Journal of Experimental Child Psychology 238 (2024) 105779

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Longitudinal associations between parental mathematics anxiety and attitudes and young children's mathematics attainment

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ARTICLE INFO

Article history:
Received 21 April 2022
Revised 25 August 2023

Keywords:
Mathematics anxiety
Mathematics attitudes
Home number experiences
Mathematics
Home learning environment

ABSTRACT

The associations between parental mathematics anxiety and attitudes and children's mathematics attainment in early primary school were explored. Initially, parents of preschool children (M_{age} = 3;11 [years;months]) completed a questionnaire indexing parental mathematics anxiety and attitudes and the frequency of preschool home number experiences. The children completed mathematics assessments in their first year (n = 231, M_{age} = 5;2) and second year (n = 119, M_{age} = 6;3) of schooling and a mathematics anxiety questionnaire in their third year of schooling (n = 119, M_{age} = 6;7). A questionnaire indexing the frequency of primary school home number experiences was completed by 119 of the parents in their children's second year of schooling (M_{age} = 6;0). All indices of parental mathematics anxiety and attitudes predicted children's mathematics attainment in their first school year. These associations were independent of parental mathematics attainment and were not mediated by the frequency of preschool home number experiences. Furthermore, the positive association between preschool home number experiences and children's mathematics attainment was not weaker in the context of high parental mathematics anxiety or negative parental mathematics attitudes. One index of parental mathematics attitudes predicted children's mathematics attainment in their second school year, but this association was not significant when prior attainment was controlled. There was a stronger association between maternal mathematics anxiety and girls' attainment versus boys'

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https://doi.org/10.1016/j.jecp.2023.105779

attainment. Parental mathematics anxiety did not predict children's mathematics anxiety. The findings suggest that children whose parents have high mathematics anxiety or negative mathematics attitudes are more likely to have lower mathematics attainment in their first year of school. However, the mechanism underpinning this association is not yet established.

Introduction

Environmental influences early in development have an enduring association with mathematics attainment (Garon-Carrier et al., 2017); therefore, it is important to identify those aspects of children's early environment that are predictive of later mathematics attainment. The home learning environment is one environmental factor that has been identified as a potential influence on mathematics development (e.g., del Rio et al., 2017; Napoli & Purpura, 2018; Niklas & Schneider, 2014; Skwarchuk et al., 2014; Susperreguy et al., 2020, 2022). In the current study, we explored the impact of the home learning environment, focusing particularly on the role of parental mathematics anxiety and attitudes.

Parental mathematics anxiety and attitudes and children's attainment

Mathematics anxiety is a feeling of worry and tension associated with mathematics performance or anticipation of performance (Dowker et al., 2016; Hembree, 1990). Although negative mathematics attitudes are associated with mathematics anxiety (Hembree, 1990), mathematics anxiety and mathematics attitudes are not synonymous (Dowker et al., 2016). The concept of mathematics attitudes is a broader one encompassing individuals' beliefs about mathematics, including their interest, their confidence, and the value placed on mathematics (Dowker, 2021; Dowker et al., 2016).

Recent studies (summarized in Table 1) have examined the extent to which parental mathematics anxiety and attitudes predict children's mathematics attainment. Parental mathematics anxiety has been negatively associated with children's mathematics performance in preschool (Becker et al., 2022) and during middle childhood and adolescence (Casad et al., 2015; Retanal et al., 2021; Soni & Kumari, 2017). However, null associations have also been reported in kindergarten (del Rio et al., 2017) and during middle childhood (Ma et al., 2021; Vanbinst et al., 2020). This variability in findings is difficult to explain. Most significant associations have been reported in samples from Canada and the United States (Becker et al., 2022; Casad et al., 2015; Retanal et al., 2021; but see Soni & Kumari, 2017, for an association in a Taiwanese sample), whereas null associations have been reported in samples from Chile (del Rio et al., 2017), China (Ma et al., 2021), and Belgium (Vanbinst et al., 2020). It is possible that the cultural context influences the strength of the association between parental mathematics anxiety and children's attainment (Hornburg et al., 2021).

Parental mathematics attitudes have been positively associated with mathematics attainment in early primary school (del Rio et al., 2017; Skwarchuk et al., 2014; Susperreguy et al., 2020) and during middle childhood and adolescence (Soni & Kumari, 2017). However, we (Soto-Calvo et al., 2020) and others (De Keyser et al., 2020; Missall et al., 2015) have reported null associations between parental mathematics attitudes and number skills assessed during the preschool period. The association between parental mathematics attitudes and children's preschool number skills appears to be weaker than the association with school-age mathematics attainment.

In the current study, we examined the associations between parental mathematics anxiety and attitudes and children's mathematics attainment during the first years of primary schooling. These data were used to explore three potential mechanisms through which parental mathematics anxiety and mathematics attitudes may influence young children's mathematics attainment. We considered

Table 1
Summary of key studies examining the associations between parental mathematics anxiety and attitudes and children's mathematics attainment.

Study	Parents			Children			Country/ Region	Parent → Child associations
	Anxiety/Attitude	Parents/ Carers surveyed	Attainment	Age (years)	Attainment	Anxiety/ Attitude		
Missall et al. (2015)	Early math beliefs and child math beliefs	1, 94% female	No	3–5	Yes	No	USA	Parental attributes not associated with early number skills.
Susperreguy et al. (2020)	Numeracy attitudes and numeracy expectations	1, gender not specified	No	3–5	Yes	No	Chile	Parental numeracy attitudes and expectations associated with early number skills.
Becker et al. (2022)	Math anxiety	1, vast majority female	No	4–5	Yes	No	USA	Parental anxiety predicted growth in attainment.
del Rio et al. (2017)	Math anxiety and numeracy expectations	2	No	5	Yes	No	Chile	Mothers' (but not fathers') numeracy expectations predicted attainment. Math anxiety was not a direct predictor.
De Keyser et al. (2020)	Math attitudes and math expectations	1, 76% mothers	No	5–6	Yes	No	Belgium	Parental math attitudes had a weak association with numerical skills[a].
Skwarchuk et al. (2014)	Numeracy attitudes	1, 86% female	No	5–6	Yes	No	Canada	Parental numeracy attitudes predicted numeracy outcomes.
Maloney et al (2015)	Math anxiety	1[b]	Yes	7	Yes	Math anxiety	USA	Parental math anxiety predicted children's math anxiety and attainment only when parents gave high levels of homework help.
Ma et al (2021)	Math anxiety	1, 67% female	No	9–10	Yes	Math anxiety	China	Parental math anxiety associated with child math anxiety but not attainment.
Vanbinst et al. (2020)	Math anxiety	2, biological parents	No	11–12	Yes	Math anxiety	Belgium	Neither parent's math anxiety predicted attainment. Mothers' anxiety predicted child anxiety.
Casad et al. (2015)	Math anxiety	1, 81% female	No	11–14	Yes	Math self-efficacy	USA	Parental math anxiety predicted child attainment and self-efficacy.
Retanal et al. (2021)	Math anxiety	1[c]·68% female	Yes	11–14	Yes	No	North America	Parental math anxiety predicted child attainment.
Soni & Kumari (2017)	Math anxiety and math attitudes	1, gender not specified	No	10–15	Yes	Math anxiety and Math attitudes	Taiwan	Parental anxiety and attitudes predicted child anxiety, attitudes, and attainment.

Note. Studies were included in the table if the associations between parental mathematics anxiety and/or attitudes and children's mathematics attainment were examined. They are ordered based on the age of the children. A parent attainment measure is noted when this was controlled in the statistical analysis.

[a] The zero-order correlation is statistically significant; Bayesian statistics indicated anecdotal evidence.

[b] 29% of the parents stated their gender, of whom 89% were female.

[c] Recruited parent or guardian who most frequently helped with homework.

whether any associations between children's mathematics attainment and parental mathematics anxiety and attitudes were underpinned by less frequent home number experiences, whether parental mathematics anxiety or attitudes moderated the association between home number experiences and children's mathematics attainment, and whether there was transmission of mathematics anxiety from parents to their children. In addition, we considered whether children's gender moderated any associations between maternal mathematics anxiety and attitudes and children's mathematics attainment.

Parental mathematics anxiety and attitudes influencing the frequency of home number experiences

In their home numeracy model, Skwarchuk et al. (2014) proposed that parental mathematics attitudes would have an impact on children's mathematics attainment via their association with the frequency of home number experiences. Home number experiences are activities or interactions, within the home environment, that involve numbers. They encompass a range of experiences, including playing games that involve numbers, parents highlighting numbers in the environment, and parents encouraging children to count items or practice calculations. Parents with negative attitudes toward mathematics or high mathematics anxiety may avoid engaging in such experiences. The resulting reduced frequency of home number experiences could influence children's mathematics attainment. For this mechanism to be supported, there needs to be evidence that the frequency of home number experiences is positively associated with children's mathematics attainment, and evidence that parents' mathematics anxiety and attitudes are associated with the frequency of home number experiences. When home number experiences are indexed during the preschool or kindergarten period, the first premise has largely been supported. Numerous studies identify associations between the frequency of preschool or kindergarten home number experiences and early mathematics attainment (e.g., del Rio et al., 2017; Hart et al., 2016; LeFevre et al., 2010; Napoli & Purpura, 2018; Niklas & Schneider, 2014; Skwarchuk et al., 2014; Susperreguy et al., 2020, 2022). When positive associations are not observed, sample sizes tend to be smaller (e.g., Blevins-Knabe et al., 2000; Missall et al., 2015; Zippert & Rittle-Johnson, 2020) or the frequency of home number experiences are indexed after children have commenced formal education (e.g., Ciping et al., 2015; Silinskas et al., 2010; Susperreguy et al., 2022; but see De Keyser et al., 2020, and Silver et al., 2022, for null associations when home number experiences are surveyed during the preschool period). A recent meta-analysis (Daucourt et al., 2021) confirmed a stronger association in preschool and kindergarten samples than in primary and secondary school samples.

Findings relating to the second premise, that parental anxiety and attitudes are related to the frequency of home number experiences, differ depending on the aspect of parental attitudes and anxiety indexed. Parents' child number expectations (i.e., attitudes valuing the importance of number education and high expectations of their children's attainment) have been consistently associated with the frequency of home number experiences in preschool and school-age children (del Rio et al., 2017; Skwarchuk et al., 2014; Zippert & Rittle-Johnson, 2020). However, studies using broader indices of parental mathematics attitudes (focusing on parents' own interest in, feelings toward, and satisfaction with mathematics) and parental mathematics anxiety present more inconsistent findings. There are reports of significant (Susperreguy et al., 2020) and null (Missall et al., 2015; Skwarchuk et al., 2014) associations between parental mathematics attitudes and the frequency of home number experiences and reports of significant (del Rio et al., 2017) and null (Hart et al., 2016) associations between parental mathematics anxiety and the frequency of home number experiences. This pattern of findings is consistent with theoretical models of parents' socialization of academic motivation (Eccles & Wigfield, 2020), where parents' child-specific beliefs have a more direct influence on parents' behavioral support for academic activities than general beliefs and attitudes.

Parental mathematics anxiety and attitudes influencing the effectiveness of home number experiences

Parental mathematics anxiety and attitudes may also influence the effectiveness of home number experiences. If parental mathematics anxiety or attitudes have an impact on the effectiveness of home number experiences, one would anticipate that the positive associations typically reported between home number experiences and children's mathematics attainment (Daucourt et al., 2021) would be weaker or negative in the context of high parental mathematics anxiety or negative mathematics atti-

tudes. Maloney et al. (2015) reported that in the context of high parental mathematics anxiety, frequent homework help had a negative association with children's mathematics attainment (which was not the case in the context of low parental mathematics anxiety). They inferred that when parents have high mathematics anxiety, their homework help was less effective and may even have a detrimental impact on children's mathematics attainment. Parents with high mathematics anxiety may communicate negativity and stress when supporting homework. Consistent with this interpretation, Retanal et al. (2021) reported that the association between parental mathematics anxiety and children's mathematics attainment was partially mediated by the tendency for more mathematics anxious parents to adopt a controlling approach toward homework support. Maloney et al. (2015) considered the impact of parental mathematics anxiety only on the association between homework help and children's mathematics attainment; the interaction between parental mathematics anxiety and broader home number experiences has not previously been examined.

Transmission of mathematics anxiety from parents to children

A further mechanism that may explain the association between parental mathematics anxiety and young children's mathematics attainment is the transmission of mathematics anxiety from parents to their children. Parents[1] with high mathematics anxiety may transmit their anxiety to their children, which then has a negative impact on their children's mathematics attainment. This transmission may be underpinned by the transmission of a genetic predisposition toward mathematics anxiety if parents are biologically related to their children (Wang et al., 2014). In addition, or alternatively, parents who are more mathematics anxious may create an environment that fosters the development of mathematics anxiety in their children. Children exposed to parents who display mathematics anxious behaviors (e.g., verbalizing a fear of mathematics, displaying anxiety when completing everyday mathematical tasks) may emulate these behaviors and have an increased likelihood of developing mathematics anxiety themselves (see Casad et al. 2015, and Vanbinst et al., 2020, for discussions). This nongenetic transmission could occur even if parents are not biologically related to the children (e.g., step or adoptive relationships). Many studies have reported associations between parental mathematics anxiety and the mathematics anxiety of children during middle childhood and adolescence (e.g., Casad et al., 2015; Ma et al., 2021; Soni & Kumari, 2017; Vanbinst et al., 2020). However, evidence of transmission of mathematics anxiety and attitudes from parents to younger children is scarce. We are aware of only one study (Maloney et al., 2015) that investigated this association in children aged 7 years or under. Maloney et al. (2015) concluded that parental mathematics anxiety did not directly predict children's mathematics anxiety; rather, mathematics anxiety was transmitted only when parents engaged in frequent homework help.

The role of gender

There is increasing interest in the extent to which the gender of both parents and children influences any associations between parental mathematics attitudes and anxiety and children's mathematics anxiety and attainment. Because mothers typically devote more time to the care of children (see Chung, 2021, for a recent review in a U.K. context), their mathematical attitudes and anxiety *may be* more closely associated with children's mathematics outcomes than fathers' mathematics anxiety and attitudes. Stronger mother–child versus father–child associations have been reported in relation to parent and child mathematics anxiety (Vanbinst et al., 2020) and to parent number expectations and children's mathematics attainment (del Rio et al., 2017). Vanbinst et al. (2020) reported that the association between mothers' mathematics anxiety and their children's mathematics anxiety was stronger when the mother had greater involvement in caregiving. This is consistent with stronger maternal associations being underpinned by greater maternal involvement with child care.

In addition to the possibility that maternal mathematics attributes have more influence on child outcomes than paternal mathematics attributes, the gender of children may interact with the gender of the parent. It has been argued that children may identify with and emulate their same-gender par-

[1] *Parent* is used to refer to an adult who has parental responsibility for the child. This encompasses biological parents but also nonbiological parents (e.g., adoptive parents).

ent to a greater extent than their opposite-gender parent. Consequently, fathers' mathematics anxiety and attitudes may be more strongly associated with their sons' mathematics outcomes, whereas mothers' mathematics anxiety and attitudes may be more strongly associated with daughters' mathematics outcomes (see Casad et al., 2015, for a discussion). The findings of Casad et al. (2015) broadly supported this hypothesis. They concluded that the strongest associations were found between parental mathematics anxiety and children's mathematics attainment within same-gender dyads, particularly mother–daughter dyads. De Keyser et al. (2020), however, found no evidence that children's gender moderated associations between parental mathematics attitudes and expectations and children's attainment.

The current study

In the current study, we used a U.K. sample to examine the associations among parental mathematics anxiety and attitudes, preschool and primary school home number experiences, and children's mathematics attainment and anxiety. Examining associations between different aspects of the home learning environment and children's attainment in different cultures is important because different languages, cultural norms, and educational systems may affect the results (Hornburg et al., 2021). We are not aware of previous studies that have examined the association between parental mathematics anxiety and attitudes and children's mathematics attainment in the United Kingdom. Furthermore, we extended existing research in three important ways. First, we examined whether any observed associations between parental mathematics anxiety and attitudes and children's mathematics attainment remained consistent when parental mathematics attainment was controlled. Becker et al. (2022) highlighted the need to evaluate whether associations between parental mathematics anxiety and attitudes and children's mathematics attainment are independent of parental mathematics attainment. High parental mathematics attainment may directly influence child mathematics attainment via genetic pathways (Garon-Carrier et al., 2017; Halpern-Manners et al., 2020; Kovas et al., 2007) and environmental pathways (Halpern-Manners et al., 2020). Furthermore, parents with high mathematics attainment are more likely to be less mathematics anxious and have more positive attitudes toward mathematics (Dowker et al., 2016). Therefore, it is possible that there is no direct association between parental mathematics attitudes and anxiety and children's attainment but rather parental mathematics attainment independently influences both parental mathematics attitudes and anxiety and children's mathematics attainment. By including parental mathematics attainment within our statistical models, the possibility that parental mathematics anxiety and attitudes and children's mathematics attainment are related to each other only via their associations with parental mathematics attainment can be excluded. Although there have been some previous attempts to control for parental mathematics attainment when examining the association between parental mathematics anxiety and children's mathematics attainment (Maloney et al., 2015; Retanal et al., 2021), parental mathematics attainment has not been controlled when examining associations between parental mathematics attitudes and children's mathematics attainment.

Second, we examined whether high parental mathematics anxiety or negative attitudes toward mathematics had an impact on any associations between home number experiences and children's mathematics attainment. The extent to which parental mathematics anxiety and attitudes moderates the impact of home learning experiences has only been examined in relation to the specific experience of homework help (Maloney et al., 2015). We extended this research by considering whether parental mathematics anxiety and attitudes moderated the association between broader home number experiences and children's mathematics attainment.

Third, we compared the extent to which children's gender moderated the associations between maternal mathematics anxiety and attitudes and children's mathematics attainment. Previous findings have suggested that children's gender has a stronger influence on the association between parental mathematics anxiety and children's mathematics attainment (Casad et al., 2015) than between parental mathematics attitudes and children's mathematics attainment (De Keyser et al., 2020). However, these different findings could be accounted for by the different age groups and different cultural contexts of the two studies (see Table 1). We were able to compare the influence of children's gender on these associations in the same sample. We addressed five research questions. Research Questions 1

to 4 were developed by the authors prior to analysis, and Research Question 5 was added following a suggestion by one of the manuscript's reviewers.

Do parental mathematics anxiety and attitudes and the frequency of home number experiences predict children's mathematics attainment in primary school?

Previous studies have identified associations between young children's mathematics attainment and both parental mathematics anxiety and attitudes (Becker et al., 2022; del Rio et al., 2017; Skwarchuk et al., 2014) and the frequency of preschool home number experiences (del Rio et al., 2017; LeFevre et al., 2010; Skwarchuk et al., 2014; Susperreguy et al., 2020). Therefore, we hypothesized that parental mathematics anxiety and attitudes and the frequency of preschool home number experiences would be predictive of children's later mathematics attainment. Children's mathematics attainment was assessed on two occasions at the end of the first and second years of primary school. Given that the association between home number experiences and children's mathematics attainment is weaker in older samples (Daucourt et al., 2021), we did not hypothesize an association between primary school home learning experiences and children's mathematics attainment.

Are any associations between parental mathematics anxiety and attitudes and children's mathematics attainment mediated by the frequency of home number experiences?

Skwarchuk et al. (2014) proposed that parental mathematics anxiety and attitudes are associated with children's mathematics attainment because they influence the frequency of home number experiences. To evaluate this proposal, we examined whether any associations between parental mathematics anxiety and attitudes and children's mathematics attainment were mediated by the frequency of home number experiences during both the preschool and primary school periods.

Do parental mathematics anxiety and attitudes moderate any associations between the frequency of home number experiences and children's mathematics attainment?

We extended Maloney et al.'s (2015) findings examining the impact of parental mathematics anxiety on the effectiveness of homework help by evaluating whether parental mathematics anxiety and attitudes moderated any associations between broader home number experiences and children's mathematics attainment. A weaker positive association or a shift to a negative association between the frequency of home number experiences and children's mathematics attainment, in the context of high parental mathematics anxiety or negative attitudes, would be consistent with these parental attributes reducing the effectiveness of home number experiences.

Does parental mathematics anxiety predict children's mathematics anxiety during the early years of primary school?

Only one previous study has examined transmission of mathematics anxiety from parents to children aged 7 years or under (Maloney et al., 2015). Those authors did not report an association across the whole sample. Because there are limited data examining the association between parental mathematics anxiety and younger children's mathematics anxiety, we examined this association in a sample of children aged 6 years.

Does children's gender moderate any associations between maternal mathematics anxiety and attitudes and children's mathematics attainment and anxiety?

Because most parental respondents in the current study were female, we could not evaluate whether maternal mathematics anxiety and attitudes had a stronger association with children's mathematics attainment than paternal mathematics anxiety and attitudes. However, it was possible to compare the strength of the associations between maternal mathematics anxiety and attitudes and boys' and girls' mathematics attainment and anxiety. Previous findings (Casad et al., 2015; De Keyser et al., 2020) would suggest that children's gender would moderate any associations between maternal mathematics anxiety and children's attainment, but not between maternal mathematics attitudes and children's attainment.

Method

Participants and design

At Time 1 (T_1), 274 parent–child dyads were recruited. The children attended 40 preschool settings situated in six local authorities in Northwest England. At T_1, when the children were in their final year of preschool, the parents completed a questionnaire that included questions relating to their own mathematics attitudes, anxiety, and qualifications and the frequency of home number experiences. At Time 2 ($T_{2,}$), the mathematics attainment and reading attainment of 231 children were assessed in their first year of primary schooling. At Time 3a (T_{3a}), in the second year of the children's primary schooling, 119 of the parents completed an additional questionnaire that indexed the current frequency of home number experiences. The children's reading attainment and mathematics attainment were assessed at T_{3b} (approximately 3 months after the parents completed the questionnaire). At Time 4 ($T_{4,}$), when the children were in their third year of primary schooling, 119 children completed a mathematics anxiety questionnaire. Children identified as having special educational needs and disabilities (SEND) were retained in the sample because they were judged as able to comprehend the assessments and responded appropriately to the practice items. Exclusion of these children would make the sample less representative of children attending primary schools in England. A summary of the measures administered at each time point and information relating to children's gender, SEND, age, and reasons for attrition is presented in Table 2.

The children's ethnicity was reported by parents at T_1 and was coded according to the categories used in the U.K. Census. In total, 249 children (90.9%) were White, 17 (6.2%) were of mixed/multiple ethnic heritage, 4 (1.5%) were Asian, 3 (1.1%) were Black, and 1 child (0.4%) was classified as "other" (a category that includes any ethnicity other than White, mixed/multiple, Asian, or Black). In the most recent census (Office for National Statistics, 2021), more than 90% of residents, in five of the six local authorities from which participants were drawn, reported their ethnicity as White. This proportion was lower in the remaining authority (Liverpool, 77.3%) and in England as a whole (81.7%). Thus, although participants reporting White ethnicity were overrepresented in the sample compared with the proportion nationally, they were not overrepresented with respect to the majority of the localities from which the sample was recruited. A total of 23 children (8.4%) spoke a language in addition to English at home.

Measures

Postcode deprivation

We used the postcode deprivation decile from the English indices of deprivation 2015 online open data of the United Kingdom (Department for Communities and Local Government, https://imd-by-postcode.opendatacommunities.org) as an index of children's socioeconomic status. Postcode indices of deprivation indicate the relative deprivation of the locality. They are calculated using a broad range of measures that relate to income, employment, health, crime, and housing (see Ministry of Housing Communities and Local Government, 2019, for a detailed discussion of how indices of deprivation are calculated).

Parental mathematics attitudes

Parents responded to 16 mathematical attitudes questionnaire items (American terms were anglicized) drawn from the Attitudes Toward Mathematics Instrument (Tapia, 1996) using a 5-point Likert scale ranging from *strongly agree* to *strongly disagree.* Higher scores indicated more positive attitudes toward mathematics. Exploratory factor analysis (EFA) using the principal axis factoring method with a promax rotation and Kaiser normalization was conducted to determine whether the items formed reliable and coherent scales. All subsequent EFAs were conducted using the same procedure. The scale fractionated into two factors. Eleven items referring to feelings toward and competence in mathematics (e.g., "I learn mathematics easily") loaded onto Factor 1. This factor was labeled *Mathematics attitudes: Feelings and competence.* Five items referring to interest and satisfaction with mathematics (e.g.,

Table 2
Participants and measures at each time point.

Time	Child educational stage and age	Key measures Parent	Child	Number of dyads and reasons for attrition
1	Preschool (M_{age} = 3 years 11 months, *SD* = 3.73 months) 15 children (5.5%) were described by their parents as having a SEND or as being referred for or undergoing investigations because such a need was suspected. The following SENDs were reported: autistic spectrum = 3; physical disabilities = 3; speech, language, and hearing issues = 6; behavior and emotional issues = 1; epilepsy = 1; unspecified = 1	Mathematics qualifications, anxiety, and attitudes. Frequency of preschool home number experiences		274 (146 female children, 254 female parents).
2	Reception (first year of primary school, final term, M_{age} = 5 years 2 months, *SD* = 3.74 months). 13 children (5.6%) with SEND issues were retained		Mathematics and reading assessments	231 (127 female children, 211 female parents) 26 children transferred to primary schools that did not consent to the continuation of the study. The school placements of 10 children could not be traced. Four children moved away, two children were persistently absent, and one child withdrew assent.
3a & 3b	Year 1 (second year of primary school, questionnaire completed at Time 3a, M_{age} = 6 years 0 months, *SD* = 3.78 months; child assessment completed at Time 3b, M_{age} = 6 years 3 months, *SD* = 3.80 months). 6 children (5.0%) with SEND issues were retained	Frequency of primary school home number experiences	Mathematics and reading assessments	119 (62 female children, 113 female parents) 22 children attended schools that did not consent for the study to continue. 89 parents did not renew consent for the extension stage. One child moved away.
4	Year 2 (third year of primary school, first term, M_{age} = 6 years 7 months, *SD* = 3.70 months)		Mathematics anxiety	119 (62 female children, 113 female parents).

Note. SEND, special educational need or disability.

"Mathematics is a very interesting subject") loaded onto Factor 2. This factor was labeled *Mathematics attitudes: Interest and satisfaction.* The reliabilities for Factor 1 (α =.96) and Factor 2 (α =.89) were very good. Details of the items and the EFA were reported in Soto-Calvo et al. (2020) and are reproduced in the online supplementary material (Table S1).

Parental mathematics anxiety

Parents responded to 11 mathematics anxiety items adapted from the Numerical Anxiety Scale of the Mathematics Anxiety Rating Scale (MARS; Rounds & Hendel, 1980) on a 5-point Likert scale ranging from *not at all anxious* to *very anxious.* American terminology was anglicized. An EFA was conducted with 10 items. One item[2] (47) was excluded from the EFA due to low correlations with the other items in the scale. Six items (1, 5, 8, 14, 59, and 67), which involved calculations (e.g., "Dividing a five digit number by a two digit number with pencil and paper"), loaded onto Factor 1. This factor was labeled *Mathematics anxiety: Calculations.* Four items (33, 50, 65, and 90) involving budgeting or payments (e.g., "Figuring out your monthly budget") loaded onto Factor 2. This factor was labeled *Mathematics anxiety: Budgeting.* The reliabilities for Factor 1 (α =.84) and Factor 2 (α =.79) were acceptable. See supplementary material (Table S2) for details of the EFA.

Parental mathematics attainment

Parents were asked to report their highest mathematics qualification, which was used to index parental mathematics attainment. Parental mathematics qualifications were coded according to the U.K. National Qualification framework (https://www.gov.uk/what-different-qualificationlevels-mean/list-of-qualification-levels). This scale levels qualifications from 1 (qualifications equivalent to a lower grade of the General Certificate of Secondary Education [GCSE] typically taken by 16-year-olds in England) to 8 (doctoral-level qualifications). If parents reported that they had not attempted any mathematics qualifications or they received a U (ungraded) at GCSE, their level was coded as 0 (zero).

Frequency of preschool home number experiences

Parents were asked to report the frequency with which they engaged with their children in each of eight home number experiences (e.g., "Is encouraged to point out or identify numbers in books or the environment") on a 6-point Likert scale ranging from *never* to *several times a day.* An EFA was conducted with six items (two items were excluded due to low correlations with the other items in the scale). All six items loaded onto a single factor and had acceptable reliability (α =.79). Details of the items and the EFA were reported in Soto-Calvo et al. (2020) and are reproduced in the supplementary material (Table S3).

Frequency of primary school home number experiences

Parents were asked to report the frequency with which they engaged with their children in six home number experiences (e.g., "Rehearses number facts e.g., Number bonds or times tables") on a 6-point Likert scale ranging from *never* to *several times a day.* An EFA conducted with these six items revealed that all six items loaded onto a single factor that had good reliability (α =.82). See supplementary material (Table S4) for details of the items and EFA.

Children's mathematics and reading attainment

At T_2 the Early Number Concepts (ENC) scale and at T_{3b} the Number Skills (NS) scale from the British Ability Scales-3 (BAS-3 ENC and BAS-3 NS, respectively; Elliot & Smith, 2011) were administered. The former assesses early number skills, including counting and simple calculations, using aurally presented problems supported by pictorial stimuli (the children respond verbally). The latter assesses number skills using a pencil-and-paper test of arithmetic problems. At T_2 the Early Word Reading scale and at T_{3b} the Passage Reading Accuracy scale from the York Assessment of Reading for Comprehension-3 (YARC-3; Hulme et al., 2009) were administered. These scales assess word reading

[2] Item numbers refer to those used by Rounds and Hendel (1980) to enable item identification from the original source.

accuracy, with the former using a single word reading test and the latter using a passage reading accuracy test.

Children's mathematics anxiety

The Situational and Performance Anxiety subscale of the Scale for Early Mathematics Anxiety (SEMA; Wu et al., 2012) was administered at T_4. This scale consists of eight items relating to mathematical situations (e.g., "Your teacher gives you some addition problems to work on"). The children are asked how nervous they would feel in each situation. They respond using a 5-point Likert scale ranging from *not at all nervous* to *very, very nervous.* We anglicized terms within the scale and incorporated the 5-point facial image scale from the Child Early Math Attitudes Screener test of the Math Brain Lab (https://mathbrainlab.com/child-attitude-screener) alongside each of the response options. A higher score indicates higher math anxiety. An EFA excluded two items[3] (13 and 14) due to low correlations with the other items in the scale. All six items loaded onto a single factor, and the scale demonstrated acceptable reliability (α =.72). See supplementary material (Table S5) for details of the EFA.

Procedure

Written consent was gained from the parents and the managers or headteachers of the preschool settings at T_1. At T_2 consent was provided by the head teachers of the primary schools to which the children transferred. Prior to stage T_{3a} additional consent was sought from the head teachers and parents to extend the longitudinal trajectory of the study to T_4. Substantial attrition occurred at this point because additional consent was provided by only a subset of the original sample (see Table 2 for details). Ethical approval was granted by the university ethics panel for all stages of the study.

The parents completed the preschool and primary school questionnaires at home and returned them confidentially to the research team. The children completed the attainment assessments and the mathematics anxiety questionnaire individually in a quiet area of their school.

Analysis

We used PROCESS (Hayes, 2020) to evaluate regression models. To address Research Questions 1 and 2, we assessed models in which parental mathematics anxiety and attitudes were defined as focal predictors of children's mathematics attainment. The frequency of both preschool and primary school home number experiences were identified as potential mediating variables. Parental mathematics attainment and postcode deprivation were entered as covariates[4] in all regression models reported. When mathematics attainment at T_3 was predicted, prior mathematics attainment at T_2 was also included as a covariate (equivalent models without prior attainment as a covariate are presented in Tables S6–S8 in the supplementary material). Direct effects on children's mathematics attainment of parental mathematics anxiety and attitudes and home number experiences were evaluated to address Research Question 1, "Do parental mathematics anxiety and attitudes and the frequency of home number experiences predict children's mathematics attainment at primary school?" The indirect effects of parental anxiety and attitudes on children's attainment via home number experiences were evaluated to address Research Question 2, "Are any associations between parental mathematics anxiety and attitudes and children's mathematics attainment mediated by the frequency of home number experiences?".

To address Research Question 3, "Do parental anxiety and attitudes moderate any associations between the frequency of home number experiences and children's mathematics attainment?", models in which preschool and primary school home number experiences were entered as focal predictors of children's mathematics attainment with parental mathematics anxiety and attitudes entered as potential moderating variables were evaluated. The interactions between parental mathematics attitudes or anxiety and home number experiences were included to determine whether any associations

[3] Item numbers refer to those used by Wu et al. (2012) so that the items can be identified within their manuscript.

[4] In all the regression models, the direct effects of both focal predictors and covariates are calculated, but mediation or moderation effects are calculated only in relation to the focal predictor.

between home number experiences and children's mathematics attainment were moderated by parental mathematics anxiety or attitudes.

To address Research Question 4, "Do parental mathematics anxiety and attitudes predict children's mathematics anxiety during the early years of primary school?", the longitudinal correlations between parental mathematics anxiety and attitudes and children's mathematics anxiety were examined.

To address Research Question 5, "Does children's gender moderate any associations between maternal mathematics anxiety and attitudes and children's mathematics attainment and anxiety?", models in which maternal mathematics attitudes and anxiety were entered as focal predictors of children's mathematics attainment with child gender entered as a potential moderating variable were evaluated. In these models, the sample was limited to female parents because we aimed to compare the associations found between mothers and daughters and between mothers and sons. The interactions between maternal mathematics attitudes and anxiety and child gender were evaluated to determine whether the associations differed for boys and girls.

In all analyses, factor scores were used for the home learning experiences, mathematics attitudes and mathematics anxiety variables, and standard scores for the attainment measures.

Results

Preliminary analyses

Parental characteristics

Descriptive statistics for parental demographics and parents' responses to the mathematical attitudes, mathematics anxiety, and home learning experiences scales are presented in Table 3. Participants were drawn from households across the socioeconomic spectrum, with the mean postcode deprivation being close to the population average of 5. The mean parental mathematics qualification rating was slightly above 2. This equates to a good pass at GCSE level.

One-way analyses of variance (ANOVAs) were employed to determine whether parental characteristics differed between the T_1 sample and the sample retained at T_2 and between the T_2 sample and the sample retained through T_3 and T_4 (see Table 3). There were no significant differences in parental mathematics attainment at the different time points. The T_2 sample did have a significantly lower postcode deprivation level than the T_1 sample, although the T_3 sample had a significantly higher level than the T_2 sample. These differences were small (η^2 =.02) and in opposing directions. When examining parental mathematics attitudes and anxiety, the $T_{3\&4}$ samples had significantly lower *Mathematics attitudes: Feelings and competence* and significantly higher *Mathematics anxiety: Budgeting* than the T_2 sample (with trends in the same direction for the other mathematics attitude and anxiety measures, p =.06). These differences were small (η^2 =.02), with the mean difference between time points in scale score being less than 1 scale point on every measure.

Child attainment

Children's performance on the attainment measures is shown in Table 4. At T_2 the children's average mathematics level, assessed via BAS-3 ENC, was slightly below the standardized mean of 50. When assessed via BAS-3 NS at T_{3b}, it was slightly above the standardized mean of 100. This increase in standard scores appears to reflect a rise in the performance of the sample over time rather than the retention of higher-performing children because the BAS-3 ENC scores of the children who were retained to $T_{3\&4}$ and those children who left the study at an earlier time point did not differ significantly (see Table 4).

Longitudinal associations between parental attributes and children's mathematics attainment

Correlations between the measures are shown in Table 5. Parents' mathematics attainment, their attitudes toward mathematics, and their mathematics anxiety all had small but significant correlations with children's mathematics attainment at T_2. Notably, these correlations were domain specific given that significant associations were not observed with reading attainment. The correlations between parental mathematics attainment, anxiety, and attitudes and children's mathematics attain-

Table 3
Parental and home learning environment characteristics.

	Potential range	Reported range	T_1 sample (N = 274)	Sample retained to T_2 (n = 231)	Sample retained to T_{3a} & T_{3b} (n = 119)	Difference between T_1 and T_2 samples[a]	Difference between T_2 and $T_{3\&4}$ samples[b]
T_1 measures							
Postcode deprivation	1–10	1 to 10	5.42 (3.32)	5.25 (3.26)	5.69 (3.19)	η^2 =.02, p =.04	η^2 =.02, p =.04
Mathematics qualification	0–8	0 to 7	2.21 (1.30)	2.18 (1.20)	2.18 (1.15)	η^2 =.00, p =.32	η^2 =.00, p =.98
Preschool home number experiences (*z*-score)	–	−2.55 to 1.99	0.00 (0.89)	−0.02 (0.91)	−0.06 (0.94)	η^2 =.00, p =.48	η^2 =.00, p =.48
(total score)	0–30	2 to 30	17.04 (5.40)	16.95 (5.47)	16.55 (5.54)		
Mathematics attitude: Feelings and competence (z-score)	–	−2.54 to 1.62	0.00 (0.98)	0.00 (0.99)	−0.14 (1.01)	η^2 =.00, p =.88	η^2 =.02, p =.04
(total score)	11–55	11 to 55	37.61 (10.51)	37.61 (10.70)	36.10 (10.94)		
Mathematics attitude: Interest and satisfaction (*z*-score)	–	−2.64 to 1.85	0.00 (0.96)	−0.01 (0.98)	−0.13 (1.04)	η^2 =.00, p =.73	η^2 =.02, p =.06
Mathematics attitude: Interest and satisfaction (total score)	5–25	7 to 25	17.74 (4.01)	17.72 (4.08)	17.20 (4.37)		
Mathematics anxiety: Calculations (*z*-score)	–	−0.69 to 4.00	0.00 (0.93)	0.02 (0.97)	0.14 (1.09)	η^2 =.00, p =.46	η^2 =.02, p =.06
Mathematics anxiety: Calculations (total score)	6–36	6 to 24	7.49 (3.38)	7.55 (3.50)	7.96 (3.88)		
Mathematics anxiety: Budgeting (*z*-score)	–	−0.67 to 4.07	0.00 (0.91)	0.02 (0.95)	0.15 (1.03)	η^2 =.00, p =.47	η^2 =.02, p =.04
Mathematics anxiety: Budgeting (total score)	4–20	4 to 16	5.56 (2.28)	5.62 (2.37)	5.96 (2.54)		
T_{3a} measures							
Primary school home number experiences (*z*-score)	–	−2.52 to 2.16	–	–	0.00 (0.90)		
Primary school home number experiences (total score)	0–30	6 to 30	–	–	19.04 (4.71)		

Note. Three parents did not supply their postcode and four did not report their mathematics qualifications.

[a] One-way between-groups analyses of variance were used to compare the scores of parents who were retained from T_1 to T_2 with those who left the study.

[b] One-way between-groups analyses of variance were used to compare the scores of T_1 parents who were retained at T_2 and to compare T_2 parents with those retained at $T_{3\&4}$. There was no attrition between T_3 and T_4.

Table 4
Child attainment and mathematics anxiety.

	Potential range	Reported range	T_2 sample (n = 231)	Sample retained to T_3 & T_4 (n = 119)	Difference between T_2 and T_3 samples
T_2 measures					
Children's mathematics attainment (BAS ENC[a])	–	27 to 90	49.40 (10.32)	48.96 (9.83)	η^2 =.00, p =.51
Children's reading attainment (YARC Early Word Reading[b])	–	72 to 131	115.86 (12.92)	117.32 (12.85)	η^2 =.01, p =.09
T_{3b} measures					
Children's mathematics attainment (BAS NS[b])	–	65 to 145		107.43 (14.29)	–
Children's reading attainment (YARC Passage Reading Accuracy[b])	–	81 to 130		110.13 (11.76)	–
T_4 measures					
Children's mathematics anxiety (z-score)	–	−1.06 to 3.33		0.00 (0.85)	–
Children's mathematics anxiety (total score)	6–30	6 to 28		11.34 (4.26)	–

Note. BAS ENC, British Ability Scales; ENC, Early Number Concepts; YARC, York Assessment of Reading for Comprehension; NS, Number Skills.
[a] Standardised scores with a mean of 50.
[b] Standardised scores with a mean of 100.

ment at T_{3b} were somewhat weaker, with only the correlation with *Mathematics attitudes: Interest and satisfaction* reaching statistical significance.

There was a small but significant positive correlation between the frequency of preschool number experiences and children's mathematics attainment at T_2. This association was not specific to mathematics given that the correlation with reading attainment at T_2 was also significant and of a similar magnitude. The correlations between both the frequency of preschool home number experiences and children's mathematics attainment at T_{3b} were weaker and did not reach statistical significance. The association between primary school home number experiences and mathematics attainment at T_{3b} was also very weak and not significant.

Addressing the research questions

To address Research Questions 1 and 2, regression models were generated to determine whether parental mathematics anxiety and attitudes and the frequency of home number experiences predicted children's mathematics attainment at T_2 and T_{3b} and whether the frequency of home number experiences mediated any associations between parental mathematics anxiety and attitudes and children's mathematics attainment. Separate models were constructed for each parental attribute (*Mathematics attitudes: Feelings and competence; Mathematics attitudes: Interest and satisfaction; Mathematics anxiety: Calculations;* and *Mathematics anxiety: Budgeting*). Models 1a to 1d are presented in Table 6 and predict mathematics attainment at T_2 from parental mathematics anxiety and attitudes and preschool home number experiences at T_1. Models 2a to 2d are presented in Table 7 and predict mathematics attainment at T_{3b} from parental mathematics anxiety and attitudes and preschool home number experiences at T_1. Models 3a to 3d are presented in Table 8 and predict children's mathematics attainment at T_{3b} from parental mathematics anxiety and attitudes and primary school home number experiences at T_{3a}.

Research Question 1: Do parental mathematics anxiety and attitudes and the frequency of home number experiences predict children's mathematics attainment at primary school?

Models 1a to 1d (presented in Table 6) indicated that all four indices of parental mathematics anxiety and attitudes and the frequency of preschool home number experiences were significant predic-

Table 5
Correlations among child and parent variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Postcode deprivation decile	–												
2. Parents' mathematics attainment (T_1)	19**	–											
3. Parents' Mathematics attitude: Feelings and competence (T_1)	.09	.31***	–										
4. Parents' Mathematics attitude: Interest and satisfaction (T_1)	.06	.32***	.74***	–									
5. Parents' Mathematics anxiety: Calculations (T_1)	−.13*	−.28***	−.65***	−.38***	–								
6. Parents' Mathematics anxiety: Budgeting(T_1)	−.17**	−.19***	−.52***	−.31*	.84***	–							
7. Preschool home number experiences (T_1)	−.03	−.01	.00	.07	−.06	−.05	–						
8. Primary school home number experiences (T_{3a})	.16	.07	−.04	−.01	.06	.03	−.46***	–					
9. Children's mathematics attainment (T_2)	.12	.17***	.17*	.21**	−.19**	−.19**	.16*	.12	–				
10. Children's reading attainment (T_2)	.20**	.04	.08	.11	−.11	−.11	.15*	.09	.51***	–			
11. Children's mathematics attainment (T_{3b})	.16	.07	.16	.19*	−.16	−.13	.13	−.02	.51***	.53***	–		
12. Children's reading attainment (T_{3b})	.18	.08	.12	.17	−.12	−.10	.17	.02	.35***	.63***	.61***	–	
13. Children's mathematics anxiety (T_4)	.08	.04	.11	.12	−.11	−.08	−.16	.24***	−.03	.10	−.02	.05	–
n	271	270	274	274	274	274	274	119	231	231	119	119	119

Note. Cases excluded pairwise. Three parents did not supply their postcode and four did not report their mathematics qualification.
* p <.05.
** p <.01.
*** p <.001.

Table 6
Models examining the associations between parental mathematics anxiety and attitudes and children's mathematics attainment at T_2, including preschool home number experiences as a potential mediating variable.

		Model 1a: Mathematics anxiety: Calculations		Model 1b: Mathematics anxiety: Budgeting		Model 1c: Mathematics attitudes: Feelings and competence		Model 1d: Mathematics attitudes: Interest and satisfaction	
		β	95% Confidence interval	*β*	95% Confidence interval	*β*	95% Confidence interval	*β*	95% Confidence interval
Direct effects									
	Parental mathematics attribute[a] → Math attainment (T_2)	−1.61*	−3.01, −0.21	−1.71*	−3.12, −0.30	1.57*	0.18, 2.96	1.93**	0.50, 3.36
	Home number experiences (preschool, T_1) → Math attainment (T_2)	1.92**	0.47, 3.36	1.90*	0.45, 3.34	1.99**	0.55, 3.44	1.89*	0.45, 3.33
	Parental mathematics attainment → Math attainment (T_2)	0.87	−0.30, 2.04	0.96	−0.19, 2.10	0.81	−0.38, 2.00	0.69	−0.51, 1.88
	Deprivation decile → Math attainment (T_2)	0.25	−0.17, 0.67	0.22	−0.20, 0.64	0.28	−0.14, 0.70	0.28	−0.14, 0.69
Indirect effect									
	Parental mathematics attribute[a] → Home number experiences (preschool, T_1) → Math attainment (T_2)	−0.05	−0.35, 0.15	−0.07	−0.35, 0.15	−0.04	−0.31, 0.26	0.70	−0.22, 0.39
	R^2	.09**		.09***		.08***		.09***	

Note. N = 225. Six dyads were not included in the analysis because either their postcode or mathematics qualification was not reported.
* p <.05.
** p <.01.
*** p <.001.
[a] *Parental mathematics attribute* refers to the attitude or anxiety variable relevant to the model (e.g., Mathematics anxiety: Calculations in Model 1a, Mathematics anxiety: Budgeting in Model 1b). If analyses 1a to 1d are repeated excluding the 13 children identified as having special educational need or disability, all the direct associations between the mathematics attitudes and anxiety measures and children's attainment remain significant, with the direct associations between the home number experiences and children's mathematics attainment just missing conventional significance (p ranges from.05 to.09 for this direct association across the four analyses).

Table 7
Models examining the associations between parental mathematics anxiety and attitudes and children's mathematics attainment at T_{3b}, including preschool home number experiences as a potential mediating variable.

		Model 2a: Mathematics anxiety: Calculations		Model 2b: Mathematics anxiety: Budgeting		Model 2c: Mathematics attitudes: Feelings and competence		Model 2d: Mathematics attitudes: Interest and satisfaction	
		β	95% Confidence interval	β	95% Confidence interval	β	95% Confidence interval	β	95% Confidence interval
Direct effects									
	Parental mathematics attribute[a] → Math attainment (T_{3b})	−1.17	−3.39, 1.06	−0.38	−2.73, 1.97	1.94	−0.47, 4.35	2.28+	−0.17, 4.73
	Home number experiences (preschool, T_1) → Math attainment (T_{3b})	1.88	−1.27, 3.63	1.17	−1.29, 3.64	1.23	−1.20, 3.67	1.15	−1.27, 3.58
	Parental mathematics attainment → Math attainment (T_{3b})	−0.19	−2.33, 1.95	0.05	−2.06, 1.17	−0.49	−2.67, 1.69	−0.77	−3.01, 1.48
	Deprivation decile → Math attainment (T_{3b})	0.27	−0.47, 1.01	0.28	−0.47, 1.03	0.29	−0.45, 1.03	0.30	−0.43, 1.04
	Child mathematics attainment (T_2) → Math attainment (T_{3b})	0.78***	0.53, 1.00	0.78***	0.54, 1.02	0.78***	0.54, 1.01	0.76***	0.52, 0.99
Indirect effect	Parental mathematics attribute[a] → Home number experiences (preschool, T_1) → Math attainment (T_{3b})	0.02	−0.46, 0.34	0.06	−0.22, 0.40	−0.05	−0.47, 0.25	−0.00	−0.41, 0.36
	R^2	.32***		.32***		.33***		.34***	

Note. N = 114. Five dyads were not included in the analysis if either their postcode or mathematics qualification was not reported.
+p =.07.
*** p <.001.
[a] *Parental mathematics attribute* refers to the attitude or anxiety variable relevant to the model (e.g., Mathematics anxiety: Calculations in Model 2a, Mathematics anxiety: Budgeting in Model 2b). Repeating the analyses without including children's mathematics attainment (T_2) as a control variable does not change the pattern of significant predictors, with the exception that the direct association with Mathematics attitudes: Interest and satisfaction reaches conventional levels of significance (p <.05) (see Table S6 in supplementary material). However, if this analysis is repeated excluding the 6 children identified as having special educational need or disability, the direct association between the Mathematics attitudes: Interest and satisfaction and children's attainment does not reach conventional significance (p =.12).

Table 8
Models examining the associations between parental mathematics anxiety and attitudes and children's mathematics attainment at T_{3b}, including primary school home number experiences as a potential mediating variable.

		Model 3a: Mathematics anxiety: Calculations		Model 3b: Mathematics anxiety: Budgeting		Model 3c: Mathematics attitudes: Feelings and competence		Model 3d: Mathematics attitudes: Interest and satisfaction	
		β	95% Confidence interval	β	95% Confidence interval	β	95% Confidence interval	β	95% Confidence interval
Direct effects									
	Parental mathematics attribute[a] → Math attainment (T_{3b})	−0.99	−3.21, 1.24	−0.16	−2.51, 2.19	1.77	−0.64, 4.17	2.23+	−0.22, 4.67
	Home number experiences (primary school, T_{3a}) → Math attainment (T_{3b})	−1.76	−4.36, 0.81	−1.87	−4.46, 0.72	−1.75	−4.31, 0.82	−1.81	−4.36, 0.73
	Parental mathematics attainment → Math attainment (T_{3b})	−0.23	−2.35, 1.88	0.01	−2.08, 2.11	−0.53	−2.69, 1.62	−0.84	−3.05, 1.38
	Deprivation decile → Math attainment (T_{3b})	0.36	−0.38, 1.10	0.38	−0.37, 1.13	0.38	−0.36, 1.11	0.39	−0.34, 1.12
	Child mathematics attainment (T_2) → Math attainment (T_{3b})	0.79***	0.55, 1.02	0.80***	0.56, 1.03	0.79***	0.56, 1.02	0.77***	0.54, 1.00
Indirect effect	Parental mathematics attribute[a] T_1 → Home number experiences (primary school, T_{3a}) → Math attainment (T_{3b})	−0.15	−0.60, 0.12	−0.16	−2.51, 2.19	0.08	−0.27, 0.51	0.06	−0.49, 0.53
	R^2	.33***		.32***		.34***		.34***	

Note. N = 114. Five dyads were not included in the analysis if either their postcode or mathematics qualification was not reported.
+p =.07.
*** p <.001.
[a] *Parental mathematics attribute* refers to the attitude or anxiety variable relevant to the model (e.g., Mathematics anxiety: Calculations in Model 3a, Mathematics anxiety: Budgeting in Model 3b). Repeating the analyses without including children's mathematics attainment (T_2) as a control variable does not change the pattern of significant predictors, with the exception that the association with Mathematics attitudes: Interest and satisfaction reaches conventional levels of significance (p <.05) (see Table S7 in supplementary material). However, if this analysis is repeated excluding the 6 children identified as having special educational need or disability, the direct association between the Mathematics attitudes: Interest and satisfaction and children's attainment does not reach conventional significance (p =.12).

tors of children's mathematics attainment at T_2. Models 2a to 2d (presented in Table 7) indicated that only parental *Mathematics attitudes: Interest and satisfaction* approached statistical significance (p =.07) as a predictor of children's mathematics attainment at T_{3b}. When prior attainment was not included as a covariate, *Mathematics attitudes: Interest and satisfaction* was a significant predictor (p <.05) (see Table S6 in supplementary material). The association between preschool home number experiences at T_1 and children's mathematics attainment at T_{3b} did not reach statistical significance. Finally, Models 3a to 3d (presented in Table 8) indicated that primary school home number experiences at T_{3a} had null associations with children's mathematics attainment at T_{3b}.

The results in relation to Research Question 1 can be summarized as follows. The hypothesis that the frequency of preschool home number experiences was predictive of children's mathematics attainment was supported in regard to children's attainment at T_2 (when the children were in the first year of primary school). These associations were independent of parental mathematics attainment. However, these associations were no longer significant at T_{3b} (when the children were in the second year of primary school). As hypothesized, the frequency of primary school home number experiences assessed at T_{3a} was not predictive of children's mathematics attainment at T_{3b}. The hypothesis that parental mathematics anxiety and attitudes would predict children's mathematics attainment was supported in regard to children's attainment at T_2, but not in regard to their attainment at T_3 after accounting for T_2 attainment.

Research Question 2: Are any associations between parental mathematics anxiety and attitudes and children's mathematics attainment mediated by the frequency of home number experiences?

There were no indications that the associations identified between parental mathematics anxiety and attitudes and children's mathematics attainment were mediated by the frequency of home number experiences. The frequency of preschool home number experiences did not mediate the associations between parental mathematics anxiety and attitudes and children's mathematics attainment at T_2 given that none of the indirect effects between the parental mathematics anxiety and attitudes variables via the frequency of home number experiences was significant (see Models 1a to 1d presented in Table 6).

Research Question 3: Do parental anxiety and attitudes moderate any associations between the frequency of home number experiences and children's mathematics attainment?

Models 4a to 4d (presented in Table 9) examined whether the significant associations between preschool home number experiences and children's mathematics attainment at T_2 are moderated by parental mathematics anxiety or attitudes. There was no evidence of moderation given that the interaction terms were not statistically significant.

Models 5a to 5d (presented in Table 10) examined whether parental attitudes and anxiety moderated associations between primary school home number experiences and children's mathematics attainment at T_{3b}. In Model 5b, the interaction between *Mathematics anxiety: Budgeting* and the frequency of primary school home number experiences was a significant predictor of children's mathematics attainment. Further inspection of this moderation effect revealed that at 1 standard deviation below the mean of parental mathematics anxiety (β = − 4.03, p <.05, confidence interval [CI] = − 7.21, −0.85) and at the mean of parental mathematics anxiety (β = − 2.73, p <.05, CI = − 5.39, −0.70), there was a significant negative association between the frequency of home number experiences and children's mathematics attainment at T_{3b}. At 1 standard deviation above the mean (β = 1.38, p =.48, CI = − 2.46, 5.23), there was no significant association. When parents had low or moderate levels of mathematics anxiety relating to budgeting, more frequent primary school home number experiences were associated with lower levels of mathematics attainment. This moderated association is illustrated in Fig. 1.

The results with respect to Research Question 3 can be summarized as follows. The positive association between the frequency of preschool home number experiences and children's mathematics attainment at T_2 was not affected by either high parental mathematics anxiety or negative parental mathematics attitudes. Parental *Mathematics anxiety: Budgeting* did moderate the association between primary school home number experiences and mathematics attainment at T_{3b}. However, the nature of the moderation was not consistent with the prediction based on Maloney et al.'s (2015) findings.

Table 9
Models examining the associations between preschool home number experiences and mathematics attainment at T_2, including parental mathematics attributes as a potential moderating variable.

	Model 4a: Mathematics anxiety: Calculations		Model 4b: Mathematics anxiety: Budgeting		Model 4c: Mathematics attitudes: Feelings and competence		Model 4d: Mathematics attitudes: Interest and satisfaction	
	β	95% Confidence interval	β	95% Confidence interval	β	95% Confidence interval	β	95% Confidence interval
Home number experiences (preschool, T_1)	1.93*	0.46, 3.39	1.86*	0.40, 3.33	1.98**	0.53, 3.43	1.92**	0.47, 3.36
Parental mathematics attribute[a]	−1.61*	−3.01, −0.21	−1.71*	−3.12, −0.30	1.58*	0.18, 2.97	1.90**	0.47, 3.33
Home Number Experiences (preschool, T_1) × Parental Mathematics Attribute[a]	0.09	−1.65, 1.82	−0.28	−2.06, 1.50	0.24	−1.19, 1.66	−0.40	−1.71, 0.91
Parental mathematics attainment	0.87	−0.31, 2.04	0.97	−0.18, 2.12	0.83	−0.36, 2.03	0.65	−0.55,1.85
Deprivation decile	0.25	−0.71, 0.67	0.22	−0.20, 0.64	0.29	−0.14, 0.71	0.26	−0.16, 0.68
R^2	.09**		.09**		.08*		.09***	

Nots. N = 225. Six dyads were not included in the analysis because either their postcode or mathematics qualification was not reported.
* p <.05.
** p <.01.
*** p <.001.
[a] *Parental mathematics attribute* refers to the attitude or anxiety variable relevant to the model (e.g., Mathematics anxiety: Calculations in Model 4a, Mathematics anxiety: Budgeting in Model 4b) If analyses 4a to 4d are repeated excluding the 13 children identified as having special educational need or disability, all the direct associations between the mathematics attitudes and anxiety measures and children's attainment remain significant, with the direct associations between the home number experiences and children's mathematics attainment just missing conventional significance (p ranges from.05 to.09 for this direct association across the four analyses).

Table 10
Models examining the associations between primary school home number experiences and mathematics attainment at T_{3b}, including parental mathematics attributes as a potential moderating variable.

	Model 5a: Mathematics Anxiety: Calculations		Model 5b: Mathematics Anxiety: Budgeting		Model 5c: Mathematics Attitudes: Feelings & Competence		Model 5d: Mathematics Attitudes: Interest & Satisfaction	
	β	95% Confidence interval	β	95% Confidence interval	β	95% Confidence interval	β	95% Confidence interval
Home number experiences (primary school, T_{3a})	−1.78	−4.36, 0.81	−1.81	−4.35, 0.74	−1.77	−4.35, 0.81	−1.78	−4.42, 0.86
Parental mathematics attribute[a]	−1.16	−3.41, 1.09	−0.42	−2.74, 1.89	1.80	−0.63, 4.23	2.23+	−0.23, 4.68
Home Number Experiences (primary school, T_{3a}) × Parental Mathematics Attribute[a]	1.34	−1.18, 3.87	3.23*	0.37, 6.10	−0.33	−2.81, 2.15	0.56	−1.77, 2.89
Parental mathematics attainment	−0.22	−2.34, 1.89	−0.01	−2.08, 2.05	−0.54	−2.70, 1.63	−0.84	−3.07, 1.39
Deprivation decile	0.32	−0.42, 1.07	0.35	−0.39, 1.08	0.38	−0.36, 1.12	0.39	−0.36, 1.13
Child mathematics attainment (T_2)	0.77***	0.54, 1.01	0.78***	0.55, 1.01	0.79***	0.55, 1.02	0.77***	0.54, 1.01
R^2	.34*		.35***		.34***		.34***	

Note. N = 114. Five dyads were not included in the analysis if either their postcode or mathematics qualification was not reported.
+p =.07.
* p <.05.
*** p <.001.
[a] *Parental mathematics attribute* refers to the attitude or anxiety variable relevant to the model (e.g., Mathematics anxiety: Calculations in Model 5a, Mathematics anxiety: Budgeting in Model 5b). Repeating the analyses without including children's mathematics attainment (T_2) as a control variable does not change the pattern of significant predictors, with the exception that the direct association Mathematics attitudes: Interest and satisfaction reaches conventional levels of significance (p <.05) (see Table S9 in supplementary material). If analyses 5b and 5d are repeated excluding the 6 children identified as having special educational need or disability, the interaction identified in 5b remains significant, but the direct association between Mathematics attitudes: Interest and satisfaction and children's attainment no longer reaches conventional significance (p =.13).

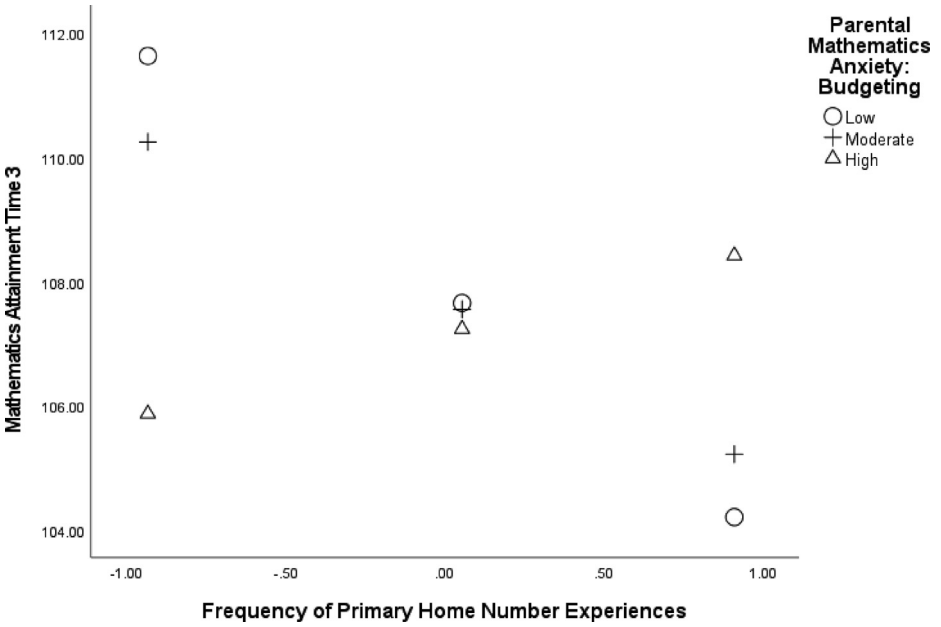

Fig. 1. Mean mathematics attainment at T_{3b} as a function of the frequency of primary number experiences and parental *Mathematics anxiety: Budgeting*. N = 114. When parents have low (b = − 4.03, 95% confidence interval (CI) [−7,21, −0.85], t = − 2.51, p <.05) or moderate (b = − 2.73, 95% CI [−5.39, −0.70], t = − 2.51, p <.05) mathematics anxiety relating to budgeting, there is a significant negative association between the frequency of primary school home number experiences and children's T_3 mathematics attainment, but there is no significant association when parents have high mathematics anxiety related to budgeting (b = 1.38, 95% CI [−2.46, 5.23], t = 0.71, p =.48).

Table 11
Models examining the associations between maternal mathematics attitudes and anxiety and mathematics attainment at T_2, including child gender as a potential moderating variable.

	Model 6a: Mathematics anxiety: Calculations		Model 6b: Mathematics anxiety: Budgeting		Model 6c: Mathematics attitudes: Feelings and competence		Model 6d: Mathematics attitudes: Interest and satisfaction	
	β	95% Confidence interval	*β*	95% Confidence interval	*β*	95% Confidence interval	*β*	95% Confidence interval
Maternal mathematics attribute[a]	−6.36*	−11.04, −1.68	−5.90*	−10.44, −1.35	3.37	−1.21, 7.95	2.44	−2.17, 7.04
Child gender	−1.09	−3.85, 1.66	−1.14	−3.90, 1.61	−1.07	−3.87, 1.73	−0.85	−3.65, 1.95
Maternal Mathematics Attribute[a] × Child Gender	3.05*	0.22, 5.87	2.74+	−0.17, 5.66	−1.42	−4.24, 1.41	−0.49	−3.32, 2.34
Maternal mathematics attainment	0.97	−0.33, 0.26	1.03	−0.24, 2.30	0.94	−0.41, 2.29	0.76	−0.59, 2.10
Deprivation decile	0.15	−0.30, 0.59	0.15	−0.29, 0.60	0.21	−0.24, 0.57	0.25	−0.20, 0.69
R^2	.08*		.08*		.05*		.06*	

Note. N = 211. Dyads with a male parent or for whom parental mathematics qualification or postcode was not reported were excluded.
+ p = 07.
* p <.05.

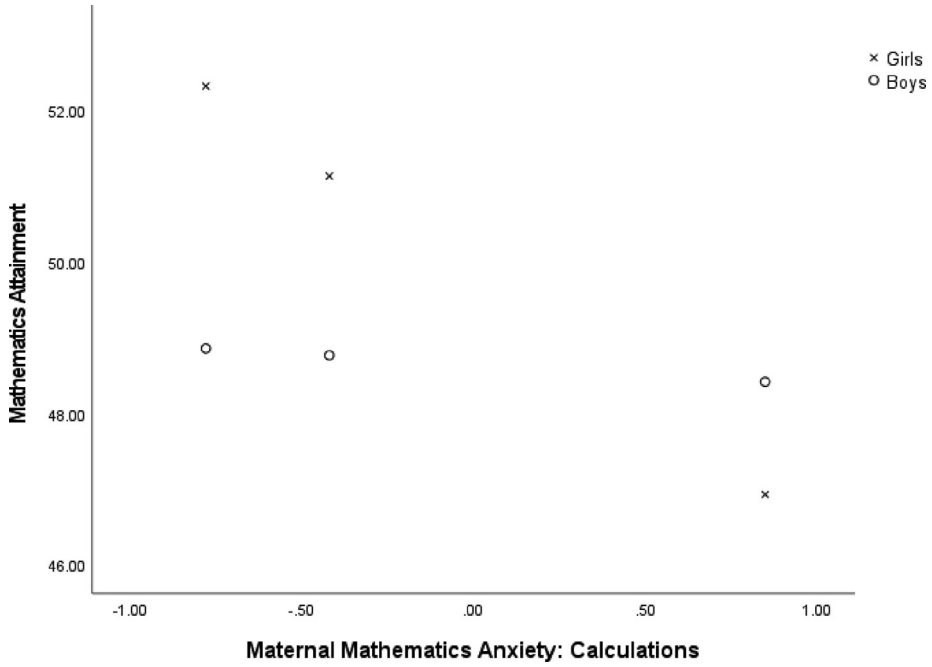

Fig. 2. Mean mathematics attainment at T_2 as a function of the maternal *Mathematics anxiety: Calculations* and child gender. $N = 211$. For girls, there is a significant negative association between maternal *Mathematics anxiety: Calculations* and children's mathematics attainment ($b = -3.32$, 95% confidence interval (CI) [−5.49, −1.14], $t = -3.01$, $p < .01$), but this association is not significant for boys ($b = -0.27$, 95% CI [−2.17, −1.63], $t = -0.28$, $p = .78$).

Rather than observing a negative association between home number experiences and children's attainment when parental mathematics anxiety was high, primary school home number experiences had a negative association with children's mathematics attainment when parental mathematics anxiety was low or moderate.

Research Question 4: Does parental mathematics anxiety predict children's mathematics anxiety during the early years of primary school?

The correlations (reported in Table 5) between parental mathematics anxiety and children's mathematics anxiety were small ($\leq .11$) and did not reach statistical significance. Furthermore, these associations remained nonsignificant within a regression accounting for parental and child mathematics attainment and postcode deprivation (see Table S9 in supplementary material). Consequently, in relation to Research Question 4, we can conclude that there is no evidence of transmission of mathematics anxiety from the parents to the children within this sample.

Research Question 5: Does children's gender moderate any associations between maternal mathematics anxiety and attitudes and children's mathematics attainment and anxiety?

Models 6a to 6d (presented in Table 11) examined whether the associations between maternal mathematics attitudes and anxiety and mathematics attainment at T2 were moderated by children's gender. There was no indication that children's gender moderated associations for either *Mathematics attitudes: Interest* and *satisfaction* or *Mathematics attitudes: Feelings and competence* given that neither interaction term reached statistical significance ($p = .74$ and $p = .32$, respectively). However, children's gender did moderate the association between *Mathematics anxiety: Calculations* ($p = .04$) and mathematics attainment, and there was a trend for it to also moderate the association between *Mathematics anxiety: Budgeting* ($p = .07$) and mathematics attainment. These interactions are illustrated in Figs. 2

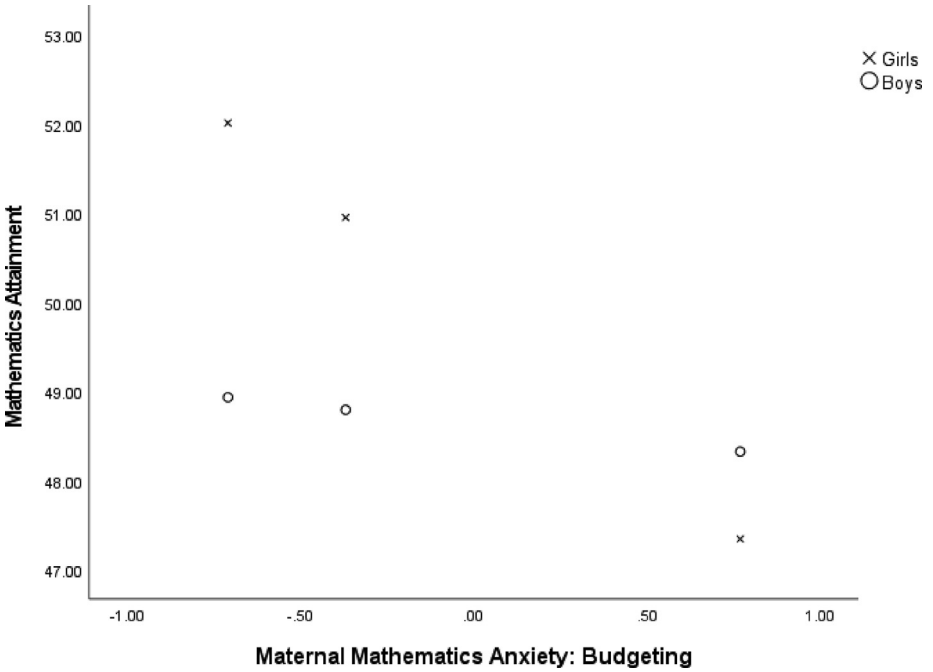

Fig. 3. Mean mathematics attainment at T_2 as a function of the maternal *Mathematics anxiety: Budgeting* and child gender. N = 211. For girls, there is a significant negative association between maternal *Mathematics anxiety: Budgeting* and children's mathematics attainment (b = − 3.16, 95% confidence interval (CI) [−5.19, −1.14], t = − 1.12, p <.01), but this association is not significant for boys (b = − 0.41, 95% CI [−2.56, −1.73], t = − 0.38, p =.70).

Table 12
Models examining the associations between maternal mathematics anxiety and mathematics attainment at T_2, including child gender as a potential moderating variable.

	Model 6a: Mathematics anxiety: Calculations		Model 6b: Mathematics anxiety: Budgeting	
	β	95% Confidence interval	β	95% Confidence interval
Maternal mathematics attribute[a]	0.10	−0.17, 0.97	0.31	−0.21, 0.82
Child gender	−0.31*	−0.62, −0.01	−0.31*	−0.62, −0.01
Maternal Mathematics Attribute[a] × Child Gender	−0.10	−0.39, 0.19	−0.20	−0.51, 0.11
Maternal mathematics attainment	0.00	−0.14, 0.14	0.01	−0.13, 0.15
Deprivation decile	0.01	−0.04, 0.06	0.01	−0.04, 0.06
R^2	.05		.06	

Note. N = 113. Dyads with a male parent or for whom parental qualification or postcode was not reported were excluded.
* p <.05.

and 3. For both maternal mathematics anxiety variables, there was a significant negative association between maternal mathematics anxiety and girls' (but not boys') mathematics attainment. Equivalent models examining whether the associations between maternal mathematics attitudes and anxiety and mathematics attainment at T_{3b} were moderated by children's gender can be found in the supplementary material (Table S10). There was no evidence of gender moderation within these models.

Models 7a and 7b (presented in Table 12) examined whether children's gender moderated associations between maternal mathematics anxiety and children's mathematics anxiety at T_4. Gender did

not moderate these associations given that neither interaction term reached statistical significance (p =.50 and p =.20, respectively). However, in both models gender was a predictor of children's mathematics anxiety. This reflects the finding that within the sample as a whole, girls had higher mathematics anxiety than boys [M_{girls} = 14.40, M_{boys} = 12.42, $F(1, 117)$ = 4.46, p =.04, η^2 =.04] despite no differences in mathematics attainment at either T_2 [M_{girls} = 49.72, M_{boys} = 49.01, $F(1, 229)$ = 0.27, p =.60, η^2 =.00] or T_3 [M_{girls} = 108.19, M_{boys} = 106.60, $F(1, 117)$ = 0.37, p =.55, η^2 =.00].

Discussion

The aim of the current study was to examine the associations between parental mathematics attitudes and anxiety and children's mathematics attainment. Addressing the call for studies to control for parental mathematics attainment (Becker et al., 2022), we demonstrated that the associations between parental mathematics attitudes and anxiety and children's mathematics attainment, in the first year of primary school, are independent of parents' mathematics attainment. Moreover, these associations were not mediated by the frequency of home number experiences. We reported novel analyses that extend the findings of Maloney et al. (2015) by demonstrating that associations between the frequency of preschool home number experiences and children's mathematics attainment are not moderated by parental mathematics anxiety or attitudes. Children's gender moderated the association between maternal mathematics anxiety and children's mathematics attainment in the first year of primary school. The association between maternal mathematics anxiety and girls' mathematics attainment was stronger than the association between maternal mathematics anxiety and boys' mathematics attainment.

Parental mathematics anxiety and attitudes and children's mathematics attainment

Parental mathematics anxiety and attitudes were associated with children's mathematics attainment, but not reading attainment, in the first year of primary school. This suggests that these parental attributes have a specific association with mathematics attainment but are not generally associated with children's academic attainment. These findings extend previous research (Becker et al., 2022; del Rio et al., 2017; Skwarchuk et al., 2014; Susperreguy et al., 2020) by demonstrating that associations between both parental mathematics anxiety and attitudes and children's mathematics attainment are independent of parental mathematics attainment. Although the inclusion of parental mathematics attainment in the statistical models increases the likelihood that parental mathematics anxiety and attitudes directly influence children's early mathematics attainment (see Becker et al., 2022), we acknowledge that causal links cannot be concluded solely on the basis of individual differences studies. Although it would seem unlikely, the possibility that the preschool children's mathematics attainment influences parents' mathematics anxiety and attitudes should be considered. Furthermore, factors outside of the measurement model may account for the association. Intervention studies, similar to those that have examined the impact of increasing the frequency of home number experiences (Niklas et al., 2016a, 2016b), are required to determine whether reducing parental mathematics anxiety or increasing positive parental mathematics attitudes is accompanied by improvements in children's mathematics attainment.

Home number experiences, parental mathematics anxiety and attitudes, and children's mathematics attainment

Consistent with previous studies (del Rio et al., 2017; Hart et al., 2016; LeFevre et al., 2010; Napoli & Purpura, 2018; Niklas & Schneider, 2014; Skwarchuk et al., 2014; Susperreguy et al., 2020), we demonstrated that the frequency of preschool home number experiences is a significant predictor of mathematics attainment in the first year of primary school. However, the association weakened and was no longer significant in the second year of primary school, and there were no significant associations between the frequency of primary school home number experiences and children's mathematics attainment. Although we are cautious in interpreting these later findings conducted with the

reduced samples at $T_{3\&4}$, they are consistent with previous studies that have reported null or negative associations between children's mathematics attainment and home number experiences indexed after primary schooling has commenced (Ciping et al., 2015; Silinskas et al., 2010; Susperreguy et al., 2022) and with Daucourt et al.'s (2021) meta-analysis indicating that associations are weaker in older samples. Together, these findings emphasize the need to explore further how the impact of home experiences varies at different developmental time points.

Parental mathematics anxiety and attitudes influencing the frequency of home number experiences

Although the frequency of preschool home number experiences predicted children's mathematics attainment in the first year of primary school, it did not mediate the associations between parental mathematics anxiety and attitudes and children's mathematics attainment. These findings are consistent with previous studies reporting null associations between parental mathematics anxiety and non-child-specific indices of mathematics attitudes and a similar lack of mediation (Missall et al., 2015; Skwarchuk et al., 2014). However, some recent studies that indexed relatively challenging home number experiences have reported significant associations and mediation (del Rio et al., 2017; Susperreguy et al., 2020). It may be that the frequency of home number experiences is associated with parental mathematics anxiety and attitudes only when the home number experiences indexed are particularly advanced or stretching for the age group studied. Susperreguy et al. (2020) reported associations between parental numeracy attitudes and the frequency of operational activities (focusing mainly on calculation skills), but not between parental numeracy attitudes and either the frequency of mapping activities (focusing mainly on counting and number recognition) or shared number game play. This suggests that the nature or challenge of the home number experiences influences the strength of its association with mathematics attainment. In the current study, the preschool home number experiences scale focused on counting, quantification, and number recognition and was very similar to the mapping activities scale employed by Susperreguy et al. (2020). Our primary scale had a greater focus on calculation skills, although these skills may be less stretching for the older age group. It may be that parents who have greater mathematics anxiety and negative mathematics attitudes are less likely to engage in stretching or challenging number experiences, but they might not be less likely to engage in more home number experiences per se.

Parental mathematics anxiety and attitudes influencing the effectiveness of home number experiences

In the moderated regressions predicting children's mathematics attainment in the first year of primary school, the interactions between the frequency of preschool home number experiences and parental mathematics anxiety or attitudes were not significant (Table 9). Because the positive associations between preschool home number experiences and children's mathematics attainment were not affected by either parental mathematics anxiety or parental mathematics attitudes, the findings do not suggest that these parental attributes influence the effectiveness of the preschool number experiences indexed in the current study.

These findings contrast with Maloney et al. (2015), who concluded that mathematics homework help was less effective when parents have high mathematics anxiety. It is likely that parental anxiety and attitudes exert less influence on the effectiveness of the preschool home number experiences examined in the current study than on help with school-prescribed homework. When supporting homework, parents must engage with the material set. The content of the homework may trigger parents' mathematics anxiety or negative mathematics attitudes and consequently make the situation stressful and less productive for their children. In contrast, when engaging in home number experiences such as those indexed in the current study, the parents can modify the experiences to their and their children's interests and avoid content that makes them anxious.

In the moderated regressions predicting children's mathematics attainment from the frequency of primary school home number experiences (Table 10), the only significant moderation effect indicated a negative association with children's mathematics attainment when parents had low or moderate levels of mathematics anxiety related to budgeting, but no significant association when parents had high levels of anxiety (Model 5b, illustrated in Fig. 1). This was unexpected given that negative associations were predicted to occur in the context of high parental anxiety because high levels of parental

anxiety could lead to home number experiences having a detrimental impact. One possible explanation for this finding is that parents who have low or moderate levels of mathematics anxiety respond to lower levels of mathematics attainment in their children with increased home number experiences, but parents who have high mathematics anxiety do not respond in this way. Their anxiety may be a barrier to them responding to their children's mathematics difficulties with increased support at home. Previous negative associations between the frequency of home number experiences and mathematics attainment have been interpreted as a parental response to children's lower achievement (Ciping et al., 2015; Silinskas et al., 2010, 2020). Given that this moderation effect is limited to one mathematics anxiety variable, it is important to be cautious when interpreting this finding. Future studies attempting replication of this effect are needed to test its generalizability.

Transmission of mathematics anxiety from parents to children

We identified no significant associations between parents' mathematics anxiety and attitudes and children's mathematics anxiety. When evaluating this finding, it is important to recognize that we indexed the mathematics anxiety of only one parent within each household and we did not ask about the nature of the parental relationship (i.e., whether the respondent was a biological parent, adoptive parent, or step-parent). Stronger associations may have been identified if the mathematics anxiety of all parents in the household were indexed. Furthermore, if parent-to-child transmission is primarily driven by the inheritance of a genetic predisposition to mathematics anxiety (see Wang et al., 2016), the association may have been stronger if the sample had been restricted to biological parents. Although these limitations are recognized alongside the relatively small sample of children reporting mathematics anxiety, the current findings are consistent with Maloney et al. (2015), who concluded that parental mathematics anxiety did not directly predict 7-year-olds' mathematics anxiety. Together our findings and those of Maloney et al. suggest that parent-to-child transmission of mathematics anxiety is weaker in younger children than during middle childhood and adolescence (Casad et al., 2015; Ma et al., 2021; Soni & Kumari, 2017; Vanbinst et al., 2020).

The role of gender

Consistent with the findings of Casad et al. (2015) and De Keyser et al. (2020), children's gender moderated the association between maternal mathematics anxiety and children's mathematics attainment in the first year of primary school but did not moderate the association with maternal mathematics attitudes. The difference in the impact of gender on these associations cannot be attributed to differences in age or cultural context. Therefore, these findings strengthen the argument that children's gender has a stronger influence on the associations between maternal mathematics anxiety and children's attainment than between maternal mathematics attitudes and children's attainment.

There are two possible explanations for children's gender moderating the association between maternal mathematics anxiety and children's mathematics attainment. The first is that girls' mathematics attainment is more susceptible to the influence of maternal mathematics anxiety than boys' mathematics attainment because girls identify with and emulate their mothers more than boys do (see Casad et al., 2015, for a discussion of this mechanism). The second is that girls are affected by parental mathematics anxiety to a greater extent than boys, regardless of the gender of the parent. We could not distinguish between these hypotheses because we did not have sufficient male parental respondents. In common with the current study, most previous studies indexed only one parent in the household, with most of these responding parents being female (Becker et al., 2022; Casad et al., 2015; De Keyser et al., 2020; Ma et al., 2021; Maloney et al., 2015; Missall et al., 2015; Retanal et al., 2021; Skwarchuk et al., 2014; Soni & Kumari, et al., 2017; Susperreguy et al., 2020). Although some of these studies included sufficient paternal respondents to compare associations between male and female parents (e.g., Casad et al., 2015; De Keyser et al., 2020), they still cannot directly compare associations between mothers and fathers from the *same households.* To effectively advance our understanding of the influence of gender on these associations, future research needs to build on the studies of del Rio et al. (2017) and Vanbinst et al. (2020), where both parents in two-parent households were surveyed.

Girls in this sample had higher levels of mathematics anxiety than boys. Although this contrasts with some null reports of gender differences in primary-school-aged children (Dowker et al., 2012; Harari et al., 2013; Wu et al., 2012), it is consistent with many studies reporting higher mathematics anxiety in females (see Dowker et al., 2016, and Stoet et al., 2016, for reviews). Despite this, we did not find evidence that associations between maternal mathematics anxiety and children's mathematics anxiety were stronger for girls than for boys.

The search for an alternative underpinning mechanism

Our findings do not provide support for any of the three mechanisms postulated to underpin the association between parental mathematics anxiety and attitudes and young children's mathematics attainment. Parents with greater mathematics anxiety and more negative mathematics attitudes did not engage in less frequent preschool or primary school home number experiences, and the positive association between the frequency of preschool home number experiences and children's early mathematics attainment was not moderated by high parental mathematics anxiety or negative mathematics attitudes. There was also no strong evidence for the parent-to-child transmission of mathematics anxiety in this young age group. Given that these mechanisms were not supported by the data, alternative mechanisms that could underpin the association need to be considered.

One possibility, outlined above, is that parents with greater mathematics anxiety and more negative attitudes do not avoid engaging in home number experiences in general but rather engage in fewer number experiences that are challenging or stretching for their children. Similarly, high parental mathematics anxiety or negative mathematics attitudes may moderate the associations between more challenging home number experiences and children's mathematics attainment but not between less challenging home number experiences and children's mathematics attainment. To investigate these possibilities, future studies need to build on the findings of Susperreguy et al. (2020) and directly compare the associations between parental mathematics anxiety and attitudes and more or less challenging home number experiences. Furthermore, they might explore whether parental mathematics anxiety and attitudes differentially moderate the associations between more or less challenging home number experiences and children's mathematics attainment. Another possibility is that parental mathematics anxiety and attitudes do not influence either the frequency or effectiveness of home number experiences or children's mathematics anxiety but rather influence children's classroom engagement. The children of parents who have lower mathematics anxiety and more positive mathematics attitudes may view school mathematics as more interesting, satisfying, or important and thus engage more with mathematics lessons at school, resulting in greater progress (see Quintero et al., 2022, and Wang et al., 2016, for a discussion of the impact of classroom engagement on mathematics attainment).

Although highly speculative at this stage, an influence mediated by children's engagement with mathematics lessons at school would be consistent with the strengthening association between parents' mathematics attitudes and children's attainment as children move from preschool to primary school. Consistent with previous null associations between parental mathematics attitudes and preschoolers' number skills (De Keyser et al., 2020; Missall et al., 2015), we previously reported that the concurrent associations between the parental mathematics attitudes scales (used in the current study) and six number skills assessed during preschool were small ($rs \leq .12$), with only one of the associations reaching statistical significance (Soto-Calvo et al., 2020). In contrast, the associations reported in the current study between these scales and children's mathematics attainment assessed in the first year of primary school are stronger and statistically significant. These stronger associations may be underpinned by parental mathematics attitudes influencing children's engagement with mathematics lessons once the children start school. Whether parental mathematics anxiety and attitudes influence children's engagement with mathematics at school is an important area for future investigation.

Limitations and future directions

Although the current study advances our understanding of the associations between parental mathematics anxiety and attitudes and children's attainment, we acknowledge some limitations. First, we recognize that both parental and child mathematics anxiety and attitudes and the frequency of

home number experiences were assessed using self-report questionnaires. Self-report measures may be limited by social desirability bias and participants' ability to accurately reflect on their own anxiety and attitudes and experiences. Some studies suggest that parental reports of home number experiences are not always consistent with the behavior recorded during observations (Missall et al., 2017) or reported in interviews (Elliott et al., 2020). However, there is evidence supporting the validity of self-report mathematics anxiety scales in young children (Lu et al., 2021; Primi et al., 2020), mathematics anxiety and attitudes scales in adults (Lim & Chapman, 2013; Suinn & Winston, 2003), and the validity of parental reports of home number experiences (Daucourt et al., 2021). Future triangulation of the data, from studies using additional methods to index mathematics anxiety and attitudes and the frequency and nature of home number experiences, would strengthen the conclusions. For children's mathematics anxiety and attitudes, this could include using teacher ratings of anxiety and attitudes or the analysis of alternative assessments of child anxiety, for example, children drawing themselves doing mathematics (this technique has been used to assess anxiety within a health context; see Clatworthy et al., 1999, and Guner Onur et al., 2020). Additional methods of indexing home number experiences could include interviews (Elliott et al., 2020) and observations (Berkowitz et al., 2021; Missall et al., 2017; Susperreguy & Davis-Kean, 2016). Observations of parent–child number experiences would enable researchers to consider directly whether the nature of parent–child number interactions differed between parents who differed in terms of mathematics anxiety and attitudes.

Second, the majority of our sample reported White ethnic heritage. The extent to which associations between parental mathematics attitudes and behaviors and children's achievement are consistent in participants with differing ethnic heritages has received only limited empirical scrutiny (see Hornburg et al., 2021; Mutaf-Yıldız et al., 2020). Therefore, further studies are needed to examine the associations in samples that represent different ethnicities.

Third, we recognize that parental anxiety and attitudes were reported by only one parent, with most responding parents being female. As noted above, our understanding of the role of gender in moderating the associations between parent and child mathematical attributes and our understanding of transmission of mathematics anxiety from parents to children would be enhanced by further studies that include all parents within the participating households. Furthermore, the dataset would be enhanced by the collection of further information about the dyads. This could include information relating to the nature of the relationship (i.e., whether the respondent was the biological parent), the extent of the respondent's caregiving input, and the strength of the parent–child relationship. These factors may influence the strength of associations between parental mathematics anxiety and attitudes and children's mathematics attainment (see Ma et al., 2021, and Vanbinst et al., 2020, for discussions of these issues).

Fourth, we recognize that although the associations between both parental mathematics anxiety and attitudes and T_2 mathematics attainment are consistent when children with SEND are excluded or included, the exclusion of SEND children has an impact on some other associations. When children with SEND are excluded, the association between the frequency of preschool home number experiences and T_2 mathematics attainment just misses conventional significance levels (p <.10) (see Table 6). This difference may occur because the removal of children with a SEND classification restricts the variability of attainment and reduces the power of the analyses due to the restricted sample size. Alternatively, there may be significant differences in the associations between the parental and child factors studied in SEND and typically developing populations. This would be an important area for future work to explore.

Finally, we acknowledge that there is significant attrition of participants from T_2 to T_3. This means that the analyses involving the frequency of primary school home number experiences at T_{3a}, children's mathematics attainment at T_{3b}, and children's mathematics anxiety at T_4 are conducted using less powerful samples than the other analyses. This can be quantified using post hoc power analyses. The effect sizes for the regression models predicting mathematics attainment at T_2 range from R^2 =.08 to R^2 =.09 (see Tables 6 and 9). These five predictor regression models, with a sample size of 225, have a power of.96. Using the same models to identify the same size effect at T_3 with a sample size of 114 results in a power of.70 or.68 with the additional predictor of T_2 mathematics attainment added. We recognize that the $T_{3\&4}$ samples have reduced power and therefore are cautious in drawing conclusions solely from these data. Furthermore, there are small differences in the characteristics of the sam-

ple retained to these later time points (e.g., slightly lower mathematics attitudes and higher mathematics anxiety; see Table 3). The null associations between the predictor variables and the T_3 measures of children's mathematics attainment and anxiety may be influenced by this reduced power and small changes in sample characteristics. Despite these issues, presenting data from the later time points is valuable. It extends the very limited research investigating the transmission of mathematics anxiety and attitudes from parents to their young children (Maloney et al., 2015) and adds a longitudinal perspective to existing research by examining the associations between parental mathematics anxiety and attitudes and both the frequency of home number experiences and children's attainment at two time points. Further investigations of the associations involving measures at T_3 and T_4 in larger samples should be a priority. These should include cross-sectional and longitudinal studies examining the extent to which the associations between parental mathematics anxiety and attitudes and children's mathematics anxiety change across development.

Conclusion

Findings from the current study extend the extant literature by demonstrating that the association between parental anxiety and attitudes and children's attainment in the first year of primary school is independent of parental mathematics attainment. Furthermore, we demonstrate that negative parental mathematics attitudes and high mathematics anxiety do not weaken the positive association between preschool home number experiences and children's mathematics attainment in the first year of primary school. The mechanism that underpins the association between parental mathematics anxiety and attitudes and children's mathematics attainment remains unclear, but potential candidates for further investigation include whether parents with positive mathematics attitudes and low mathematics anxiety differ in the challenge of the home experiences they offer or inculcate greater engagement in school mathematics lessons in their children.

Data availability

The authors do not have permission to share data.

Acknowledgments

This project was funded by the Nuffield Foundation, but the views expressed are those of the authors and not necessarily those of the foundation (EYP/42410 and EDO/43747). We thank the educators, children, and parents who participated in the project.

Appendix A. Supplementary material

Supplementary analyses referred to in this article can be found online at https://doi.org/10.1016/j.jecp.2023.105779.

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