National Research and Development Centre
for adult literacy and numeracy

The intergenerational transfer of numeracy skills

Research report

Prepared for NIACE by the National Research and Development Centre for Adult Literacy and Numeracy (NRDC) at the Institute of Education (IOE), University of London

Contact:
David Mallows
Director, of Research, National Research and Development Centre for Adult Literacy and Numeracy, Institute of Education
20 Bedford Way, London WC1H 0AL
T: +44 (0) 20 7612 6592
E: d.mallows@ioe.ac.uk

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University of London

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Report authors:

JD Carpentieri
Senior Policy & Research Officer, NRDC

Olga Cara
Senior Research Officer, NRDC

Jenny Litster
Senior Project and Business Development Officer, NRDC

National Research and Development Centre for Adult Literacy and Numeracy,
Institute of Education, University of London

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Executive summary

I. The purpose of this report is to investigate the intergenerational transmission of numeracy, that is, the relationship between parent and child numeracy skills. It was undertaken by the National Research and Development Centre for Adult Literacy and Numeracy (NRDC) as part of a suite of studies on numeracy commissioned by the National Institute for Adult and Continuing Education (NIACE).

II. This study builds on earlier work by de Coulon et al (2009) for the NRDC which analyses data from the 1970 British Cohort Study (BCS70) to assess the impact of parents' basic skills in literacy and maths on their children's cognitive outcomes. The current study uses data from BCS70 to investigate the specific role of the impact of parents' numeracy on their children's numeracy.

III. Analysis was performed on a "Parent and Child" subsample of the BCS70 dataset, consisting of 2,246 parents (cohort members) and their children (3, 466 in total) who were aged 3-16 in 2004. In particular, this study makes use of results from a numeracy assessment cohort members completed at the age of 34 (in 2004) and emergent numeracy (ages 3-5) and numeracy (ages 6-16) tests completed by their children in that year.

IV. Relationships between parental numeracy and child numeracy are explored using bivariate analysis and regression analysis. Drawing on previous research, analytical models include explanatory variables such as socioeconomic factors; home environment, including parent-child behaviours and interactions; and parental cognitive ability. Analysis is performed separately for parents and younger children (age 3-5) and parents and older children (6-16).

V. Bivariate analyses produces surprising results – for example, school-aged children of parents with qualifications at Level 3 and above had lower average numeracy scores than children of parents with qualifications at Level 2 and below. However, in controlling for other factors through OLS regression, all of these surprising results disappear.

VI. Using regression analysis this study finds strong evidence for an intergenerational numeracy effect, separate from and generally stronger than the effects of a host of other factors. When parents have better numeracy, their children also tend to have better numeracy, even when controlling for a wide range of potentially confounding factors.

VII. Higher parental numeracy levels are associated with higher child numeracy scores, even when controlling for all relevant factors available in the dataset. In other words, even if two parents have the same income, occupational status, qualifications, and so on, if one parent has a higher numeracy level, his or her child is likely to have a higher numeracy score.

VIII. This study also finds a greater association between fathers' numeracy skills and those of their children. In particular, there is a relatively strong relationship between the numeracy skills of fathers and their school-aged children.

IX. For young children, parental numeracy levels appear to have a greater impact on the highest scoring children. This is reversed for older children: the relationship between parent and child numeracy is strongest for children whose scores were closer to the bottom of the distribution

1. Introduction

This report investigates the intergenerational transmission of numeracy, that is, the relationship between parent and child numeracy skills. It was undertaken by the National Research and Development Centre for Adult Literacy and Numeracy (NRDC) as part of a suite of studies on numeracy commissioned by the National Institute for Adult and Continuing Education (NIACE).

A wide range of international research focuses on the intergenerational transmission of educational advantage and disadvantage. Children of more highly-educated parents tend to perform better on cognitive tests and to achieve higher levels of qualifications (de Coulon et al 2009; Sutton Trust, 2010). This intergenerational transfer appears to be driven by a number of factors, including social inequality (Waldfogel & Washbrook, 2011), socio-economic advantage/disadvantage (Bradbury et al, 2012), cultural capital (Bourdieu 1986; Reay, 1998; Lareau, 2003); parental cognitive ability (Crawford et al, 2010) and home learning environment (Desforges, 2003; Melhuish et al., 2008).

Other research analyses the intergenerational transmission of cognitive skills. Crawford et al (2010), for example, investigated the relationship between parents' cognitive skills, their children's cognitive skills, and family socio-economic status. Using a composite measure combining literacy and numeracy skills, de Coulon et al (2009) analysed the relationship between parents' basic skills (as assessed in adulthood) and the cognitive skills of their children. Some studies focus on the intergenerational transmission of specific cognitive skills such as literacy; however, such research tends to focus on the impact of parental or family literacy practices (e.g. parent-child book reading) on children's literacy skills, rather than the relationship between parent and child literacy skills per se (Carpentieri et al, 2011).

Far less is known about the intergenerational transmission of numeracy. In one of the few studies on this topic, Brown et al (2009) used birth cohort data from the National Child Development Study (NCDS) to investigate intergenerational relationships in educational attainment in reading and in mathematics. Exploring the link between cohort members' literacy and numeracy test scores at age 7 (in 1965) and the test scores of their children in 1991, when these children were 5 or older, Brown et al found that the performance of the parents in their sample in mathematics as a child had a positive association with their child's performance. Although this association was far weaker than the association observed for reading, it was statistically significant. Adding child and family controls did not change this relationship. In discussing their findings, Brown et al hypothesised that, while parenting practices appeared to influence child literacy, genetic factors might have a pivotal role to play in the inter-generational transmission observed in numeracy.

In addressing the evidence gap on intergenerational transmission of numeracy, the current study builds on existing analyses of cognitive skills, particularly that of de Coulon et al (2009), whose report National Research and Development Centre for Adult Literacy and Numeracy (NRDC) provides the foundation for this work. This study, however, focuses specifically on the relationship between parents' numeracy skills and those of their children.

2. Methodology

2.1 Data and sample

As in de Coulon et al (2009) – and also Crawford et al (2010) – this study analyses data from the British Cohort Study (BCS70), a birth cohort study which follows the lives of more than 17,000 individuals born in England, Scotland and Wales in a single week in April, 1970. Data were collected when cohort members were born, and follow-up interviews were conducted at ages 5, 10, 16, 26, 30, 34, 38 and, most recently, 42. Coverage includes key indicators of circumstances and experience relevant to life stage and ranges widely over family life, education, health and citizenship.

For this study, researchers made particular use of two assessments: (i) a comprehensive basic skills assessment taken by all cohort members at age 34 (in 2004) which included a numeracy test, and (ii) a numeracy or emergent numeracy test given to the children of cohort members in the same year.

To gather intergenerational data on a wide range of topics, including literacy and numeracy (Bynner and Parsons 2006), a “Parent and Child” sub-sample was drawn. Of the 9,665 cohort members in the full BCS70 dataset in 2004, 4,792 were randomly selected into the “Parent and Child” survey. Of these, 2,246 had at least one child who was aged 3-16 and completed a numeracy assessment[1]. This group of 2,246 parents (and their children) is the subject of this paper’s analysis.

Of the 1359 children aged 3-5 in this sample, 1226 completed the Early Number Concepts assessment. 2240 children and young people aged 6-16 completed the Number Skills assessment (out of a sample of 2522 children in this age group). Therefore total of 3466 children (and 2246 parents) are included in our analysis.

One limitation of the following analysis is that no data are available on the non-cohort member parent of these children. While models control for overall family income (and thus the income impact of both parents), the impacts on children of the other (i.e. non-cohort member) parent’s cognitive traits and parenting practices cannot be investigated. As Brown et al (2009) note, such impacts may be significant. For example, assortative mating may lead more cognitively able cohort members to partner with other highly able individuals;

[1] Female cohort members made up 61% of the adults in the Parent and Child survey; this is in keeping with the tendency of females to become parents younger than males (Bynner and Parsons, 2006). The 2,246 parents in the “Parent and Child” sub-sample had a total of 5,207 children aged 0 to 16 years. Of these children, only those aged between 3 and 16 undertook numeracy assessments; therefore only children aged 3-16 (and their parents) our included in our study.

this could then increase the potential in some families for genetic transmission of high cognitive ability.

2.2 Measure of parental numeracy skills

In 2004, 9,665 cohort members had their numeracy (and literacy) skills assessed using standardised tests. The numeracy assessment instrument combined open-response, paper-based questions previously used to assess the functional numeracy skills of cohort members at age 21 with multiple-choice computer-based questions extracted from the 2002-3 Skills for Life Survey (SFL2003). To obtain as balanced a set of questions as possible in relation to curriculum coverage and difficulty levels, the final instrument was made up of five questions set at Entry Level 2, four at Entry Level 3, five at Level 1 and three at Level 2 (17 in total).

This study uses the 17 questions in the computer-based assessment as the main measure of numeracy. Seven aspects of number skill from the numeracy curriculum were assessed: Basic Money (BM); Whole Numbers and Time (NT); Measures and Proportion (MP); Weights and Scales (WS); Length and Scaling (LS); Charts and Data (CD), and Money Calculations (MC). The questions were presented in order of difficulty within each curriculum topic.

For numeracy, computation of an overall score was straightforward as all cohort members completed all questions. Any correct answer was given “1” point, any incorrect answer “0” points. The maximum numeracy score available from the multiple-choice questions is therefore within the range 0 to 17 for all cohort members.

For detailed discussion of the instrument used see Parsons (2012).

2.3 Measure of child numeracy skills

Data on children’s numeracy skills are derived from the British Ability Scale Second Edition (BAS II), a set of individually administered, age-specific tests of cognitive abilities (Bynner and Parsons, 2006). In 2004, children aged 3-5 were given the “Early Years” set, which included one test of emergent numeracy, the Early Number Concepts assessment. This assessment uses child-friendly art work and manipulable objects to assess a range of cognitive abilities, including an understanding of early number concepts: knowledge of, and problem solving using, pre-numerical and numerical concepts (Bynner and Parsons, 2006). For example, three questions referred to an illustration of ladybirds in the test booklet. On one half of the page were several yellow ladybirds; on the other half were several red ladybirds. The interviewer pointed to a particular yellow ladybird, then asked the child to point to all the red ladybirds that had the same number of spots as that yellow one[2].

Children aged 6-16 were given the “School Years” set from BAS II, which also included one numeracy test, the Number Skills assessment, which tests skills such as arithmetic calculations.

For both age groups, raw test scores – the number of correct answers – were converted to ability scores – a measurement which reflects the raw score and the difficulty of those questions[3].

2.4 Analytical strategy

To investigate the relationship between parent and child number skills, this study looks first at correlations between children’s numeracy scores and a range of parental characteristics that may influence these scores.

2.4.1 Variables of interest

Other studies identify a number of characteristics that are associated with children’s educational outcomes: parental gender; whether the child is first-born; the number of siblings the child has; the parent’s age at the child’s birth; whether the parent is a lone parent; whether the parent receives state benefits; and household income.

As well as these socio-economic factors, analysis for this study included a number of home/parenting factors that could conceivably influence child numeracy performance. As emphasised by Desforges and Abouchaar (2003), Feinstein et al (2004) and Michael (2005), children’s cognitive outcomes are heavily affected by the home environment, including parent-child behaviours and interactions.

First, a variable was included indicating how often the parents in the sample read to the children, where the measurement was frequency of child-parent reading (where children were aged nine or below). There is a rich literature showing that more frequent parent-child reading is correlated with better cognitive outcomes for children (see e.g. Feinstein *et al* 2004). While it is logical that parent-child reading would have an impact on child literacy skills, it

[2] This paper refers to young children’s “numeracy” skills; however, this is for ease of expression only. In the BAS II, children aged 3-5 were tested on emergent numeracy skills.

[3] In the School Years tests, for example, test items were ordered from easiest (Question 1) to hardest. While six-year-olds started at Question 1, older children started with a later question; therefore a six-year-old and an 11-year-old (for example) could get the same number of questions right but have different ability scores. However, the tests were not age-normalised so that average ability scores were consistent across all ages: older children had, on average, higher ability scores. More detail is available in Bynner and Parsons, 2006.

may also influence overall child development, including cognitive skills such as numeracy.

A number of studies find correlations between the warmth of the interactions between parents and children and the cognitive outcomes of those children (see Feinstein et al, 2004, p. 25). Other research (see de Coulon et al, 2009) finds that parent-child conflict can have a negative effect on children's cognitive development. For example, Michael (2004, 2005) finds that parental "caring" behaviours during pregnancy and the child's early years are associated with improved cognitive outcomes.

Models used in this study therefore include measures of parenting warmth and of parent-child conflict, using, as in de Coulon et al (2009), the first and second principal component from the *Child–Parent Relationship Scale* (Pianta: Short Form) for these variables.

Finally, the dataset used in this study allows analysis that controls for the cohort member parent's cognitive ability. It is likely that a key factor influencing children's cognitive abilities, including their numeracy, is genetic inheritance. Children are likely to inherit some of their parents' innate abilities, thereby influencing the intergenerational transmission of numeracy skills. While it is not possible to measure and control for genetic inheritance of cognitive abilities, it is possible to draw on the BCS70's rich data; in particular, all cohort members' undertook a cognitive assessment at age five. This assessment included tests on vocabulary, copying designs, human figure drawing and profile recognition (Crawford et al, 2010). Incorporating data from these tests allows researchers to at least partially control for the cohort members' (i.e. parents') cognitive abilities, and thus the genetic inheritance of these abilities by their children (Tyler, 2004; Crawford et al, 2010).

2.4.2 Bivariate analysis

Initially, parental factors are considered one at a time in bivariate analysis which compares the relationship between one factor (e.g. parent numeracy) with another (e.g. child numeracy).

Bivariate correlations illustrate the apparent relationships between child numeracy and parental characteristics, including occupation, household income and home learning environment, but not always the true ones. This is because the comparison of child numeracy to one parental factor at a time does not take account of the fact that parental factors are often related. It can appear, for instance, that parents' education levels are a key determinant of child numeracy skills; however, closer investigation may show that other factors related to parental education – e.g. family income – are the primary drivers of child numeracy skills.

2.4.3 Regression analysis

To take account of this, a statistical technique called OLS regression is used to estimate the correlation between two factors, taking account of (controlling for) other factors. The dependent (explained) variable is the child's numeracy outcome, i.e. the age 3-5 and 6-16 tests scores. The dependent variable is explained by (regressed on) a series of explanatory variables; because the main focus of this study's analysis is the link between parent and child numeracy, all other explanatory variables other than parents' basic skills are treated as control variables only. Through regression the true association between parent and child numeracy can be isolated. In effect, it allows researchers to construct an equation such as this: "If parents are exactly alike in all relevant ways except for their numeracy, how do those differing numeracy skills appear to be related to their children's numeracy?" In this study regression analyses are performed both for children in general and for specific sub-groups of children, such as those whose parents have limited education.

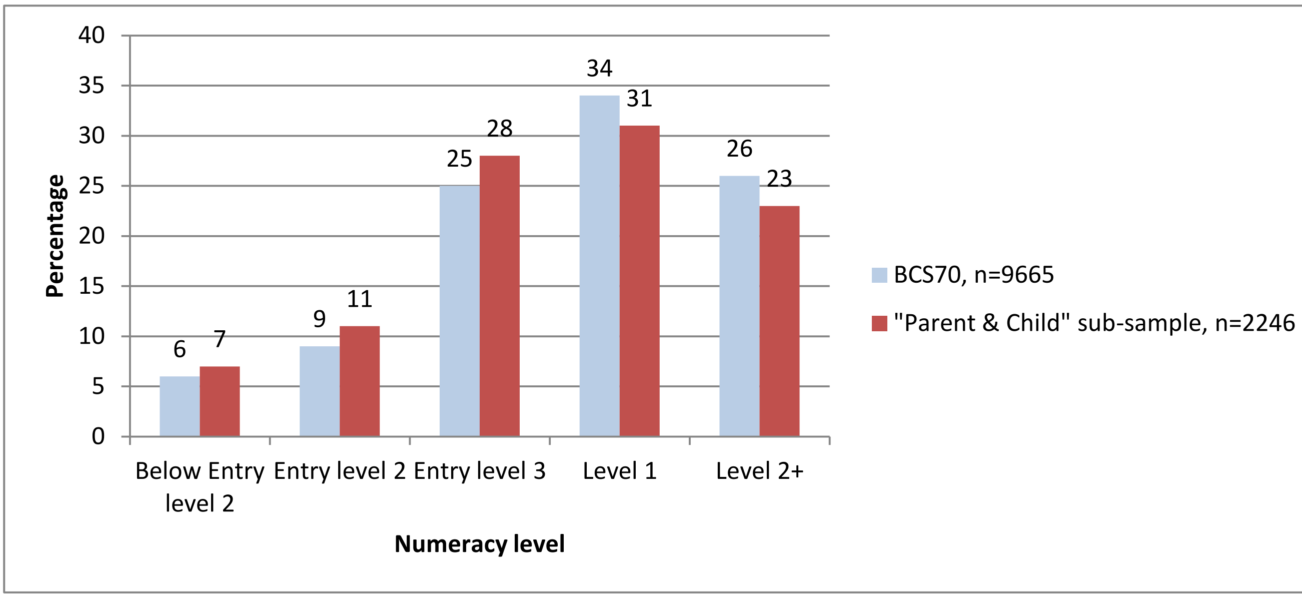
3. Data description

3.1 Parents' numeracy skills

Figure 1 illustrates the full distribution of numeracy levels for BCS70 cohort members at age 34. In BCS70 as a whole, 15% of individuals have skills below Entry level 3, the level considered the minimum required to function effectively in modern society (Leitch, 2006), and a further 25% have skills at Entry level 3. A third (34%) of the sample achieved Level 1 and 26% achieved at Level 2[4].

Figure 1 also shows the distribution for the BCS70's "Parent and Child" sub-sample. Parents in this sub-sample were more likely than other BCS70 cohort members to have Entry level numeracy, and less likely to have Level 1 or Level 2 skills. The poorer literacy skills of cohort members in the "Parent and Child" sub-sample is consistent with evidence that adults with poor skills tend to have children at a younger age than adults with better skills (Parsons and Bynner, 2007).

Figure 1: Numeracy levels, 2004: full BCS70 sample and "Parent & Child" sub-sample



In the BCS70, parents' numeracy skills were fairly well correlated with their education levels. Table 1 shows parents' highest qualification level (academic or vocational) as of 2004, and the relationship between these qualification levels and numeracy skills. Parents with high levels of qualifications tended to

[4] While the test did not seek to measure numeracy skills above Level 2, it can be surmised that some parents had skills above this level; therefore, throughout this document, we refer to this category as "Level 2 and above".

have good numeracy. For example, only 6% of parents with Level 4 qualifications (i.e. degree level) had numeracy skills below Entry level 3. Parents with low or no qualifications had poorer numeracy. This was particularly true for parents with no qualifications: 40% had numeracy skills at Entry level 2 or below. While numeracy and qualifications do appear to be correlated, there is significant variation in numeracy levels among cohort members with low or no qualifications. This suggests that numeracy is developed through a range of activities, not just education, and an individual with no qualifications may still have reasonable, or even very good, numeracy skills.

Table 1: Parents' numeracy skills, based on their highest qualification, 2004

Highest qualification			**Numeracy level**					
	N	***% of all parents***	**% with < Entry 2 numeracy**	**Entry 2**	**Entry 3**	**Level 1**	**Level 2+**	**Total %**
No qualifications	*201*	*9*	21	19	37	14	7	100
Level 1 (e.g. CSE, low GCSEs)	*691*	*31*	8	15	36	29	12	100
Level 2 (e.g. good GCSEs, NVQ2)	*513*	*23*	6	13	28	30	23	100
Level 3 (e.g. A-levels)	*269*	*12*	6	7	23	38	26	100
Level 4 (e.g. Degree)	*461*	*21*	2	4	19	37	38	100
Level 5 (e.g. MSc, PhD)	*110*	*5*	0	2	13	35	51	100
Total	*2245*	*100*						

3.2 Child numeracy skills

Table 2 provides a brief overview of children’s performance on the two age-specific numerical assessments, showing the mean score and standard deviation for each age group. Because these two tests have different scales, they are not directly comparable.

Table 2: Children's ability scores

Child age	Number of children	Test	Mean score	Std. Dev.
3-5	1226	Early Number Concepts	124	26
6-16	2240	Number Skills	107	32
Total	**3466**			

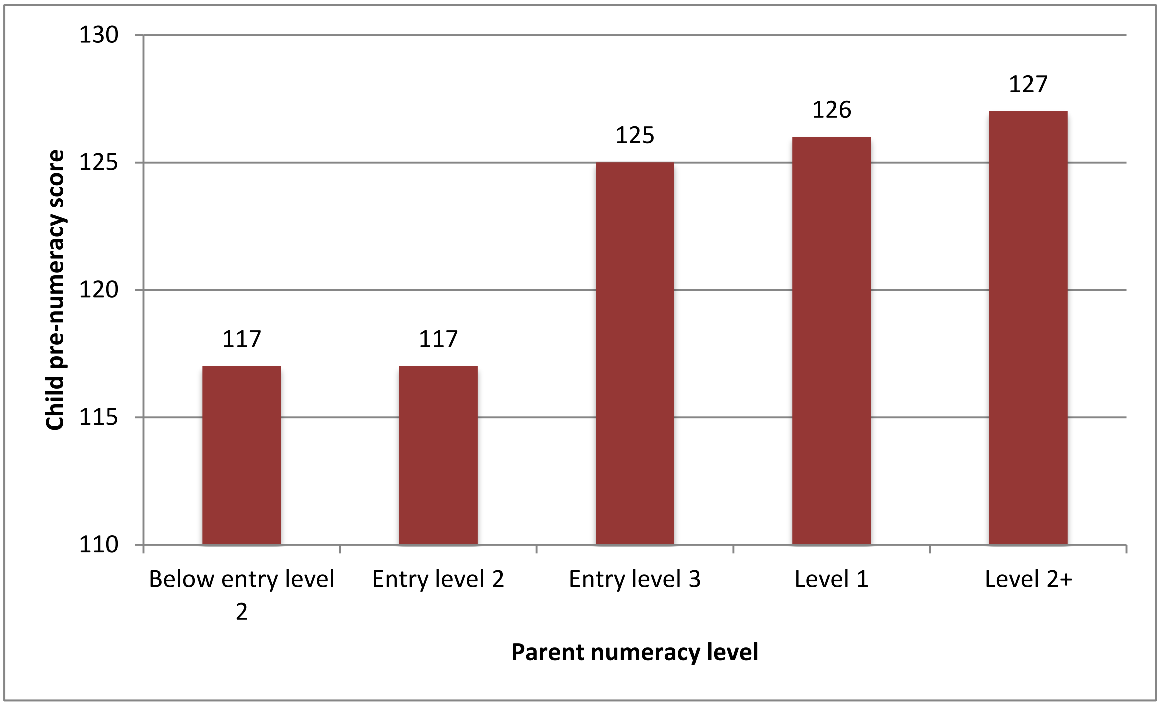
4. Relationships between parental factors and child numeracy skills

This section reports on look the relationships between a range of parental factors that could theoretically influence children's numeracy skills.

4.1 Parent numeracy and child numeracy

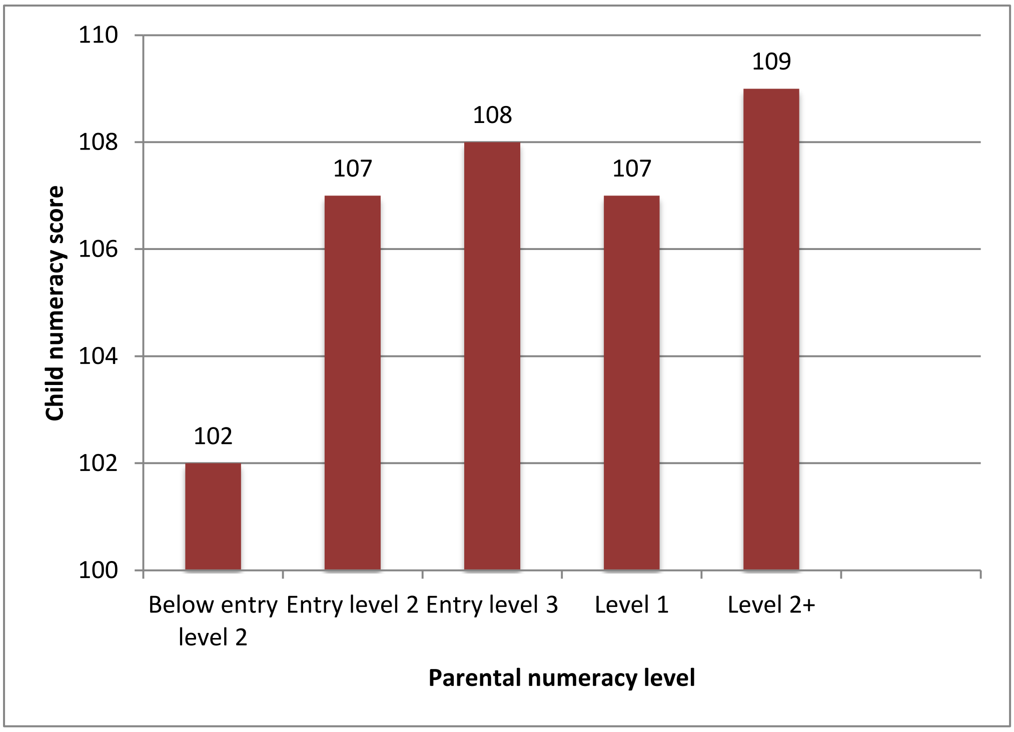
Looking first at the relationship between parent numeracy and child numeracy, Figure 2 presents the average (mean) ability scores for children aged 3-5 (the vertical or y-axis), broken down by parents' numeracy level (horizontal or x-axis). Young children's numerical ability scores were positively associated with their parents' numeracy levels – that is, parents with higher numeracy levels tended to have children with higher numeracy scores. In particular, children of parents with Entry level 3 or higher numeracy had much better number skills than children of parents at Entry level 2 and below.

Figure 2: Relationship between 3-5-year-old children's number ability scores and their parents' numeracy levels



For children aged 6-16, the key dividing point was Entry level 2 (see Figure 3). Children of the 7% of parents who had very poor numeracy (below Entry level 2) had markedly poorer numeracy scores than children of parents at Entry level 2 and above. It is not clear why the relationship between parent and child numeracy differs depending on the child's age group.

Figure 3: Relationship between 6-16-year-old children's number ability scores and their parents' numeracy levels

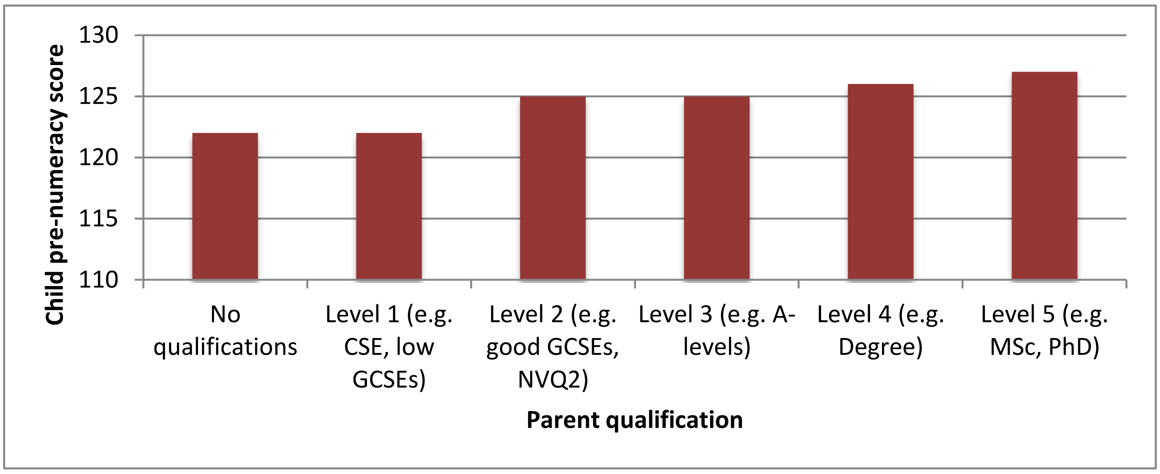


4.2 Parent qualifications and child numeracy

Parents' qualification levels have a strong positive correlation with children's educational achievements: children of highly qualified parents are more likely to become highly qualified themselves (Feinstein et al, 2004). However, the association between parents' qualifications and their children's numeracy scores may be less straightforward.

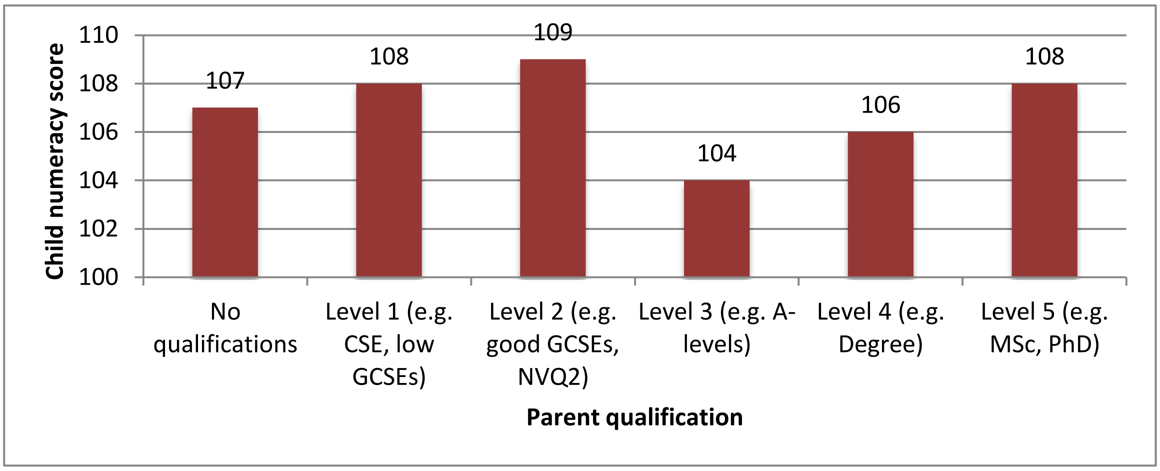
Investigation of the BCS70 data did find a relationship between parental qualifications and the emergent numeracy abilities of children aged 3-5. As Figure 4 shows, young children's average numeracy scores were somewhat higher if their parents had higher levels of qualifications. The distribution of child numeracy scores in relation to parental qualifications was more compressed than when looking at the association between parent numeracy and child numeracy.

Figure 4: Relationship between parents' qualifications and children's (aged 3-5) numeracy



For older children (6-16), there was no clear correlation between parents' qualifications and children's numeracy skills (see Figure 5). For example, children of parents with Level 5 qualifications (Masters or Doctorate) had the same numeracy scores as children of parents with Level 1 qualifications. To some degree, this may be a product of sample size: only 49 parents of children aged 6-16 had a Level 5 qualification. However, sample sizes were much larger for parents who had older children and Level 3 and (especially) Level 4 qualifications: 188 parents with Level 3 and 284 with Level 4. The reasons for the particularly low numeracy scores of children of parents with Level 3 qualifications are unclear. However, in the regression analysis (section 6), this effect disappears when other factors are taken account.

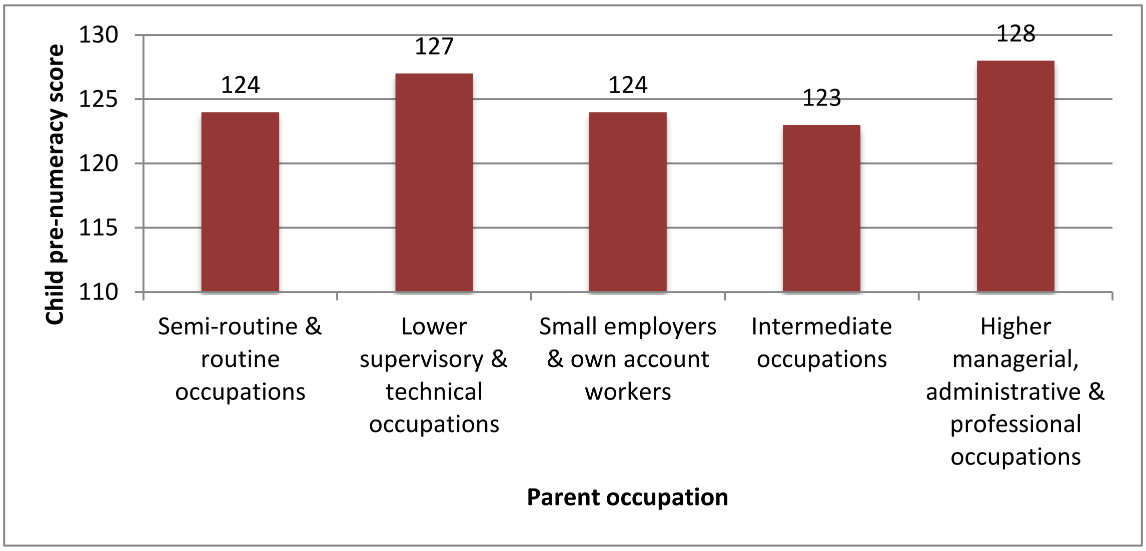
Figure 5: Relationship between parents' qualifications and children's (aged 6-16) numeracy



4.3 Parental occupation and child numeracy

Like qualifications, parental occupation is strongly associated with children's educational achievements: children of parents in higher level occupations are more likely to do well in school (Lauder et al, 2008). However, in the BCS70, the relationships between children's numeracy scores and their parents' occupations are mixed (see Figure 6). While younger children of parents in the highest occupational category – higher managerial, administrative and professional occupations[5] – had higher average numeracy scores than other young children, there were no clear associations between other occupational groupings and young children's emergent numeracy scores.

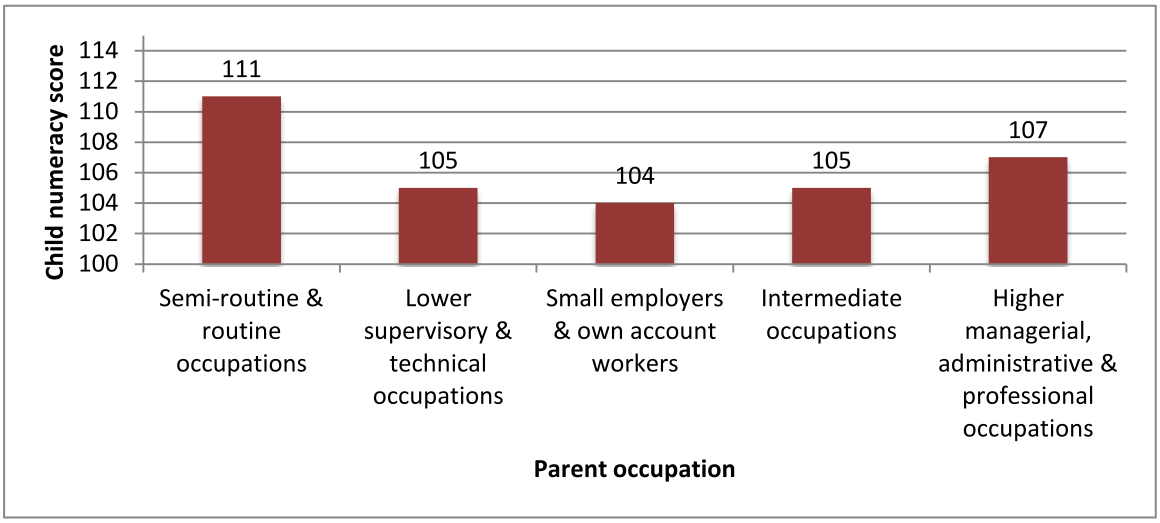
Figure 6: Relationship between parents' occupation (NS-SEC5) and children's (aged 3-5) emergent numeracy



For 6-16-year-olds, the highest average numeracy scores were found among children of parents in routine and semi-routine occupations (see Figure 7). Given the well-evidenced correlations between parental occupation and children's academic outcomes, this is a surprising finding. However, in the regression analysis (section 6), this impact ceases to exist once other factors are taken account of by the regression model.

[5] This report used the NS-SEC 5 category breakdown for occupational status.

Figure 7: Relationship between parents' occupation (NS-SEC5) and children's (aged 6-16) numeracy



5. Modelling the relationships between parent and child scores

Section 5 describes the raw relationships between various parental characteristics and children's numeracy skills. This section reports on the results of regression analyses for children in general and for specific sub-groups of children.

5.1 Main results

Without controlling for other factors such parental education and household income, it is impossible to say, for example, that parent numeracy directly influences child numeracy as other factors related to numeracy skills may influence (i.e. confounding) the relationship. Using regression analysis the correlation (i.e. relationship) between two factors, controlling for other factors, can be estimated. (Algebraically, regression allows us to estimate the relationship between *a* and *b,* controlling for *x, y, z,* and so on.)

For this study, five different statistical models were constructed. Each contains more controlling factors than the previous one, and should therefore get closer to the true relationship between parent and child numeracy. In Tables 3 and 4 below:

- Model 1 looks at the association between parent and child numeracy, controlling for child's age, gender, birth order and number of siblings. This model also takes account of whether the cohort member is a lone parent.
- Model 2 adds in a range of socio-economic variables: parental occupational level; household income; and whether the parent receives state benefits.
- Model 3 adds the parent's education level.
- Model 4 adds the parent's "innate" ability, as measured by the cognitive assessment taken by all BCS70 cohort members at the age of five.
- Model 5 adds variables related to the home learning environment: parental warmth; parent-child conflict; and how often children (aged 3-9) are read to by their parents.

Each of these five models was investigated separately for young children, and then for older children. Results of all models are highly statistically significant. Each table show the average (mean) impact on child numeracy of a standard deviation increase in parental numeracy.

5.1.1 Young children

Table 3 shows that, controlling for the child's age, gender, birth order and number of siblings, as well as whether or not the cohort member is a lone parent (Model 1), a one standard deviation increase in the parental numeracy score is associated with a 0.135 standard deviation increase in the child numeracy score, that is, an increase of 13.5% of a standard deviation.

Adding in the impact of parental occupational level, household income and whether or not the parent receives state benefits (Model 2) a one standard deviation increase in the parental numeracy score is associated with a child numeracy score increase of 12% of a standard deviation.

In Model 3 (adding the parent's education level) a one standard deviation increase in the parental numeracy score is associated with a child numeracy score increase of 10.9% of a standard deviation. When the parent's "innate" ability is taken into account (Model 4), this correlation decreases to 0.092, i.e. 9.2% of a standard deviation. Adding home learning environment factors (Model 5) does not change this.

Therefore, with Models 1-4, each new model sees the apparent strength of the relationship between parent and child numeracy decrease somewhat, but remain meaningful in size, and statistically significant. For comparison's sake, parental occupation, income, family make-up and home learning environment all have a much smaller association with children's numeracy scores (and even these small associations are statistically insignificant). Importantly then, although all these factors have been shown to impact on children's educational success, they do not appear (at least for this sample) to be associated with child numerical skills as assessed by the BAS II tests.

Moreover, the relationship between parent and child numeracy exists even when controlling for parents' education and "innate ability". In fact, when the parent-child numeracy association is taken into account (alongside other relevant factors), parental education appears to have no statistically significant association with young children's pre-numeracy abilities.

Innate ability does show a statistically significant association with the performance of cohort member's young children on the BAS II numerical ability test. This is unsurprising, as there is good evidence for the intergenerational transmission of cognitive ability (Crawford et al, 2010). However, even when controlling for cohort member's cognitive ability in childhood, parental numeracy skills (as measured in adulthood) were correlated with improved numerical abilities in their own young children.

Table 3: Relationship between parent and child numeracy (children age 3-5): Average (mean) impact on child numeracy of a one standard deviation increase in parental numeracy

Model	(1)	(2)	(3)	(4)	(5)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.135***	0.120***	0.109***	0.092***	0.092***
Child age, gender, birth order, number of siblings, and whether cohort member is a lone parent	√	√	√	√	√
Parental occupational level, household income and whether or not the parent is receiving state benefits		√	√	√	√
Parent's education level			√	√	√
Parent's "innate" ability, as measured by a cognitive test taken by all BCS70 cohort members at the age of 5				√	√
Parental warmth, parent-child conflict, and how often young children are read to by their parents					√

Number of observations: 1219; Table shows standardised beta coefficients;
Dependent variable: Ability score on numerical abilities.
****All coefficients: $p < 0.001$*

5.1.2 School-age children

Table 4 shows the same analysis for school-age children. Controlling for all other factors in our model, the correlation between parent and child numeracy is 0.09. This indicates that a one standard deviation increase in parental numeracy score is associated with an average increase in child numeracy of 9% of a standard deviation. This is very similar to that found for young children. As with young children, the result is highly statistically significant.

Table 4 shows the relationship between parent and child numeracy, as additional controls are added. As was the case with young children, parental education, occupation and income all had insignificant impacts on child numeracy ability, when parental numeracy was taken into account. In contrast to findings for young children, parents' innate ability (as measured at age 5) did not show an association with their school-age children's numeracy skills. However, the Home Learning Environment did: higher levels of parent-child conflict were associated with lower child numeracy scores.

Table 4: Relationship between parent and child numeracy (children age 6-16)

Model	(1)	(2)	(3)	(4)	(5)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.127***	0.116***	0.102***	0.093***	0.090***
Child age, gender, birth order, number of siblings, and whether cohort member is a lone parent	✓	✓	✓	✓	✓
Parental occupational level, household income and whether or not the parent is receiving state benefits		✓	✓	✓	✓
Parent's education level			✓	✓	✓
Parent's "innate" ability, as measured by a cognitive test taken by all BCS70 cohort members at the age of 5				✓	✓
Parental warmth, parent-child conflict, and how often young children are read to by their parents					✓

Number of observations: 1219; Table shows standardised beta coefficients;
Dependent variable: Ability score on numerical abilities.
****All coefficients: $p < 0.001$*

5.2 Sub-group analysis

The relationship between parent and child numeracy may differ, depending on particular characteristics of children and/or parents.

5.2.1 Parents' education levels

Tables 5-8 show the results of sub-group analyses for a range of different parent-child combinations. As with the main analysis, this analysis uses five progressively fuller statistical models. These new models omit variables shown in the full analysis to have no correlation with child numeracy.

In all tables, Model 1 shows the parent-child numeracy relationship before taking account of the factors added into Models 2-5. Model 5 shows the parent-child numeracy correlation taking account of: child characteristics (age, gender, whether first-born); family structure (number of siblings, whether cohort member is a lone parent); cohort member's occupational status; household (log) income and poverty status; and parent's innate ability at age five. The progressive inclusion of these factors is indicated by ticks under the model numbers.

Tables 5-8 focus on parental education, comparing the parent-child numeracy correlation for low-educated parents (National Vocational Qualifications Level 2 or lower) against more highly education parents (National Vocational

Qualifications Level 3 or above). For young children, parental numeracy skills appear to matter more if the parent has a lower level of education. Among low-education parents, a one standard deviation increase in numeracy score is associated with a 0.098 (i.e. 9.8%) standard deviation increase in the child's numeracy score; for more highly educated parents, a one standard deviation increase in numeracy is associated with a 7.4% standard deviation increase in child numeracy. (Note also that the 9.8% result has a higher degree of statistical significance, meaning that it is much less likely to have been arrived at by error.)

For school-age children, this relationship was reversed: parents' numeracy skills mattered more for children of more highly educated parents.

Table 5: Young children, low educated parents

Model	(1)	(2)	(3)	(4)	(5)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.115^{***}	0.114^{***}	0.113^{***}	0.113^{***}	0.098^{***}
Child characteristics (age, gender, whether first-born)	√	√	√	√	√
Family structure (no. of siblings, lone parent)		√	√	√	√
Occupational status			√	√	√
Household (log) income and poverty status				√	√
Parents' ability at age 5					√

Observations in all models: 729; $p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 6: Young children, medium and high educated parents

	(1)	(2)	(3)	(4)	(5)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.102**	0.102**	0.089*	0.087*	0.074*
Child characteristics (age, gender, whether first-born)	√	√	√	√	√
Family structure (no. of siblings, lone parent)		√	√	√	√
Occupational status			√	√	√
Household (log) income and poverty status				√	√
Parents' ability at age 5					√

Observations in all models: 490; $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: School-age children, low educated parents

	(1)	(2)	(3)	(4)	(5)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.119***	0.118***	0.114***	0.113***	0.098***
Child characteristics (age, gender, whether first-born)	√	√	√	√	√
Family structure (no. of siblings, lone parent)		√	√	√	√
Occupational status			√	√	√
Household (log) income and poverty status				√	√
Parents' ability at age 5					√

Observations in all models: 1656; $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: School-age children, medium and high educated parents

	(1)	(2)	(3)	(4)	(5)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.137***	0.135***	0.120***	0.113***	0.111***
Child characteristics (age, gender, whether first-born)	√	√	√	√	√
Family structure (no. of siblings, lone parent)		√	√	√	√
Occupational status			√	√	√
Household (log) income and poverty status				√	√
Parents' ability at age 5					√

Observations in all models: 572; $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.2.2 Mothers and fathers

Tables 9-12 compare the parent-child numeracy relationship, depending on whether the cohort member parent is male or female. For both age groups (young children and school-age children), a father's numeracy ability appears to be more strongly correlated than a mother's numeracy ability. Amongst school-age children, for example, a one standard deviation increase in the paternal numeracy score is associated with a 14.1% standard deviation increase in the child's numeracy score. This is more than double the correlation for mothers (6.7% of a standard deviation).

Table 9: Young children, mothers only

	(1)	(2)	(3)	(4)	(5)	(6)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.145^{***}	0.143^{***}	0.127^{***}	0.124^{***}	0.111^{***}	0.092^{**}
Child characteristics (age, gender, whether first-born)	√	√	√	√	√	√
Family structure (no. of siblings, lone parent)		√	√	√	√	√
Occupational status			√	√	√	√
Parental qualifications				√	√	√
Household (log) income and poverty status					√	√
Parents' ability at age 5						√

Observations in all models: 745; p < 0.05, ** *p* < 0.01, *** *p* < 0.001

Table 10: Young children, fathers only

	(1)	(2)	(3)	(4)	(5)	(6)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.150^{***}	0.151^{***}	0.135^{***}	0.134^{***}	0.132^{***}	0.122^{**}
Child characteristics (age, gender, whether first-born)	√	√	√	√	√	√
Family structure (no. of siblings, lone parent)		√	√	√	√	√
Occupational status			√	√	√	√
Parental qualifications				√	√	√
Household (log) income and poverty status					√	√
Parents' ability at age 5						√

Observations in all models: 474; p < 0.05, ** *p* < 0.01, *** *p* < 0.001

Table 11: School-age children, mothers only

	(1)	(2)	(3)	(4)	(5)	(6)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.115***	0.114***	0.095***	0.091***	0.082***	0.067**
Child characteristics (age, gender, whether first-born)	✓	✓	✓	✓	✓	✓
Family structure (no. of siblings, lone parent)		✓	✓	✓	✓	✓
Occupational status			✓	✓	✓	✓
Parental qualifications				✓	✓	✓
Household (log) income and poverty status					✓	✓
Parents' ability at age 5						✓

Observations in all models: 1610; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 12: School-age children, fathers only

	(1)	(2)	(3)	(4)	(5)	(6)
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.161***	0.162***	0.173***	0.174***	0.136***	0.141***
Child characteristics (age, gender, whether first-born)	✓	✓	✓	✓	✓	✓
Family structure (no. of siblings, lone parent)		✓	✓	✓	✓	✓
Occupational status			✓	✓	✓	✓
Parental qualifications				✓	✓	✓
Household (log) income and poverty status					✓	✓
Parents' ability at age 5						✓

Observations in all models: 618; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

5.2.3 Parent and child gender

Parent gender appears to matter, so does the combination of parent and child gender influence the numeracy relationship? Tables 13 and 14 show gender-specific intergenerational numeracy correlations: mothers-daughters, mothers-sons, fathers-daughters and fathers-son. These tables show only the full model, i.e. the one which controls for all factors. The weakest relationship is found between mothers and sons; this is true for both age groups. The strongest relationships are between fathers and sons; this is particularly true for school-aged children, where the father-son correlation is nearly three times that of mothers-sons. For young children, mother-daughter and father-daughter correlations are also relatively high.

Table 13: Young children, parent-child relationships

	Mothers-daughters	**Mothers-sons**	**Fathers-daughters**	**Fathers-sons**
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.117**	0.067	0.112*	0.117*
All controls	√	√	√	√
Observations	389	356	238	236

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 14: school-age children, parent-child relationships

	Mothers-daughters	**Mothers-sons**	**Fathers-daughters**	**Fathers-sons**
Average (mean) impact on child numerical ability of a 1 standard deviation increase in parental numeracy	0.073*	0.060*	0.095	0.176***
All controls	√	√	√	√
Observations	811	799	283	335

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.2.4 Parent numeracy, by NQF levels

Throughout this report, parental numeracy is discussed in terms of scores on a standardised test. This approach makes it possible to analyse the relationship between parent-child numeracy when parental numeracy is even slightly higher or lower. Although a focus on parents' numeracy levels does not allow such fine-grained analysis, it is possible to investigate the relationship between parental numeracy levels and child numeracy scores (see Table 15). The reference category (or baseline) is parents with numeracy skills below Entry level 2 on the National Qualifications Framework (NQF). The cells below this reference category show the average gain in child numeracy associated with an increase of parent numeracy from below Entry level 2 to the level in question. For example, compared to school-aged children of parents with below Entry level 2 numeracy, school-aged children of parents with Entry level 3 skills have numeracy skills that are, on average, 10.4% of a standard deviation higher.

Table 15: Parents' numeracy levels (NQF)

	Young children	School-age children
Reference category below entry level 2		
Entry level 2	0.046	0.039
Entry level 3	0.127**	0.104**
Level 1	0.150**	0.105**
Level 2	0.171***	0.140***
All controls	✓	✓
Observations	1219	2228

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

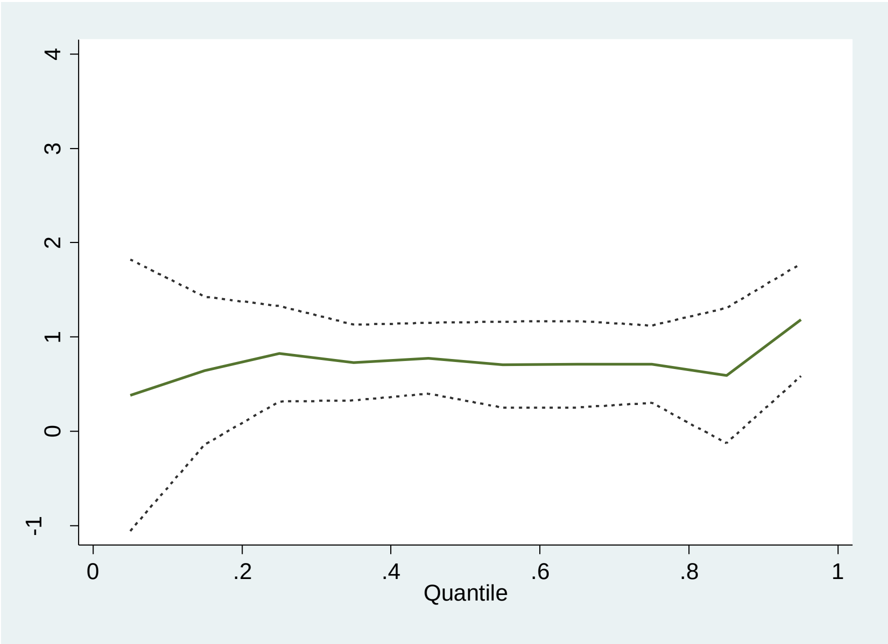
5.2.5 Quantile regressions

The previous (OLS) regressions show the average relationship between the explanatory variables in the models and the dependent variable: child numeracy. OLS regressions show how the mean of the dependent variable (child numeracy) changes with the vector of explanatory variables. Because OLS regression focuses on the mean, it assumes that the effect of the explanatory variables is the same across the full distribution of child numeracy scores. That is, it assumes that the impact of parental numeracy on child numeracy is the same for low performing children, medium performing children and high performing children. This assumption may be erroneous. For example, parental numeracy may have more impact on child numeracy skills at the bottom end of the distribution, while school effects or socio-economic status may have more impact at the higher end of the child numeracy performance distribution (de Coulon et al, 2009).

Quantile regression allows for an exploration of the relationship between parent and child numeracy at different points on the distribution of child numeracy outcomes. In Figures 8 and 9, the horizontal x-axis of each figure shows child numeracy results, divided into five quintiles. The first quintile (0-0.2) shows the bottom 20% of performers on the BAS II numeracy test; 0.2-0.4 shows the next 20%, and so on up to 1. The vertical axis shows the coefficient for parental numeracy, that is, the apparent impact of parental numeracy on the child's numeracy for different quintiles of child numeracy performance. The larger the coefficient, the greater the association between parent numeracy and child numeracy. The dotted lines show 95% confidence intervals.

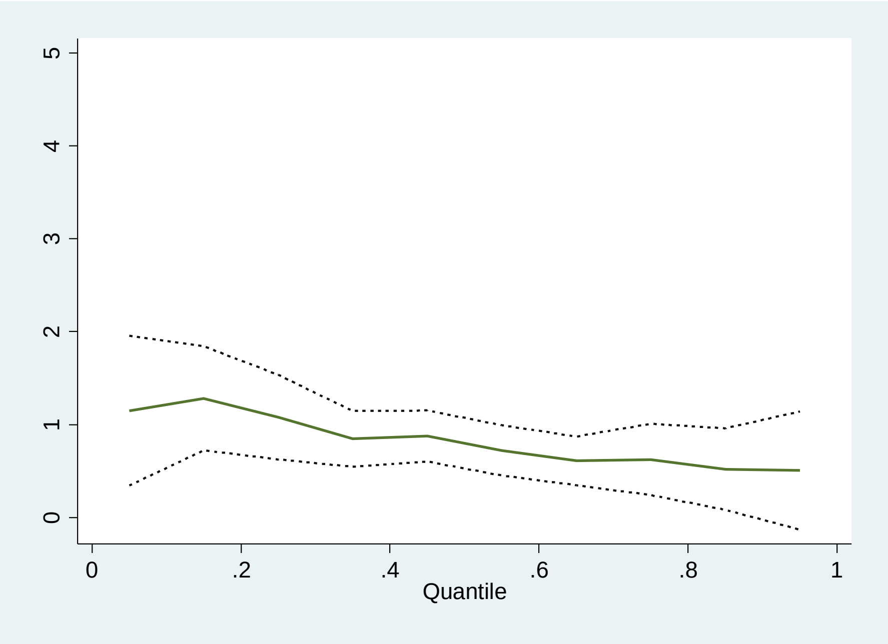
Looking at young children (Figure 8), quantile regression suggests that the impact of parental numeracy is consistent across the middle three quintiles of child numeracy. That is, young children in these three quintiles get roughly equal benefit if their parents have better numeracy. The apparent impact of parental numeracy is greatest for the highest scoring children: high-scoring young children appear to receive particular benefit when their parents are also high scoring. In contrast, the relationship between parent and child numeracy is weakest for the lowest scoring quintile of children; however, the much wider confidence interval in this section of the chart suggests that results for this quintile are too varied to be trusted.

Figure 8: Quantile regressions: young children



For school-age children (Figure 9), the relationship between parent and child numeracy is strongest for children whose scores are closer to the bottom of the distribution. That is, the apparent impact of higher parent numeracy is greater for the lowest achieving children.

Figure 9: Quantile regressions: school-age children



6. Discussion and conclusions

The aim of this study is to investigate the relationship between parents' numeracy skills and those of their children. Using the "Parent and Child" subsample of the 1970 British Cohort Study (BCS70), the study analyses date on parents' numeracy scores at age 34 and their children's scores on either a test of emergent numeracy (for children aged 3-5) or numeracy (children aged 6-16). Bivariate analyses of these data produces surprising results – for example, school-aged children of parents with qualifications at Level 3 and above had lower average numeracy scores than children of parents with qualifications at Level 2 and below. However, once other factors were taking account of through OLS regression, all of these surprising results disappear.

The main finding of the OLS regression is that parents' numeracy skills are positively correlated with their children's. This remains true even when controlling for a broad range of other factors that might influence child numeracy: parents' occupation, income and education, lone parent status, child gender, whether the child was first born, the number of siblings, parenting style and parents' cognitive ability as measured at age 5. For young children (aged 3-5) and older ones (aged 6-16), a one standard deviation increase in the parent's numeracy score was associated with 9% of a standard deviation increase in the child's numeracy score. In families where the parents had less education and training (highest qualification of NVQ2 or below), the association was somewhat stronger: 10% of a standard deviation. This study finds strong evidence for an intergenerational numeracy effect, separate from and generally stronger than the effects of a host of other factors. When parents have better numeracy, their children also tend to have better numeracy, even when controlling for a wide range of potentially confounding factors such as parental education, income and general cognitive ability.

Higher parental numeracy levels are associated with higher child numeracy scores, even when controlling for all relevant factors available in the dataset. In other words, even if two parents have the same income, occupational status, qualifications, and so on, if one parent has a higher numeracy level, his or her child is likely to have a higher numeracy score. Compared to our baseline category (parents with below Entry level 2), we found particular effects at Entry level 3. While children of parents with Entry level 2 numeracy skills did not perform significantly better than children of parents with below Entry level 2, the children of parents with Entry level 3 did. This finding may lend support to the government's establishment of Entry level 3 as the minimum standard for full functioning in modern society. This threshold level was defined in the Leitch review (Leitch, 2006) and is still referred to in discussions about numeracy skills, although the threshold target is no longer the focus of Public Service Agreement targets.

This study also finds a greater association between fathers' numeracy skills and those of their children. In particular, there is a relatively strong relationship between the numeracy skills of fathers and their school-aged children: a paternal score increase of one standard deviation is associated with a school-aged son increase of 18% of a standard deviation – roughly double the relationship for the sample as a whole.

Finally, in quantile regressions, the relationship between parent and child numeracy at different points on the distribution of child numeracy outcomes is explored. These regressions find different results for younger and older children. For the first group, parents appear to have a greater impact on the highest scoring children. This is reversed for older children: the relationship between parent and child numeracy is strongest for children whose scores were closer to the bottom of the distribution.

The finding that parents' numeracy skills appear to be correlated with their children's, even when controlling for a rich range of other factors, is an important one. There has been very little research on the relationship between parent and child numeracy, but this report suggests that relationship is meaningful. It is, however, challenging to move from that finding to implications for policy. In their analysis of the parent-child numeracy relationship in the NCDS (cohort members born in 1958), Brown et al (2009) hypothesised that genetic factors play the main role in this relationship. That is, parents who are for some reason more innately capable in mathematics pass that innate capability on to their children. This would suggest that efforts to improve parents' numeracy skills would have little impact on their children's maths performance. In contrast, de Coulon et al (2009, p. 53), using the BCS70 to look at a composite measure of child literacy and numeracy, suggested the opposite, writing that policies "aimed at increasing parents' basic skills may have potentially large intergenerational effects on the cognitive performance of children".

Both of these studies suffer from the same primary weakness as this one: an inability to draw causal conclusions. All three analyses are cross-sectional, rather than longitudinal: they look at parent and child outcomes at only one point in time. This means that all three studies allow us to increase our understanding of the relationship between parents' basic skills and those of their children; however, they do not provide sufficient evidence to enable us to draw conclusions about the impacts on children if parents were to improve their skills. To draw such causational conclusions, we would need longitudinal data on parent and child numeracy scores, collected at least two points in time. The longitudinal nature of cohort studies is their greatest strength; unfortunately, numeracy assessments have only been conducted once in the BCS70 and so numeracy-specific data is cross-sectional. Policymakers would be well served by commissioning additional research that would allow researchers to move beyond statements of correlations to those of causation.

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