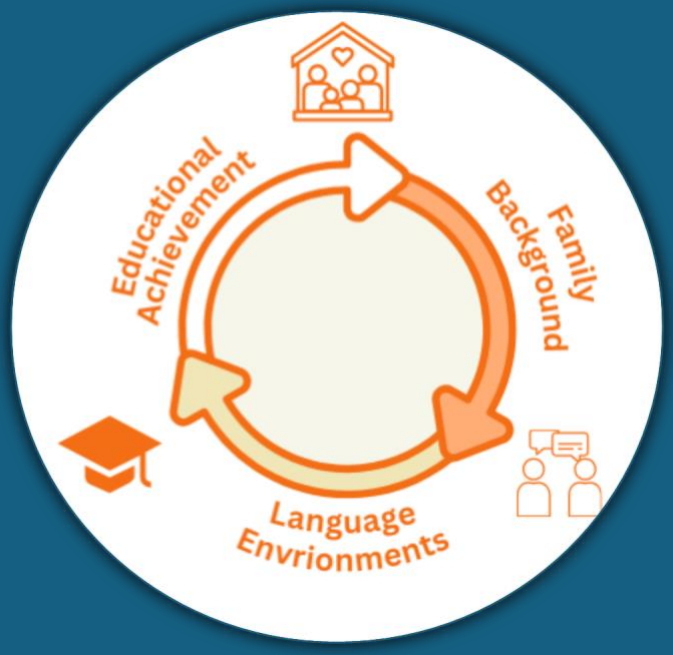
The role of mothers' speech in the transmission of family background inequality



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Executive Summary

Introduction

Children from well-resourced families achieve, on average, higher school grades and gain more educational qualifications than those from under-resourced family backgrounds. The association between family background and children's education-related outcomes is likely driven by many factors. Here, we studied the role of one specific factor: The speech that children hear from their mothers.

Mothers' speech is part of a much wider constellation of influences. Yet, it has been pointed to as a likely driver of family background inequality in education. As a result, interventions that seek to increase children's educational success have targeted mothers' speech. To ascertain the potential long-term effectiveness of such interventions (i.e., the degree of change they will likely achieve), robust, longitudinal studies are needed that test associations between mothers' speech and children's education-related outcomes beyond the early years. This is the first study to report associations between mothers' speech and children's education-related outcomes during primary and secondary school. In addition, our research is the first to explore whether genetic confounding affects the association between mothers' speech and children's education-related outcomes. We leveraged data from a large, genetically sensitive, and UK-representative family cohort study that included 1,116 families with children born in the mid-90s who were assessed from age 5 through to 18 years.

Background

Children's early life language environments. Children differ considerably in their language development. The language environments that children grow up in are strong predictors of these differences in language development. Language environments are significantly shaped by caregivers' speech, in particular the speech that parents direct at their children and the speech that children overhear from their parents. Accordingly, previous studies observed significant associations between mothers' and children's quantity and quality of speech in early childhood.

The language gap. The language environments that children experience in early life vary systematically between families as a function of their socioeconomic status (SES). SES describes the economic and social resources that are available to families relative to the resources that other families have. In their seminal work, Hart and Risley (1995) concluded that there was a '30 million word' gap between the number of words that children from low SES backgrounds hear over a three-year period compared to children from high SES

families. Mothers with greater socioeconomic resources tend to speak more often with their children, use more sophisticated vocabulary (i.e., rare words), and include a broader range of syntactic structures than mothers with fewer resources. Thus, SES-related variability in mothers' speech is thought to give rise to the 'word gap' during the early years that in turn leads to differences in children's language development. However, the notion of the 'word gap' has been criticised for deficit framing, as it risks portraying the language practices of lower SES families as inherently deficient rather than different.

Language ability in education. Language ability is a basic skill that underpins learning, including reasoning, cognition, and literacy, as well as of educational achievement itself (i.e., school performance). Children with greater language abilities at school entry are likely to outperform children with weaker language in learning progress and educational achievement, even when they are taught by the same teachers in the same classrooms on the same curriculum. These early performance differences can magnify across school years and education stages, like a snowball effect. An initially small difference in language ability builds on itself and can produce lasting inequities in education-related outcomes. It follows that SES-related disadvantages in language development likely forecast long-term differences in educational achievement and in the attainment of educational qualifications.

Research Questions

With studies presented in this report, we sought to overcome three limitations of previous research on the role of mothers' speech in the transmission of family background inequality in education. First, associations between mothers' speech and children's educational outcomes were not longitudinally studied beyond the early years – that is, not throughout the primary and secondary school years. Second, children's early life language environments were often only assessed in small samples that were not population-representative and afforded low statistical power. Third, associations between mothers' and children's language are genetically influenced, because mothers and their biological children share genes that affect language. Yet, previous studies in this area did not control for genetic confounding.

We capitalised on a large, genetically sensitive family cohort study called E-Risk (https://eriskstudy.com). The families in the cohort were identified with great care to represent the full range of socioeconomic conditions of England and Wales. From the full UK register of twin births, families were stratified and selected to mirror the UK population on key variables, including geographic region, urban versus rural residence, socioeconomic deprivation, and family structure (i.e., single-parent versus two-parent households). The

representativeness of E-Risk of the wider UK population is reflected, for example, by E-Risk families' residential addresses that were matched to the United Kingdom's Index of Multiple Deprivation. The distribution showed that 25% of the families live in Britain's wealthiest and 25% in the poorest areas. E-Risk has maintained high representativeness since its inception, due to stratified sampling, oversampling of families from high-risk contexts, and exceptionally high retention (i.e., low attrition and loss due to longitudinal follow-up).

We addressed four principal research questions:

1. Does family background predict mothers' speech?
2. Does mothers' speech predict their children's education-related outcomes across school years?
3. Does mothers' speech mediate the association between family background and children's education-related outcomes?
4. To what extent is the role of mothers' speech in the transmission of family background inequality in education influenced by genetics?

Methods

E-Risk recruited 1,116 families with twins born between 1994 and 1996 across England and Wales. For 894 families, interview recordings were available of mothers' naturalistic speech, meaning that mothers spoke freely about their twins and their speech was recorded. These interviews were recorded by trained health researchers during visits to the families' homes when the twins were 5 years old. Interviews lasted at least 10 minutes, resulting cumulatively in 336 hours of recordings and an overall corpus of 2.5 million words of mothers' speech. From the interview transcripts, we extracted for each mother their vocabulary sophistication (% of rare words used in speech), lexical diversity (range of word types used in speech), and grammatical complexity (e.g., mean length of utterance). Between the twins' ages of 5 and 18 years, their learning skills – cognition and literacy – and their educational achievement were assessed using psychometric tests and teacher ratings. Learning skills refer to the basic capacities for processing information and acquiring knowledge, such as reading and writing, while educational achievement reflects the extent to which these capacities are realised within formal education. Family background was inferred from mothers' educational attainment, occupation and household income. Mothers' and children's genetic propensities for language and educational attainment were operationalised by polygenic scores that aggregate DNA variants.

Findings

Research Question 1. Does family background predict mothers' speech?

We found that mothers' education, occupation, and household income significantly predicted mothers' vocabulary sophistication, with small effect sizes. Small effects are meaningful: they are consistent and non-random, but far from large enough to be the primary determinants of mothers' vocabulary sophistication. Weaker and less consistent associations were observed between family background indicators and mothers' lexical diversity and grammar. The findings suggested mothers' SES is reflected in their vocabulary sophistication but not in other characteristics of mothers' speech. Thus, mothers' vocabulary sophistication may be a pathway in the transmission of family background inequality in education.

Research Question 2. Does mothers' speech predict their children's education-related outcomes across school years?

We investigated the long-term influence of mothers' speech on children's education-related outcomes. We found that the sophistication of mothers' vocabulary significantly predicted children's cognition, literacy, and educational achievement from age 5 through 18 years. Mothers' other speech characteristics – lexical diversity and grammatical complexity – were not significantly related to children's education-related outcomes. Our findings suggested that mothers' vocabulary sophistication plays a unique role in explaining children's differences in education-related outcomes. This result lends further support to the hypothesis that mothers' vocabulary sophistication is a distinct, meaningful pathway in the transmission of family background inequality in education.

Research Question 3. Does mothers' speech mediate the association between family background and children's education-related outcomes?

We tested whether mothers' vocabulary sophistication mediated the association between family background and children's education-related outcomes. We found this was the case: Mothers' vocabulary sophistication mediated the associations between family background (i.e., mothers' education and household income) and children's cognition and literacy. However, mothers' vocabulary sophistication did not mediate the association between family background and children's educational achievement (i.e., teacher ratings of school performance). These findings suggest for one that family background inequality that is transmitted through mothers' speech likely manifests in children's learning skills, like reasoning and reading abilities, rather than in educational achievement. For the other, they

substantiate once more that mothers' vocabulary sophistication contributes to the transmission of family background inequality in education. That said, mothers' speech emerged as one meaningful factor among many, but not as a primary driver.

Research Question 4. To what extent is the role of mothers' speech in the transmission of family background inequality in education influenced by genetics?

We tested the influence of genetics on the associations between mothers' educational attainment, mothers' speech, and children's educational attainment. We used polygenic scores to capture mothers' and children's genetic propensities for speech and education-related outcomes. Polygenic scores, which aggregate DNA variants, offer a probabilistic estimate of a person's genotype to become expressed as a phenotypic trait, like educational achievement. That is, genetic propensities refer to a person's tendencies or preferences for certain behaviours that are associated with inherited DNA differences. We found that polygenic scores predicted mothers' educational attainment, mothers' speech, and children's educational attainment. This finding suggested that genetics influence the role of mothers' speech in the transmission of family background inequality in education. In further analyses, we partitioned the association between mothers' and children's educational attainment into pathways that likely reflect causal versus non-causal influences. Genetic confounding occurs when a putatively environmental factor, like mothers' speech, become associated with a developmental outcome, like children's education, because mothers' and children share genes, rather than because mothers' speech has an independent effect. Genetic confounding can mimic environmental causes but implies non-causal influences. Genetic nurture describes environmental influences on children's development that follow from their mothers' genetic propensities but are independent of children's genetic differences (i.e., DNA variants that mothers did not pass on to their children but that influence how mothers raise their children). Genetic nurture effects are interpreted as causal because they are environmentally mediated. Finally, we discerned nurture effects in our analyses that were independent of mothers' and children's genetic propensities. These nurture effects are thought to represent causal environmental influences. In our analyses, we found evidence for significant genetic confounding, genetic nurture, and nurture effects. These findings underscore the importance of discerning the gene-environment interplay when trying to understand how family background influences children's development. Furthermore, we found that mothers' vocabulary sophistication explained about 3% of the variance in family background inequality in education via genetic nurture and nurture, respectively. While these transmission effects are small, they likely reflect causal effects of mothers' vocabulary

sophistication on the intergenerational transmission of educational attainment. We therefore conclude that mothers' vocabulary sophistication is an effective target for interventions that seek to improve children's education-related outcomes. That said, such interventions are likely to only achieve modest change, because of the small effect size: Mothers' vocabulary sophistication matters, but its influence is limited and only explains a small share of the differences observed. We also caution that further research is needed to assess whether mothers' vocabulary sophistication is modifiable before resources are invested in the development and implementation of related interventions.

Limitations

Our research has many strengths but must be interpreted with three key limitations in mind. First, we focused on mothers' adult-directed speech, including their vocabulary sophistication, lexical diversity, and grammatical complexity. Other aspects of mothers' speech and children's language environments were not assessed, including mothers' child-directed speech and the speech that children experience from other caregivers like fathers, peers, and teachers. Thus, our findings allow conclusions about only one of many language experiences that are potentially relevant for children's education-related outcomes. Second, identifying the causes that underpin associations between parenting and child development is difficult, because parents and children cannot be randomly allocated to each other, as true experiments require. Here, we analysed observational data from a well-powered, population-representative family cohort study that was genetically sensitive. While these data help strengthen causal inferences, causality cannot be proven. Third, our sample included families with twins, who may differ in their development from children of singleton births. To address this issue, we compared twins' and their younger siblings' (singleton births) language development from age 2 through 7 years, in a subsample of the Twins Development Study (TEDS). We found that twins were delayed in language development relative to their younger singleton siblings from age 2 through 4 years. However, by the age of 7 years, when children had started formal schooling, differences in language development between twins and their singleton siblings were no longer significant. Thus, we conclude that our findings about the role of mothers' speech for children's education-related outcomes based on analyses of a twin sample are generalisable to singleton birth children.

Conclusion

In a genetically sensitive, UK-population representative family cohort study, we found that an important characteristic of mothers' speech – vocabulary sophistication – likely exerts causal influences on children's education-related outcomes. Yet, corresponding effect sizes were

small. By comparison, families' socioeconomic resources had more pervasive, long-term influence on children's education-related outcomes than did mothers' speech. Our findings suggest that any to-be-developed interventions that target mothers' vocabulary sophistication to improve children's education-related outcomes will likely produce modest change in these outcomes. Greater impact could be achieved if the socioeconomic inequalities were ameliorated that occur between the families that children are raised in.

Executive summary word count: 2,294 words.

Glossary of genetic terms

Term	Definition
Genetic Confounding	Genetic confounding occurs when genetic factors influence both an environmental characteristic (e.g., mothers' speech) and an outcome (e.g., a child's education-related outcomes). The association between environment and outcome may be due to shared genetics between parent and child; these shared genetic can create the false impression of a causal environmental effect.
Adoption Study Design	Adopted children share genes with their biological, but not with their adoptive parents. Conversely, adopted children share environments with their adoptive, but not with their environment biological parents. Comparing resemblances of children with their biological relative to their adoptive parents helps discerning genetic (similarities with biological parents) and environmental effects (similarities with adoptive parents).
Twin study design	The classic twin study design relies on comparisons of the phenotypic resemblance between identical (monozygotic) and fraternal (dizygotic) twins to estimate additive genetic, shared, and non-shared environmental influences on a trait. Monozygotic twins share 100% of their genome, while dizygotic twins share on average 50% of their segregating genetic variants; they resemble each other genetically as much as other fraternal siblings. If monozygotic twins are more similar to each other in a given phenotypic trait than dizygotic twins, we can conclude that genetic factors influence people's differences in that trait.
Heritability	Heritability is the proportion of differences in a phenotypic trait (i.e., phenotypic variation) that can be attributed to genetic differences between people in a given population at a given time. Genetic and environmental influences exist in a concerted balance: Individual differences in all traits are heritable, but no trait is 100% heritable.
Phenotype	Phenotype refers to an individual's observable or expressed traits. People's phenotypic differences result from the

	interplay of their genes (genotype) and their environments. In GWAS (below), the behavioural or psychological trait for which DNA variants' associations are tested is referred to as target phenotype.
Genome	The genome is the complete set of genetic information of an organism.
Genotype	A genotype is a scoring of the type of variant present at a given location (i.e., a locus) in the genome, represented for example by the DNA sequence at a specific location, such as CC, CT, TT. Some genotypes contribute to an individual's phenotype or observable traits.
Polygenic scores	Polygenic scores are aggregates of the SNPs (see below) that are spread across the genome and were identified in a GWAS to be associated with a target phenotype. The SNPs that are included in polygenic scores are typically weighted by the effect size of their association in the GWAS; this information is contained in the GWAS summary statistics. Polygenic scores can be computed in any independent (validation) sample, for whom genotypes are available, to index a person's genetic propensity for a target phenotype.
Single-nucleotide polymorphisms (SNPs)	A SNP refers to a base-pair difference in the genome, which occurs at one location of the genome (i.e., single nucleotide), independent of base-pair differences in other locations, and presents in many different (i.e., poly) versions (i.e., morphisms). SNPs are the smallest unit of genetic variation between people. A base-pair is a 'rung in the DNA ladder' that bonds together two bases (i.e., Adenine with Thymine, and Guanine with Cytosine). The human genome includes about three billion base-pairs, and SNPs occur about one in every 300 base-pairs (i.e., there are about ten million SNPs within the human genome).
Genome-wide association studies (GWAS)	GWAS test associations between SNPs across the genome and individual differences in a phenotypic trait, also known as a target phenotype (e.g., years spent in full-time education), in a discovery sample. GWAS produce summary statistics of

	the strength with which each SNP is associated with the target phenotype in the GWAS discovery sample.
Genetic Propensity	An individual's genetic propensity suggests behavioural, cognitive, and affective tendencies or preferences for a particular trait given their inherited DNA differences. These reflect probabilistic rather than deterministic estimates.
Causality and prediction	In statistics, causality is an inference made between two variables, where variable X causes variable Y. Prediction describes the associations between two variables, whereby variable X predicts the occurrence of variable Y, for example when X occurred in time before Y. Observing that variable X predicts variable Y does not imply that X causes Y. In the context of genomic research, polygenic scores are said to predict rather than cause phenotypic differences.

The role of mothers' speech in the transmission of family background inequality