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# Trade-offs in modern parenting: a longitudinal study of sibling competition for parental care

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**Abstract**

Evolutionary and economic models of the family propose that parents face a fundamental trade-off between fertility and investment per offspring. However, tests of this hypothesis have focused primarily on offspring outcomes rather than direct measures of parental investment. Existing studies of parenting also suffer a number of methodological problems now recognized as common sources of error in sociodemographic studies. Here, we present a more definitive picture of the effects of family structure on parental care by analyzing an extensive longitudinal dataset of contemporary British families (the Avon Longitudinal Study of Parents and Children). Unlike other studies, we simultaneously track maternal and paternal behaviors within the same family and consider variation both across time and between distinct population subgroups. Parental investment was measured as frequency of engagement in key care activities over the first decade of life. For both parents, larger family size was traded off against investment per offspring, representing the strongest explanatory variable considered in our analysis. However, contrary to the predictions of traditional quantity–quality trade-off models, increasing family socioeconomic status did not alleviate this effect. In fact, for paternal care in particular, increases in wealth and education created stronger trade-offs. We also demonstrate that large sibships were particularly costly for later-born offspring. Sex of siblings did not influence parental care, however maternal investment was biased towards daughters and paternal investment biased towards sons. Unrelated father figures were also associated with lower investment from both parents. Results are discussed in relation to parental investment theory and evolutionary models of modern low fertility.


*Keywords:* Parental investment; Sibling competition; Life history theory; Demographic transition; ALSPAC

## 1. Introduction

Childhood is a decisive period in human life history. In many contexts, levels of parental and alloparental investment received during this period can literally mean the difference between life and death (Sear & Mace, 2008). For those that survive childhood, the conditions of early life remain key determinants of adult functioning, a factor that may underpin the evolution of prolonged immaturity in humans (Bogin, 1997; Kaplan, Hill, Lancaster, & Hurtado, 2000). Even in modern wealthy populations, there is considerable evidence that high quality parenting plays a substantial role in ensuring positive child and adult outcomes across multiple domains of development (Downey, 1995; Flouri & Buchanan, 2004; Rogers, Hallam, & Shaw, 2008; Stewart-Brown, 2008). However, with finite resources, parents face the problem of how best to allocate investment across offspring in order to maximize chances of offspring success and ultimately their returns in Darwinian inclusive fitness.

Human behavioral ecologists have been particularly concerned with the extent to which parents face a trade-off in number of children and allocations of investment per child (Borgerhoff Mulder, 2000; Mace, 2007). Most of this research has focused on documenting trade-off effects between fertility and offspring outcomes such as early life mortality (Penn & Smith, 2007; Strassmann & Gillespie, 2002; Voland & Dunbar, 1995), anthropometric measures (Desai, 1995; Hagen, Barrett & Price, 2006; Hagen, Hames, Craig, Lauer & Price, 2001; Lawson & Mace, 2008), and, in some cases, marital and reproductive success (Borgerhoff Mulder, 1998, 2000; Gillespie, Russell, & Lummaa, 2008; Low 1991; Penn & Smith, 2007; Mace, 1996; Voland &

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Dunbar, 1995). Few such studies have considered actual measures of parental investment, with the exception of wealth transfers which typically occur later in the life course (Borgerhoff Mulder, 1998; Mace, 1996). In review of this research, it is evident that under most conditions, humans do indeed face a meaningful trade-off between offspring quantity and quality. However, there is also considerable variation in the magnitude and form of such effects across populations. An important goal then for future research is to determine more clearly how family size and structure influences the parental investment schedules which are proposed to mediate effects on offspring.

One factor commonly believed to underlie the extent to which siblings compete for parental care is variation in resource budgets. A central assumption of quantity–quality trade-off models is that parental resources are finite (Becker & Lewis, 1973; Lack, 1947; Stearns, 1992; Williams, 1966). Increases in personal or societal wealth may therefore relax this assumption and reduce the magnitude of trade-off effects (Tuomi, Hakala, & Haukioja, 1983; van Noordwijk & de Jong, 1986). In line with this position, the costs of high parental fertility to individual offspring have been found to be less pronounced in relatively wealthy strata in both contemporary African (Borgerhoff Mulder, 2000) and preindustrial European (Gillespie et al., 2008) populations. However, some studies suggest the opposite pattern. For example, in a cross-country analysis of the influence of family size on child growth in 15 developing populations, Desai (1995) found that higher levels of both access to safe drinking water and health care facilities was associated with larger negative effects of family size. Grawe (in press) has also demonstrated that, in the modern US, large family size is associated with negative consequences on the income generation of offspring in wealthy families but of little consequence to children from poor families (see also Keister, 2004). In this study, we present data on family structure effects on parental time investments in children in contemporary British families. Exploring a large range of independent variables, we question the relative importance of family size in influencing levels of parental investment in this population and whether or not trade-offs significantly interact with socioeconomic status (SES).

Studying parental investment in a contemporary Western population also raises additional issues. Following demographic transition, modern fertility is both dramatically reduced and typified by relative socioeconomic leveling in comparison to many traditional populations (Nettle & Pollet, 2008). Many demographers argue that this shift is due to a cultural change more or less unrelated to the expense of child-rearing (Bongaarts & Watkins, 1996; Montgomery & Casterline, 1996), whilst others believe that the perceived relative costs of raising children has played an important role in fertility decline (Becker, 1981; Szreter, 1996). Evolutionary demographers are also split on the extent to which modern fertility represents maladaptation to novel environmental conditions, where cultural evolution is driving low fertility (Barkow & Burley, 1980; Boyd & Richerson, 1985; Newson, Postmes, Lea, & Webley, 2005), or due to perceived or real high costs and benefits of parental investment (Kaplan, Lancaster, Tucker, & Anderson, 2002; Mace, 2007; Mace 2008). In many of these studies, it is assumed that, in our well-nourished and relatively wealthy society, the costs of childrearing are in fact rather low. However, there are indications that siblings are still competing for parental investment, perhaps as much or more than ever. Strong negative effects of sibship size on education (Downey, 1995; Steelman, Powell, Werum, & Carter, 2002), wealth ownership (Keister, 2003; Keister, 2004), and even physical development (Lawson & Mace, 2008) have all been demonstrated in Western populations. Whether or not these negative effects represent real competitive disadvantages to offspring in terms of long-term fitness, these debates may be informed by an improved understanding of the parental investment schedules that characterize the modern family.

### 1.1. Methodological issues in the study of parental care

In recent years, a number of researchers have studied human parenting in modern populations from the perspective of evolutionary life history theory (Anderson, Kaplan, & Lancaster, 1999, 2007; Daly & Wilson, 1998; Keller, Nesse, & Hofferth, 2001; Nettle, 2008), and there are a several highly relevant studies in the wider sociological literature (e.g., Downey, 1995; Hill & Stafford, 1980; Price, 2008; Zick & Bryant, 1996). However, much of this work shares a number of important methodological limitations which raise serious concerns about the reliability of their conclusions. We provide a brief review of these points as some readers may be relatively unfamiliar with methodological debates presently more dominant in sociology, demography and public health. These issues are not trivial and cannot afford to be ignored if evolutionary models are to produce robust findings and integrate more fully with the applied social sciences.

First, researchers of life history theory have long recognized that failure to account for differences in resources between individuals (and the resulting phenotypic correlations) can mask or distort true trade-off functions or predicted biases in parental investment (Sear, 2007; van Noordwijk & de Jong, 1986). However, many studies of the modern family attempt to encapsulate variation in SES with a limited set of measures, or a single measure such as occupation coding, even when alternative measures may be available (e.g. Nettle, 2008). This ignores strong evidence that SES is multidimensional, varying through dimensions such as household income, education, wealth ownership, or neighborhood quality often with a surprising degree of independence (Braveman et al., 2005). Furthermore, variation in "social resources" such as levels of support or social network size are rarely considered despite their demonstrated importance (e.g., Ceballo & McLoyd, 2002). Unfortunately,

it is therefore more common to read a confident assertion that socioeconomic and demographic differences between families have been reliably "controlled," than to be truly convinced this is the case. Considering multiple dimensions of wealth is also crucial because effects may not always run in the same direction. For example, while higher levels of education are often associated with lower fertility in modern populations, the independent relationship with income may be the reverse, at least for men (Hopcroft, 2006; Nettle & Pollet, 2008).

Second, the vast majority of studies have been cross-sectional in design. Cross-sectional methods do not allow for outcome variables and associated covariates to change in value over time. Compared to longitudinal studies, which incorporate repeated time-varying measures of each variable, such studies are therefore relatively inadequate at controlling for underlying associations which may confound results (Singer & Willett, 2003). This is particularly important in studies of family structure as variables such as family size, birth order, and father absence are clearly dynamic. Studies of family effects on educational achievement and IQ have been met with considerable controversy (Rodgers & Cleveland, 2000; Steelman et al., 2002), as subtle within-family and longitudinal models have not always generated results consistent with the conclusions of cross-sectional studies (Guo & VanWey, 1999; Rodgers, 2001). Longitudinal methods also offer the additional advantage of defining and illustrating changing relationships over time. This ultimately offers us a more complete picture of human parenting and further assists the interpretation of differences in results across studies.

Finally, a large majority of existing studies of parental care do not distinguish between the activities of distinct carers within the same family, most commonly focusing on transfers from a single parent. However, parenting activities are rarely restricted to a single individual in human societies, with high rates of paternal or alloparent involvement characteristic of our species (Sear & Mace, 2008). Studies of joint investments, such as money saved for college (e.g., Downey, 1995), may mask important variation in the investment schedules of different carers. Conclusions based on a single parent (e.g., Anderson et al., 2007; Keller et al., 2001) may lead to a distorted view of parental investment strategies because, for example, increases or deficits in parental care by one individual may be cancelled out by compensatory action from other carers. Studies simultaneously tracking investment of multiple parent figures are therefore required to understand the full effects of family structure on parental care.

Addressing all of the above issues, we present a longitudinal analysis of both maternal and paternal time investments across childhood in contemporary British families. To do this, we use data collected over a 10-year period from the Avon Longitudinal Study of Parents and Children (ALSPAC), a uniquely detailed, ongoing cohort study designed to examine environmental and genetic influences on the health and development of British children (Golding, Pembrey, Jones, & Team, 2001).

### 1.2. Hypotheses

The principal aim of this study is to evaluate the hypothesis that parents face a trade-off between fertility and investment per child (Becker & Lewis, 1973; Lack, 1947; Stearns, 1992; Williams, 1966). Following a strict quantity–quality trade-off model, increasing family size should hold the greatest penalties to individual investment for initially small families, and taper off as family size increases. This is because, there will be a $1/x$ ($x$=number of offspring) division of parental resources (assuming equal allocation among consumers). Few existing studies have explored the utility of this prediction (Downey, 1995). We further anticipate that the magnitude of trade-off effects will be decreased as SES increases reflecting a relaxation in the assumption of finite parental resources (Tuomi et al., 1983; van Noordwijk & de Jong, 1986).

Equal investment in offspring is not necessarily anticipated by evolutionary theories of parental care. This complicates a simple quantity–quality trade-off model. Our data enable us to specifically explore how sibling age and sex relate to parental investment schedules. With regard to age, two factors provide competing predictions on the direction of the bias. On the one hand, younger offspring may be favored because, being typically more dependent on parents than older siblings, the effects of each additional unit of investment will be higher (Clutton-Brock, 1991). On the other hand, older offspring may be favored because they have a higher reproductive value (expected future reproduction: Fisher, 1930). This is because older offspring are both closer to reproductive maturity and because levels of juvenile mortality tend to decrease with increasing age (Clutton-Brock, 1991). Modelling these factors as opposing forces supports the evolution of a general bias towards older offspring as ultimately the reproductive value of offspring will contribute more directly to parental fitness (Jeon, 2008). However, even if it is assumed that parents aim for equity between offspring in parental care, bias may ultimately form towards earlier born offspring, at least during the critical early years of life, because of unrivalled consumption of parental resources prior to the birth of later-borns (Hertwig, Davis, & Sulloway, 2002). As such later-born offspring enter a family at a time when resources are relatively depleted with potentially lower levels of both intrauterine and postnatal investment.

Evolutionary models also predict parents will bias investment towards one sex over the other if fitness payoffs differ. In human societies, there is often a larger variance in male relative to female reproductive success, with most females producing a modest number of offspring and males more likely to be represented at the extremes. As such, if reproductive success is dependent on parental investments, the returns on producing a daughter may be higher for

relatively resource poor parents while the returns on producing a son may be higher for relatively rich parents (Trivers & Willard, 1973). However, in relation to investment in existing offspring, particularly when chances of survival are high, parents can be expected to bias resource transfers towards males across the population, as each additional unit of investment will have a larger return for sons relative to daughters (Keller et al., 2001; Mace, 1996). We test for sex biases in relation to parental time allocation to child-related activities in our sample. We further test if siblings of either sex differ in their costs to individual investment, predicting that the sex which receives the most parental investment will be more costly as a sibling.

Finally, following classic evolutionary studies of child abuse and homicide (Daly & Wilson, 1981, 1998) there has been considerable interest in the extent to which paternal investment is influenced by genetic relatedness. A number of studies have suggested stepchildren receive lower levels of paternal care than genetic offspring (Anderson et al., 1999, 2007; Cooksey & Fondell, 1996; Marsiglio, 1991). ALSPAC data enable a further assessment of the relative contribution of biological versus unrelated father figures. Furthermore, we are able to consider the impact of paternal presence and relatedness on maternal behavior; an issue largely neglected in previous studies.

## 2. Data and methods

### 2.1. ALSPAC

ALSPAC study recruitment started during pregnancy, enrolling women who had an expected delivery date between April 1991 and December 1992 from the three main Bristol-based health districts of the former English county of Avon. There were 14,472 pregnancies (14,062 live births) recruited into the initial sample. Avon has a predominantly white population, a mixture of rural and urban communities and a socioeconomic mix similar to the rest of the UK. A major advantage of ALSPAC is the exceptional frequency of data collection with data collected up to three times a year focusing on the study child, the mother, and the mother's current partner. Data are collected mainly through self-completion of postal questionnaires but also extraction from clinical records and direct examination of children at research clinics (Golding et al., 2001).

We use all relevant data currently available up until the study child was 10 years of age. A number of exclusion criteria remove rare family configurations from our sample. Children from multiple births, children recorded as dying or experiencing sibling death, and children living with other children unrelated to either the mother or her current partner (e.g., foster or adopted children) over the study period were all excluded. Cases where the child's "mother figure" is ever recorded as other than the biological mother, as absent, or in a lesbian relationship were also excluded. Cases of biological father absence after birth were included, but cases where the mother is recorded as in a relationship with someone other than the biological father at pregnancy were excluded. After implementing these criteria, our total study sample contained 13,176 children, each belonging to different families.

### 2.2. Parental investment: mother and partner scores for engagement in childcare

Data on the frequency of parenting activities engaged in by the mother and her current partner were collected by questionnaire at seven points over the study period ranging from 1 year, 6 months to 9 years (Table 1). The specific list of activities varies with child age, but at each questionnaire can be considered as a measure of direct interaction-based investment focused on the study child as an individual offspring. Overall standardized measures, which we refer to as the "mother score" and "partner score," were calculated at each time point from these data. Frequency of each activity was ranked on a scale between 0 and 3/4 (Table 1). This measure was summed for each time point and standardized to a maximum of value of 10. Thus, a score of 0 indicates that all activities were coded at the minimum frequency possible (they never occurred), while 10 indicates that they carried out each activity at the maximum frequency specified (nearly every day/often). In total the 59,710 mother and 56,742 partner scores are available for 11,142 and 10,969 individual children, respectively.

Two factors complicate the comparison of parent scores across time. First, ALSPAC did not use a consistent measure of frequency, switching between an objective and subjective style of questioning across the study period (Table 1). In all reported analyses, we include a dichotomous covariate term ("Question Style") to control for the positive effect of subjective relative to objective frequency estimates on parent scores (see results section). Second, at the final two questionnaires, parenting questions are directed at any adult females or males rather than the mother or her current partner specifically, with 48–53% of mothers and 31–34% of partners recording the involvement of one or more additional adults. We compared all final models using the full sample with that when only the parent figure is involved in the calculation of the parent scores. While the involvement of other adult carers had a positive main effect on the total care received, in no case did the exclusion of nonparents affect other covariates. Therefore, in all reported analyses, we use the full data set, retaining maximum sample size, but include a dichotomous covariate term ("Question Reference") to take into account the significant main effect of additional adults on each parent score.

### 2.3. Independent variables

Complete information on the distribution of each independent variable over the study period and descriptive statistics can be found in Lawson and Mace (2008). Where

Table 1
Standardized parent scores and percentage engaging in each parenting activity at the highest specified frequency[a]

| | Child age | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 year, 6 months | | 3 years, 2 months | | 3 years, 6 months | | 4 years, 9 months | | 5 years, 5 months | | 6 years, 9 months[b] | | 9 years, 0 months[b] | |
| | Mother | Partner | Mother | Partner | Mother | Partner | Mother | Partner | Mother | Partner | Mother | Partner | Mother | Partner |
| Parent score (0–10) | | | | | | | | | | | | | | |
| Mean | 9.01 | 6.65 | 8.38 | 7.07 | 7.95 | 5.98 | 8.34 | 6.83 | 8.12 | 6.58 | 6.72 | 4.57 | 5.45 | 3.71 |
| Standard deviation | 0.94 | 1.77 | 1.04 | 1.64 | 1.34 | 1.77 | 1.01 | 1.62 | 1.01 | 1.60 | 1.03 | 1.53 | 1.20 | 1.44 |
| *N* | 10,049 | 9550 | 9416 | 8804 | 9339 | 8723 | 8759 | 8129 | 8308 | 7545 | 7225 | 7282 | 6614 | 6709 |
| Activities included | | | | | | | | | | | | | | |
| Show pictures/reading | 70 | 32 | 84 | 56 | 64 | 29 | 80 | 46 | 78 | 46 | 56 | 14 | 17 | 4 |
| Cuddle child | 99 | 89 | 98 | 88 | 98 | 83 | 96 | 77 | 96 | 81 | 92 | 68 | 86 | 58 |
| Play with toys | 86 | 50 | 79 | 58 | 62 | 34 | 50 | 37 | 38 | 31 | 20 | 9 | 5 | 2 |
| Physical play | 64 | 64 | 69 | 71 | 31 | 47 | 26 | 38 | 21 | 36 | 12 | 14 | 6 | 9 |
| Feed/prepare food | 87 | 19 | 79 | 35 | 68 | 12 | 93 | 28 | 93 | 27 | 90 | 8 | 16 | 2 |
| Take walking/to playground | 66 | 9 | 72 | 36 | 51 | 8 | 32 | 22 | 26 | 19 | 3 | 1 | 2 | 1 |
| Sing to child | 67 | 19 | 70 | 26 | 48 | 12 | 46 | 15 | 36 | 12 | 20 | 5 | 11 | 2 |
| Bathe child | 49 | 13 | 88 | 42 | 39 | 10 | 83 | 34 | 82 | 31 | 32 | 4 | 13 | 2 |
| Imitation games | 76 | 39 | – | – | 34 | 17 | – | – | – | – | – | – | – | – |
| Put to bed | – | – | 84 | 50 | – | – | 83 | 47 | 84 | 47 | 72 | 17 | 68 | 16 |
| Makes things with | – | – | – | – | – | – | 42 | 21 | 34 | 17 | 6 | 5 | 2 | 1 |
| Swimming | – | – | – | – | – | – | 31 | 16 | 30 | 15 | 3 | 1 | 2 | 1 |
| Draw or paint | – | – | – | – | – | – | 38 | 14 | 27 | 10 | 4 | 1 | 1 | 0 |
| Takes to classes | – | – | – | – | – | – | – | – | – | – | 40 | 4 | 19 | 3 |
| Shopping | – | – | – | – | – | – | – | – | – | – | 5 | 1 | 2 | 1 |
| Watch sports | – | – | – | – | – | – | – | – | – | – | 1 | 0 | 0 | 0 |
| Help with homework | – | – | – | – | – | – | – | – | – | – | 34 | 5 | 17 | 4 |
| Conversations | – | – | – | – | – | – | – | – | – | – | 98 | 83 | 96 | 82 |
| Prepare things for school | – | – | – | – | – | – | – | – | – | – | 75 | 12 | 65 | 10 |

Total *N*: mother score, 59,710 for 11,142 individuals; partner score, 56,742 for 10,969 individuals.

[a] Frequency measures: 1 year 6 months, 3 years 6 months–never (0), <1/week (1), 1–2/week (2), 3–5/week (3), nearly every day (4), 3 years 2 months, 4 years 9 months, 5 years 5 months–never (0), rarely (1), sometimes (2), often (3), 6 years 9 months, 9 years 0 months–never (0), <1/week (1), 1/week (2), 2–5/week (3), nearly every day (4).

[b] Refers to adult females/males, not specifically the parent.

appropriate, independent variables are coded as categorical variables to enable the identification of threshold effects. Siblings of the study child are defined as maternally related siblings (i.e., including children of different biological fathers, but excluding those from different mothers) resident with the mother. Total family size and number of younger siblings are time-varying measures, coded at five intervals over the current study period. Number of older siblings is time-invariant. Half (51%) of the study children were firstborns, around a third (33%) were second-borns, and a significant number (16%) were third- or later-born. At all points of data collection subsequent to the birth of the study, child modal family size was two. By age 10, 27% of families contained three children and 10% contained four or more. Father presence was assessed at the same intervals and coded as present provided the mother states the live-in "father figure" of the study child is the biological father. In cases where the father is coded as absent, the mothers are either coded as alone or as with a new live-in partner. Almost a quarter of children (24%) had an absent biological father at age 10, with 40% (589/1457) of these children acquiring new live-in father figures. Maternal and paternal age at the birth of the study child were also included as independent variables.

We include mother's educational attainment (coded in pregnancy) as a time invariant measure of SES (educational status rarely changes during motherhood). Note that in the UK, O-level and A-level qualifications correspond to 16 and 18 years of formal education respectively. In addition we use three repeated measures of wealth—"take-home" household income, home ownership, and self-rated neighborhood quality. Household income was coded into bands by ALSPAC questionnaires, with the modal take-home weekly income at £200–299 when first recorded at 2 years, 9 months. Multicollinearity between socioeconomic measures was not a serious issue, given the large sample size and lack of correlations over 0.5 between any two measures at the same time point (Braveman et al., 2005). Two time-invariant measures of social support were also incorporated, both based on questionnaires distributed to the mother in pregnancy. The "social network score" comprises 10 items which ascertain the quality and frequency of social contact with friends and family and ranges from 0–30. The "social support score" measures perceived social support from

family, friends, and official agencies using a set of 10 items specifically designed for the cohort. The item presents statements relating to emotional, financial, and instrumental support, with a summed overall score also ranging between 0 and 30. Both measures were banded into three groups of equal size, coded as "low," "medium," and "high." Finally, a time-varying measure of mother's employment status is also included as an additional dichotomous covariate term in all models, as previous research has indicated this factor may be an important determinant of time related investments in children (Bianchi, 2000).

### 2.4. Data analysis

The relationship between the independent variables and each parent score over the study period was examined using multivariate multilevel models (Singer & Willett, 2003). Individuals were treated as Level 2 units, and the timing of measures, as Level 1 units. All analyses were carried out using MLwiN 2.02. Modelling data in this way requires contemporaneous data on predictor and outcome variables, a feature not strictly met by the temporal distribution of time-varying measures included in this study (Lawson & Mace, 2008). To overcome this issue, we assumed that time-varying independent variables had equal values to the midpoints between each coding, imputing their value at the months where outcome data were recorded.

The major advantage of a multilevel modeling strategy is that it allows us to incorporate all available outcome data rather than restrict analysis to participants who provided complete assessments at a specific subset of time points. However, in order to have unbiased estimates in the presence of missing data, it must be assumed that responses are missing at random (MAR); that is, the probability of any parent score measure being missing may depend on observed, but not unobserved, measures (Little & Rubin, 1987). Although we do not formally investigate this issue, given the large range of relevant independent variables included in our models, it is likely that our analyses conform to the MAR assumption.

We first determined "unconditional growth models" (Singer & Willett, 2003) which establish the overall relationship of each parent score with time (child age in years). We then assessed the impact of total family size on each parent score, constructing final multivariate models in a series of blocks. For each independent variable, effects

Table 2
Main mother score model: predictors of maternal investment in childhood

| | | Initial status (at 1y 6m) | | Rate of change (per year) | |
|---|---|---|---|---|---|
| | | Coefficient (*B*) | 95% CI | Coefficient (*B*) | 95% CI |
| Intercept[a] | | 8.62*** | 8.52–8.72 | −0.77*** | −0.75 to 0.79 |
| Family size (reference: 1) | 2 | −0.09*** | −0.12 to −0.06 | – | – |
| | 3 | −0.20*** | −0.24 to −0.16 | – | – |
| | 4 | −0.28*** | −0.34 to −0.22 | – | – |
| | 5+ | −0.27*** | −0.37 to −0.17 | – | – |
| Sex (reference: male) | Female | 0.06*** | 0.02–0.10 | – | – |
| Mother's age (reference: <25) | 25–29 | – | – | 0.00 | −0.01 to 0.01 |
| | 30–34 | – | – | −0.01 | −0.02 to 0.00 |
| | 35+ | – | – | −0.02** | −0.03 to −0.01 |
| Father presence (reference: Present) | Mother alone | 0.09*** | 0.04–0.14 | – | – |
| | New partner | −0.16*** | −0.23 to −0.09 | – | – |
| Mother's education (reference: <O level) | O level | 0.07* | 0.01–0.13 | −0.01* | −0.02 to 0.00 |
| | A level | 0.25*** | 0.19–0.31 | −0.03*** | −0.04 to −0.02 |
| | Degree | 0.17*** | 0.10–0.24 | −0.05*** | −0.06 to −0.04 |
| Family income (reference: <£200/week) | £200–299 | 0.03 | −0.01 to 0.07 | – | – |
| | £300–399 | 0.04* | 0.00–0.08 | – | – |
| | £400+ | 0.06** | 0.01–0.11 | – | – |
| Home ownership (reference: Renting) | Mortgaged/Buying | 0.07* | 0.01–0.13 | −0.03*** | −0.04 to −0.02 |
| | Owned | 0.22*** | 0.10–0.34 | −0.05*** | −0.08 to −0.02 |
| Social network score (reference: Low) | Med | 0.16*** | 0.09–0.23 | – | – |
| | High | 0.29*** | 0.22–0.36 | – | – |
| Social support score (reference: Low) | Med | 0.10*** | 0.08–0.12 | – | – |
| | High | 0.21*** | 0.19–0.23 | – | – |
| Maternal employment (reference: No) | Yes | −0.05*** | −0.07 to −0.03 | – | – |
| Question style (reference: Objective) | Subjective | −0.30*** | −0.34 to −0.26 | 0.35*** | 0.34–0.36 |
| Question reference (reference: Parent only) | Additional adults | 0.19*** | 0.17–0.21 | – | – |

Final *N*=37,658.

[a] The estimated mean value for initial status and rate of change for the group with the baseline values for every factor included in the model.

* $p<.05$.

** $p<.01$.

*** $p<.001$.

were estimated by both a main effect term (effect on initial status at one year, six months) and an interaction term with child age (effect on rate of change per year). Note that, in cases where only main effect terms reach significance, this implies that effects are constant over the study period. Statistical significance of each predictor term was assessed (as in standard linear regression) by dividing the regression coefficient by its standard error and 95% confidence intervals calculated. All variables relating to family configuration (except variables sibling sex and age) were entered in the initial block. This model was then reduced down by a backwards procedure removing associations that did not reach significance at the $p<.05$ level, unless their removal impacted a notable change on the coefficients of family size. All family configuration variables maintained in the model at this stage were carried forward to final model. The second block then entered all variables relating to parental resources and maternal employment and was reduced down in a similar fashion to produce the final model. Predictor terms were maintained if $p<.05$ or their presence effected notable changes on any of the family configuration coefficients.

Variation in family size effects by SES was explored by running separate versions of the final family size models stratified first by family income and then maternal education levels. Household incomes of below £200 per week were coded as low SES, between £200 and 400 as middle SES, and above £400 as high SES. Maternal education of less than an O level was coded as low SES, O-level and A-level qualifiers as middle SES, and Degree level education as high SES. Comparison of effect sizes between SES strata is made incrementally at each increase to family size (i.e., effect of increasing family size from one to two children, from two to three children and so on) to allow for the possibility that interactions with SES may vary at different family size thresholds. Finally, two further separate models for each parent score were constructed to consider the effects of sibling age and sex configuration. Final models for total family size for each parent score were used as a template and models specified by replacing the predictor terms for total family size with, first, number of older and younger siblings, and then number of brothers and sisters.

## 3. Results

### 3.1. Relationships between parental care and child age

Across the study period mean mother scores are higher and have a smaller standard deviation than mean partner

Table 3
Main partner score model: predictors of paternal investment in childhood

| | | Initial status (at 1y 6m) | | Rate of change (per year) | |
|---|---|---|---|---|---|
| | | Coefficient (*B*) | 95% CI | Coefficient (*B*) | 95% CI |
| Intercept[a] | | 1.57*** | 1.39–1.75 | −0.18*** | −0.20 to −0.16 |
| Family size (reference: 1) | 2 | −0.24*** | −0.29 to −0.19 | 0.04*** | 0.02–0.06 |
| | 3 | −0.46*** | −0.54 to −0.38 | 0.06*** | 0.04–0.08 |
| | 4 | −0.61*** | −0.74 to −0.48 | 0.09*** | 0.06–0.12 |
| | 5+ | −0.71*** | −0.93 to −0.49 | 0.11*** | 0.07–0.15 |
| Sex (reference: male) | Female | – | – | −0.04*** | −0.05 to −0.03 |
| Father's age (reference: <25) | 25–29 | 0.01 | −0.09 to 0.11 | – | – |
| | 30–34 | −0.07 | −0.17 to 0.03 | – | – |
| | 35+ | −0.19*** | −0.30 to −0.08 | – | – |
| Father presence (reference: Present) | Mother alone | N.A. | N.A. | N.A. | N.A. |
| | New partner | −0.33*** | −0.47 to −0.29 | – | – |
| Mother's education (reference: < O level) | O level | 0.09 | 0.00–0.18 | −0.02* | −0.04 to 0.00 |
| | A level | 0.30*** | 0.20–0.30 | −0.04*** | −0.06 to −0.02 |
| | Degree | 0.55*** | 0.43–0.67 | −0.07*** | −0.09 to −0.05 |
| Family income (reference: <£200 per week) | £200–299 | 0.10*** | 0.05–0.15 | – | – |
| | £300–399 | 0.12*** | 0.06–0.18 | – | – |
| | £400+ | 0.10** | 0.04–0.16 | – | – |
| Social network score (reference: Low) | Med | 0.24*** | 0.23–0.25 | – | – |
| | High | 0.32*** | 0.31–0.33 | – | – |
| Social support Score (reference: Low) | Med | 0.44*** | 0.35–0.53 | −0.03*** | −0.04 to −0.02 |
| | High | 0.64*** | 0.55–0.73 | −0.03*** | −0.04 to −0.02 |
| Maternal employment (reference: No) | Yes | 0.18*** | 0.13–0.23 | −0.01** | −0.02 to 0.00 |
| Mother score | Continuous (0–10) | 0.37*** | 0.35–0.37 | – | – |
| Question style (reference: Objective) | Subjective | 1.04*** | 1.02–1.06 | – | – |
| Question reference (reference: Parent only) | Additional adults | 0.08*** | 0.04–0.12 | – | – |

Final $N$=37,296.

[a] The estimated mean value for initial status and rate of change for the group with the baseline values for every factor included in the model.

* $p<.05$.

** $p<.01$.

*** $p<.001$.

scores (Table 1). To estimate overall relationships between parental care and child age we used unconditional growth models (Singer & Willett, 2003). These models contain only significant effects of child age and dichotomous control variables to indicate questionnaire style (objective vs. subjective frequency measure) and reference (refers only to the parent vs. additional adults). For each parent score, a negative linear relationship with child age is not significantly improved upon by any higher order function. In the mother score model, initial status (i.e. at one year, six months) was estimated at 9.11 (CI: 9.06–9.16, $p<.001$) decreasing at −0.85 units per year (CI: −0.86 to −0.84, $p<.001$). In the partner score model, initial status was estimated at 5.62 (CI: 5.55–5.69, $p<.001$) decreasing at −0.56 units per year (CI: −0.58 to −0.54, $p<.001$). Hence, mothers are more heavily involved in care, especially for young children, but the higher rate of decline for the mother score indicates that the difference between mother and partner scores attenuates over time.

### 3.2. Main models: parental resources, family structure and parental care

Tables 2 and 3 summarize the final multivariate models for the mother score and partner score respectively. Pseudo $R^2$ statistics estimate the percentage of total variance explained by these models. In the mother score model, 63% of within-person variance, 19% of between-person variance in initial status, and 20% of between-person variance in rate of change are accounted for by the independent variables. In the partner score model, these values are 57%, 28% and 39%, respectively.

Higher SES was associated with higher parent scores particularly in the earliest years of the cohort. Compared to low-level qualifications (Certificate of Secondary Education/ Vocational), children of higher educated mothers scored higher initial status for both parent scores. However, for each group, this difference declined over time due to a reduced rate of change per year. Relative to a family earning under £200/week, higher earning families had consistently higher parent scores particularly for father figures. Home ownership status also was associated with higher mother scores, with children living in mortgaged or owned accommodation having higher initial scores compared to rented accommodation. However, negative rate of change effects per year reverse this effect by the end of the study period.

Higher maternal social support and social network scores were associated with higher parent scores for both mothers and partners. Maternal employment was associated with a modest reduction in the mother score consistent across the study period. However, the effect was the opposite on the partner score, with maternal employment having a positive initial status effect gradually reduced over time by a negative effect on rate of change; so, at least, for young children, partners become more involved in care if the mother goes out to work. Older parents (mothers and fathers over 35 compared to those under 25) engaged in the coded parenting activities at lower frequencies. Including mother score as a covariate in the partner score model, we estimate the association between parent scores. For each unit increase in the mother score, partner scores were consistently higher across the study period. In other words, those children with attentive mothers also tend to have attentive fathers.

Independent of these relationships, negative family size effects represented the largest comparisons estimated in each parent score model. Each additional sibling markedly reduces the amount of care that both mother and father give to each child. The magnitude of the family size effects on the mother score did not change over time. Partner score effects were the largest in the earliest years, with initial status effects substantially reduced over time by positive rate of change effects. For both parent scores, the negative effects of increasing family size are incremental with some sign of tailing off amongst the largest families. Fig. 1 compares the overall effects (i.e., main effects only) of family size on each parent score. Family size had larger negative effects on partner scores than mother scores.

Girls had consistently slightly higher mother scores than boys but had lower partner scores, particularly in later years (with no main effect but a rate of change effect). Single motherhood was associated with consistently higher mother scores relative to children with biological fathers present.

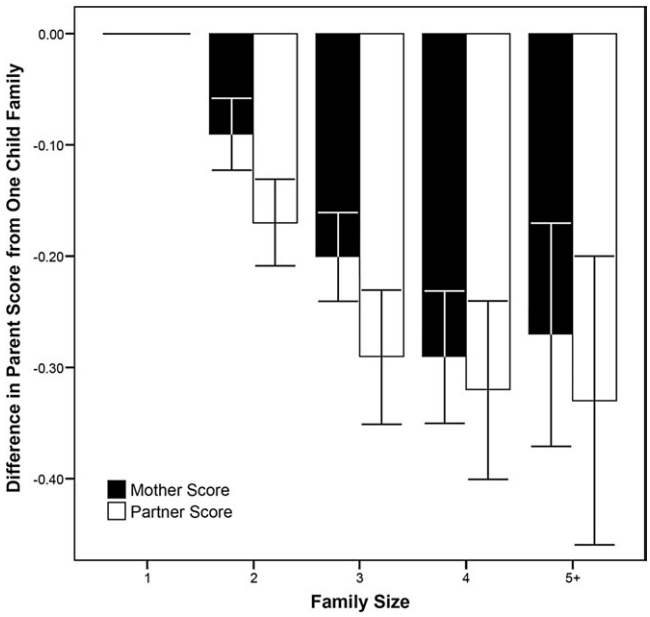


Fig. 1. Family size and parent scores over the study period (main effects of family size only). Family size is negatively associated with levels of maternal and paternal time investment over the study period (1.5–9 years, all contrasts $p<.001$). Final models control for time of measurement, sex of study child, parental age, father presence, mother's education, family income, home ownership status (mother score model only), maternal social support and network scores, maternal employment, mother score (partner score model only), and questionnaire style and reference variables (see Tables 2 and 3 for full models).

However, children with nonbiological father figures had consistently lower mother scores and lower partner scores across the study period. Hence, mothers are reducing investment in offspring from former partners only if a new partner is present.

### 3.3. Interactions between family size and socioeconomic effects on parental care

We refit the main models separately for socioeconomic strata categorized first by household income and then maternal education. To simplify comparison of family size effects, models only estimate the main effects (i.e., initial status effects) of sibling number. For all other covariates, both main effects and interactions with time are included (as in Tables 2 and 3). In total, 12 separate models were fit to explore socioeconomic variation (summarized in Table 4). Fig. 2 graphically contrasts the incremental effects of increasing family size by family income. For the mother score, the transition from one to two children shows a clear socioeconomic gradient with high income associated with the lowest costs of increasing family size (not significantly different from one child). However, in the transition from two to three children, the costs of increasing family size are relatively level across income strata. Finally, caring for four or more children relative to three children brings no additional cost in low income families (not significantly different from caring for three children), with middle- and high-income families facing the largest costs of a similar magnitude. For the partner score, the highest costs of increasing family size are concentrated in high and middle income strata across all transitions. These results are very similar when the sample is partitioned by maternal education (Table 4).

### 3.4. Sibling age and sex models

Rerunning the main models but replacing family size with number of older and number of younger siblings revealed that for both parent scores older siblings led to higher costs than younger siblings (Table 5). For the mother score, compared to first-borns, children with one, two, and three or more elder siblings had consistently lower mother scores, while having one and two or more younger siblings led to smaller but still significant deficits. For the partner score, compared to first-borns, children with one, two, and three or more older siblings had reduced initial status effects, attenuated over time by positive rate of change effects, while having one younger sibling was not significantly different to having no younger siblings and having two or more led only to a relatively small deficit. Sibling sex configuration models (Table 6) revealed no clear difference in the costs of brothers versus sisters, with effects being of comparable magnitude in both mother score and partner score models. The effects of other covariates and model fit statistics show little variation between final model and sibship age and sex models (not shown). However, the effects of parental age are of lower magnitude and significance in sibship age configuration models. This suggests, at least in part, that parental age

Table 4
Final parent score models for family size by socioeconomic strata: (a) family income strata (b) maternal education strata

| (a) Income strata | | | | | (b) Education strata | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Main effect | | | | | Main effect | |
| | | | Coefficient (B) | 95% CI | | | | Coefficient (B) | 95% CI |
| Mother score | Low income ($n$=8179) | 2 (Ref: 1) | −0.19*** | −0.26 to −0.12 | Mother score | Low education ($n$=10,218) | 2 (Ref: 1) | −0.19*** | −0.26 to −0.12 |
| | | 3 (Ref: 2) | −0.11** | −0.19 to −0.03 | | | 3 (Ref: 2) | −0.06 | −0.13 to 0.01 |
| | | 4+ (Ref: 3) | 0.00 | −0.11 to 0.11 | | | 4+ (Ref: 3) | −0.09 | −0.18 to 0.09 |
| | Middle income ($n$=25,807) | 2 (Ref: 1) | −0.13*** | −0.17 to −0.09 | | Middle education ($n$=27,734) | 2 (Ref: 1) | −0.10*** | −0.14 to −0.06 |
| | | 3 (Ref: 2) | −0.14*** | −0.18 to −0.10 | | | 3 (Ref: 2) | −0.13*** | −0.17 to −0.09 |
| | | 4+ (Ref: 3) | −0.12*** | −0.19 to −0.01 | | | 4+ (Ref: 3) | −0.12*** | −0.19 to −0.05 |
| | High income ($n$=13,499) | 2 (Ref: 1) | −0.01 | −0.14 to 0.12 | | High education ($n$=7592) | 2 (Ref: 1) | −0.05 | −0.12 to 0.02 |
| | | 3 (Ref: 2) | −0.11** | −0.16 to −0.06 | | | 3 (Ref: 2) | −0.10*** | −0.16 to −0.06 |
| | | 4+ (Ref: 3) | −0.13** | −0.22 to −0.06 | | | 4+ (Ref: 3) | −0.03 | −0.15 to 0.09 |
| Partner score | Low income ($n$=6163) | 2 (Ref: 1) | −0.11 | −0.25 to 0.03 | Partner score | Low education ($n$=9032) | 2 (Ref: 1) | −0.18*** | −0.28 to −0.08 |
| | | 3 (Ref: 2) | −0.17** | −0.31 to −0.03 | | | 3 (Ref: 2) | −0.03 | −0.13 to 0.07 |
| | | 4+ (Ref: 3) | −0.04 | −0.23 to 0.15 | | | 4+ (Ref: 3) | −0.01 | −0.15 to 0.14 |
| | Middle income ($n$=24,546) | 2 (Ref: 1) | −0.14*** | −0.20 to −0.08 | | Middle education ($n$=27,554) | 2 (Ref: 1) | −0.21*** | −0.26 to −0.16 |
| | | 3 (Ref: 2) | −0.23*** | −0.32 to −0.14 | | | 3 (Ref: 2) | −0.19*** | −0.25 to −0.13 |
| | | 4+ (Ref: 3) | −0.13** | −0.22 to −0.04 | | | 4+ (Ref: 3) | −0.14** | −0.13 to −0.05 |
| | High income ($n$=13,132) | 2 (Ref: 1) | −0.20*** | −0.27 to −0.13 | | High education ($n$=7255) | 2 (Ref: 1) | −0.23*** | −0.32 to −0.14 |
| | | 3 (Ref: 2) | −0.16*** | −0.23 to −0.09 | | | 3 (Ref: 2) | −0.18*** | −0.28 to −0.08 |
| | | 4+ (Ref: 3) | −0.10 | −0.22 to 0.02 | | | 4+ (Ref: 3) | −0.01 | −0.17 to 0.15 |

Models contain control variables for additional aspects of family configuration and parental resources (see Tables 2 and 3).
$n$ indicates the number of parent score measures included in each income/education group model. Ref indicates the reference category for each comparison.
** $p<.01$.
*** $p<.001$.

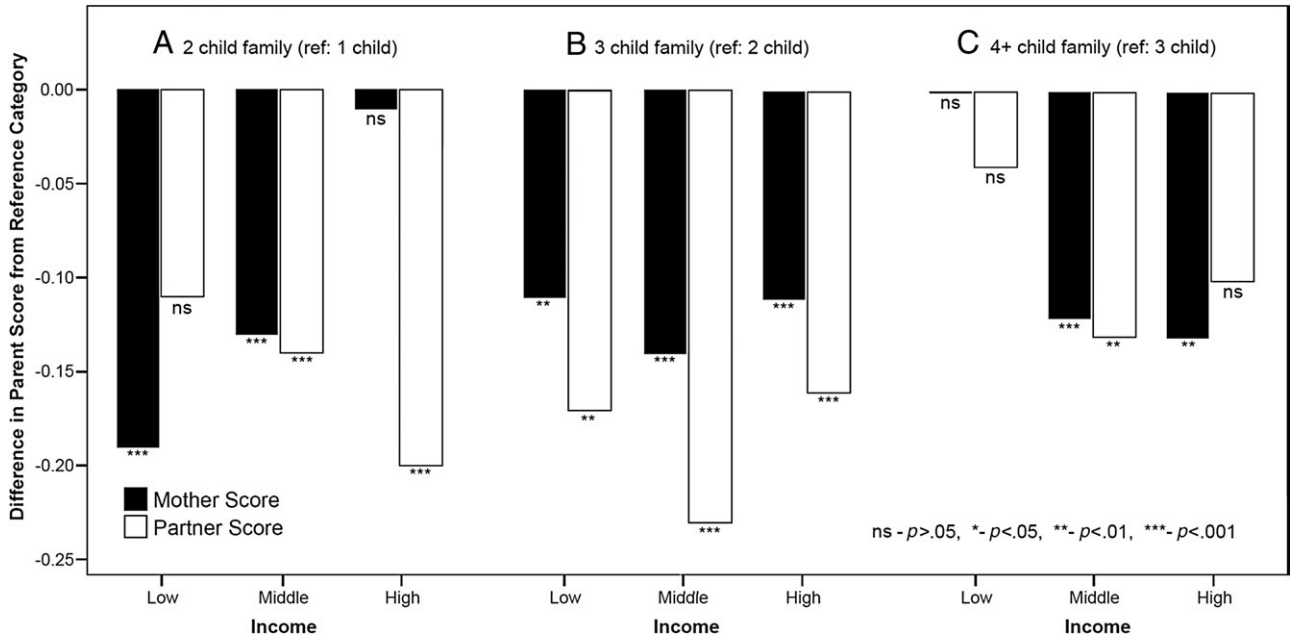


Fig. 2. Incremental differences in parent score values as family size increases, by household income strata: a) caring for two relative to one child, b) caring for three relative to two children, c) caring for 4+ relative to three children. In most cases, middle and high income families face the strongest trade-offs between family size and parental care. Final models control for time of measurement, sex of study child, parental age, father presence, mother's education, home ownership status (mother score model only), maternal social support and network scores, maternal employment, and questionnaire style and reference variables (see Table 4 for confidence intervals).

effects reflect covarying birth order patterns, rather than independent effects.

## 4. Discussion

### 4.1. Parental care in modern families

In this study, we used British longitudinal data to define the parental investment schedules which characterize childhood in modern families. We measured parental investment as reported frequencies of parental engagement in childcare activities. We find clear asymmetry in parental care, characteristic of a vast majority of animals (Clutton-Brock, 1991), with mothers consistently investing more time than father figures, and with lower levels of variation between individuals. Even at the level of individually coded behaviors, for only one activity (physical play) was maternal involvement lower than paternal involvement (Table 1). This asymmetry of male and female care likely also reflects a division of parental investment forms, with

Table 5
Final parent score models for sibling age configuration: (a) mother score (b) partner score

| | | Initial status (at 1y 6m) | | Rate of change (per year) | |
|---|---|---|---|---|---|
| | | Coefficient (*B*) | 95% CI | Coefficient (*B*) | 95% CI |
| (a) Mother score | | | | | |
| No. of older siblings (reference: 0) | 1 | −0.24*** | −0.28 to −0.20 | – | – |
| | 2 | −0.27*** | −0.33 to −0.21 | – | – |
| | 3+ | −0.42*** | −0.52 to −0.32 | – | – |
| No. of younger siblings (reference: 0) | 1 | −0.03* | −0.06 to 0.00 | – | – |
| | 2+ | −0.10*** | −0.15 to −0.05 | – | – |
| (b) Partner score | | | | | |
| No. of older siblings (reference: 0) | 1 | −0.54*** | −0.62 to −0.46 | 0.07*** | 0.06–0.08 |
| | 2 | −0.81*** | −0.92 to −0.70 | 0.09*** | 0.07–0.11 |
| | 3+ | −0.98*** | −1.19 to −0.77 | 0.12*** | 0.08–0.16 |
| No. of younger siblings (reference: 0) | 1 | −0.03 | −0.07 to 0.01 | – | – |
| | 2+ | −0.07* | −0.14 to 0.00 | – | – |

Models contain control variables for additional aspects of family configuration and parental resources (see Tables 2 and 3).
Final *N*, Mothers Score=37,658; Partners=36,691.
* $p<.05$.
*** $p<.001$.

Table 6
Final parent score models for sibling sex configuration: mother score (a) and partner score (b)

| | | Initial status (at 1 y 6m) | | Rate of change (per year) | |
|---|---|---|---|---|---|
| | | Coefficient (*B*) | 95% CI | Coefficient (*B*) | 95% CI |
| (a) Mother score | | | | | |
| No. of brothers (reference: 0) | 1 | −0.09*** | −0.12 to −0.06 | – | – |
| | 2+ | −0.23*** | −0.29 to −0.17 | – | – |
| No. of sisters (reference: 0) | 1 | −0.09*** | −0.12 to −0.06 | – | – |
| | 2+ | −0.24*** | −0.30 to −0.18 | – | – |
| (b) Partner score | | | | | |
| No. of brothers (reference: 0) | 1 | −0.29*** | −0.35 to −0.23 | 0.04*** | 0.03–0.05 |
| | 2+ | −0.49*** | −0.62 to −0.36 | 0.06*** | 0.04–0.08 |
| No. of sisters (reference: 0) | 1 | −0.24*** | −0.30 to −0.18 | 0.03*** | 0.02–0.04 |
| | 2+ | −0.53*** | −0.63 to −0.43 | 0.07*** | 0.05–0.09 |

Models contain control variables for additional aspects of family configuration and parental resources (see Tables 2 and 3).
Final *N*, Mothers Score=33,575; Partners=32,798.
*** $p<.001$.

mothers being more likely to spend time at home with children, while the contribution of fathers may be largely in the form of accumulation of family resources through employment. The inclusion of unrelated father figures in our sample can account for only a small proportion of estimated differences between maternal and paternal care, while contrasts between biological and unrelated fathers are significant, they are of not of comparable magnitude to the overall gap between the sexes.

Strong socioeconomic gradients characterized the quality of maternal and paternal care. Thus, children in wealthy families appear doubly advantaged by both improved access to material resources and higher levels of interpersonal investment. This conclusion is supported by a number of studies of parental time allocation to childcare (Bianchi, 2000; Hill & Stafford, 1980; Zick & Bryant, 1996). Time is a tightly constrained resource, and economically stressed parents may be forced to make allocations elsewhere for family maintenance. In addition, some of the activities included in our study, such as taking the study child to watch sports, to shopping, or to classes, are in part dependent on the financial resources to do so, although it should be noted that the great majority of our measures of care did not involve monetary outlay. Positive effects of SES were particularly strong on paternal care, indicating that the relative involvement of fathers to mothers increases with SES (see also Nettle, 2008). Positive effects of maternal social support on investment from both parent figures were also strong. Higher levels of social support and larger social networks may free up more time for childcare activities. Alternatively, these effects may be mediated through improving the emotional well-being of the parents, known to show a strong association with social support in this sample (Thorpe, Dragonas, & Golding, 1992).

Even after controlling for other significant covariates, levels of parental investment were positively correlated between mothers and father figures caring for the same child. However, our results also indicate signs of cooperative replacement. For example, deficits in maternal care caused by maternal employment were substituted by higher levels of paternal care. This finding underlines the importance of considering multiple carers in studies of parental investment, as previous studies examining care deficits in relation to maternal employment may make erroneous conclusions by focusing on the mother alone (Bianchi, 2000). Our results are also supportive of Gregg, Washbrook, Propper, and Burgess (2005) who found little evidence of negative impacts of maternal employment on cognitive development within the ALSPAC cohort.

### 4.2. Family structure and parental care

All aspects of family structure showed strong independent associations with parental care. Most importantly, both mother and fathers can only achieve large family size at a significant cost to the quality of care provided to individual children (Fig. 1). In fact, family size was the strongest explanatory variable considered in our analysis. Our results are therefore consistent with the position that established negative relationships between family size and offspring outcomes in modern societies are mediated by reductions in parental investment (Downey, 1995; Grawe, in press; Keister, 2003; Lawson & Mace, 2008; Steelman et al., 2002). We also find that the incremental costs of each additional child tailed off in the largest families consistent with a quantity–quality trade-off model (Downey, 1995). However, contrary to the expectations of life history theory (Tuomi et al., 1983; van Noordwijk & de Jong, 1986), we found that family size effects on parental investment were generally not alleviated in wealthy or well educated families. In fact, our results suggest, particularly in relation to paternal investment, that middle or high SES may actually increase the magnitude of trade-off effects relative to low SES families (Fig. 2).

It is interesting to reflect that the best evidence that parental resources alleviate quantity–quality trade-off effects comes from studies of traditional human populations (Borgerhoff Mulder, 2000; Gillespie et al., 2008). From an adaptive

perspective, these studies fit neatly with observed strong positive correlations between wealth and fertility (Nettle & Pollet, 2008), as when sibling competition is relaxed individuals can afford to raise more offspring. However, in addition to the current study, Grawe (in press) and Keister (2004) both find that impoverished strata in the modern US face comparatively weak trade-offs between fertility and offspring quality (in this case, with regard to offspring wealth). Downey (2001:499) also cites unpublished work which apparently confirms this pattern for family size effects on investment in educational attainment. If such a reversed inequality truly characterizes modern populations, with wealth increasing rather than reducing trade-off effects, this could act as a relative disincentive to high fertility in wealthy strata, offering a rational explanation for why cultural modernisation is associated with socioeconomic leveling in family size (see also Kaplan et al., 2002). However, the ultimate question of whether or not modern low fertility is adaptive remains difficult to evaluate in the absence of sufficient multigenerational data (Kaplan, Lancaster, Bock, & Johnson, 1995; Mace, 2007; McNamara & Houston, 2006).

For Downey (2001), the failure of increased parental resources to reduce trade-offs may be understood by categorizing parental care into guaranteed "base investments" and "surplus investments," which only parents of sufficient wealth are able to provide. As such children in poor families may be relatively unaffected by family size because surplus investments are beyond their reach and minimal base investments guaranteed. This model is theoretically a much better fit to modern societies in which base levels of schooling, healthcare, and social opportunity are guaranteed by the welfare state. In the context of our study, high levels of parental care, particularly from fathers, may therefore be seen as surplus investment with lower base levels guaranteed across socioeconomic strata. In fact, the particularly strong effects of SES on paternal care means that low SES fathers literally have limited ability to reduce investment any further as family size increases.

For both parents, we find that time investments decreased linearly with increasing child age. While investment levels over time cannot be interpreted directly due to the inclusion of age-specific activities in our models, this finding likely reflects a growing independence of children and movement towards nursery and primary school education systems. Higher levels of time investment in younger children might predict a higher cost of younger relative to older siblings for individual offspring. However, as predicted from evolutionary models (Jeon, 2008), we find clear evidence of a later-born disadvantage with the presence of older siblings impacting a larger deficit in parental care (see also Price, 2008). Strong birth order effects on IQ (Bjerkedal, Kristensen, Skjeret, & Brevik, 2007) and health outcomes (Hertwig et al., 2002; Lawson & Mace, 2008) have also been demonstrated in modern populations consistent with a later-born disadvantage.

A "gendering" of parenting activities characterized this population with each parent investing relatively more in same-sex offspring (see also Zick & Bryant, 1996). Nevertheless, given that gender of child effects were much larger for fathers than mothers (particularly in later childhood), this result is consistent with the prediction of an overall parental investment bias towards sons (Keller et al., 2001).

We also predicted that the preferred sex (in this case, girls for maternal investment and boys for paternal investment) would make for more costly siblings but find no evidence for this conclusion (Table 6). However, studies of related aspects of parental behavior are consistent with an overall risk of growing up with more sisters than brothers. For example, Dahl and Moretti (2004) demonstrate that sons relative to daughters have a positive effect on marital stability, as evidenced by US divorce rates (see also Lundberg, 2005).

Following previous studies of paternal investment (Anderson et al., 1999, 2007; Cooksey & Fondell, 1996; Marsiglio, 1991), we find that unrelated father figures invested less in offspring. Considering maternal behavior towards the same child, we also find for the first time that maternal investment is only negatively influenced when unrelated father figures are present. It is possible that this result reflects a trade-off between parenting and mating effort of the mother who, in order to attract and retain a new mate, must sacrifice some time allocations to her former partner's offspring in favor of the new partner and his current or future offspring. The methodological advancements of the current study provide particularly strong confidence that these results are not confounded by socioeconomic or demographic differences between families.

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