The Behavioural Ecology of Modern Families: A Longitudinal Study of Parental Investment and Child Development

Thesis submitted for the degree of

Doctor of Philosophy

to

University College London

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2009

Declaration

I, David William Lawson, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed:

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Abstract

In recent decades, behavioural ecologists have contributed to our understanding of the family through extensive studies of animal and traditional human populations. This research emphasises the importance of sibling competition for parental resources and adaptive patterns of biased parental care. In contrast, modern human families are rarely considered by behavioural ecologists, with increases in wealth generally considered to decrease the importance of resource dilution within families and modern cultural rules discouraging of unequal treatment of children. In this thesis, I question the validity of these assumptions and use rich longitudinal data to consider family structure effects on parental investment and child development in contemporary Britain. I consider time-based and financial investment in offspring and measures of physical, cognitive and behavioural development over a 10 year period. The following specific hypotheses are tested. First, parents will face a trade-off between fertility, investment per child and ultimately child well-being. This hypothesis is supported for all measures, except for behavioural well-being. Second, parents will bias investment towards early-born offspring. This hypothesis is largely supported. Later-born children receive lower investment and have reduced physical and cognitive well-being. However, mental health is improved in the presence of older siblings. Third, parents will bias investment towards male offspring. Support for this hypothesis is mixed. Measures of investment indicate a male-bias driven by fathers, while number of brothers relative to sisters is associated with reduced cognitive, but not physical or behavioural well-being. Fourth, children with unrelated father figures will receive less investment. This hypothesis is supported. Unrelated father figures are associated with lower investment from both parents and reduced physical and behavioural well-being. Finally, I test the hypothesis that higher socio-economic status will alleviate family size trade-offs. This hypothesis is rejected, with some evidence that resource competition is of increased importance in relatively wealthy and well-educated families.

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Acknowledgements

Firstly, I thank Ruth Mace for igniting my passion for science, anthropology and evolution and for her continuing inspiration and encouragement. I thank all the families which have taken part in the Avon Longitudinal Study of Parents and Children (ALSPAC) and the whole ALSPAC team. In particular, Jean Golding and George Davey Smith for their generosity in providing me access to this unique resource. This thesis would also not be possible without the support and guidance of Rebecca Sear, Mhairi Gibson, Laura Fortunato and Tom Dickins, each of whom has been a source of motivation, debate and timely distractions over the last three and a half years. Sara Randall and Gillian Bentley offered valuable advice in the development of this project. Jon Heron provided essential assistance with data management. Heidi Colleran, Anna Goodman and Shakti Lamba made thoughtful comments on draft material. Finally, I extend thanks most of all to Nicolas Deshayes, my family and to the Lincolns for their kindness and support.

This research was funded by an Economic and Social Research Council (ESRC) Studentship. A small grant from the Parkes Foundation also funded several trips to Bristol required in the early stages of the project. The UK Medical Research Council, the Wellcome Trust and the University of Bristol provide core financial support for ALSPAC.

Chapter 1. Introduction

1.1 Aims of Thesis

Humans demonstrate substantial variation in reproductive and parenting behaviour, both between and within cultures, leading to a diversity of family environments in which children are raised. Understanding the implications of this diversity for offspring outcomes, and identifying the underlying mechanisms which shape variation in human family structure are perennial research themes in the human sciences, including studies in anthropology, demography, economics, epidemiology, sociology and psychology. In this thesis, I address these questions from the integrative and broad comparative framework of human behavioural ecology and with specific regard to modern Western families.

In recent decades, behavioural ecologists have contributed to our understanding of the family through extensive studies of animal and traditional human populations. Grounded in evolutionary life history theory, this work emphasises the importance of sibling competition for parental resources, and adaptive patterns of biased parental care. In contrast, modern human families are rarely considered by behavioural ecologists, with increases in wealth generally considered to decrease the importance of resource dilution within families and modern cultural rules discouraging of unequal treatment of children. I question the validity of these assumptions using data from the Avon Longitudinal Study of Parents and Children (ALSPAC), an exceptionally detailed cohort study of contemporary British families. I consider time-based and financial investment in offspring and measures of physical, cognitive and behavioural development over a 10 year period. Through these analyses and review of related studies, I aim to characterise the role of modern family structure in determining schedules of parental investment and offspring development.

I also aim to provide an empirical evaluation of the standard life history theory prediction that increases in wealth alleviate family size effects on investment and offspring outcomes. Human behavioural ecology uniquely links the consequences of resource dilution within families with evolved mechanisms of fertility regulation, envisaging diversity in reproductive behaviour as ecologically dependent optima which maximise the production of socially and economically competitive offspring, and ultimately, Darwinian inclusive fitness. Challenging this perspective, cultural modernisation is characterised by the concurrence of substantial increases in material wealth and dramatically reduced fertility, now reaching the lowest levels in recorded human history. Conditions of modernity may however reverse the usual effects of wealth on resource competition between offspring favouring low fertility and extended periods of parental investment.

1.2 Human Behavioural Ecology

1.2.1 Key concepts

Human behavioural ecology is concerned with explaining human behavioural variation within its ecological and adaptive context (Borgerhoff Mulder 1991; Cronk 1991a; Winterhalder and Smith 2000; Hames 2001; Borgerhoff Mulder 2005). The field arose in the 1960s and 1970s with primary roots in evolutionary biological approaches to animal behaviour and early works in biosocial anthropology (Cronk 1991a). It remains closely aligned to studies in animal behavioural ecology (e.g. Krebs and Davies 1993), utilising the same key theoretical concepts, such as optimality theory (Parker and Maynard Smith 1990), to generate testable predictions about human behaviour. The behavioural ecology approach conceptualises behavioural variation as largely a product of phenotypic plasticity, whereby the same genotype can give rise to multiple phenotypes dependent on local ecological conditions. As the 'decision rules' that underlie this plasticity are subject to natural selection, models assume that observed behavioural strategies ultimately act to maximise Darwinian inclusive fitness across different environments.

Behavioural ecology models envisage few barriers to this adaptive flexibility. In general, pathways of inheritance (genetic or cultural) and the physiological or cognitive mechanisms that lie behind reaction norms are not seen to seriously limit adaptive responses to ecological variation. These mechanisms are largely ignored under the 'phenotypic gambit' (Grafen 1984) - which assumes that there is some linkage between genes and behaviour, and therefore behaviour can be analysed in ultimate terms, but the nature of the linkage is not an explicit concern. As such predictions are somewhat general and transferable across a wide array of organisms.

As a subfield of anthropology, human behavioural ecology can be seen as an alternative research program to sociocultural anthropology (Borgerhoff Mulder 1991; Winterhalder and Smith 2000; Hames 2001). It proposes that, under the common goal of fitness maximisation, differences in local socioecological factors provide a more tangible explanation for human behavioural variation. Behaviour is studied at the level of individual responses to ecology, and 'culture' envisaged as the product of individual decisions and interaction. In contrast, sociocultural anthropologists have traditionally insisted upon emergent properties of culture irreducible to the facts of biology and psychology and hence opposed the reduction of behavioural patterns to lower levels of analysis. Moreover, as an empirical science, human behavioural ecology differs in its employment of a hypothetico-deductive research strategy, exploring research questions through formalised models and systematically collected data.

1.2.2 Life history theory and parental investment

Life history theory forms a major branch of behavioural ecology concerned with the distribution of key life events that figure directly in the reproductive and survival schedules of an organism (Lessells 1991; Stearns 1992; Roff 2002). Life history traits include factors such as: age at sexual maturity; number and timing of reproductive bouts; and number and investment per offspring. Critical to this body of research is the concept that life history is constrained by the 'principle of allocation' – a unit of resource (energy, time, etc) that is spent on one function cannot be spent on another (Levins 1968). As such we should not expect observed life histories to reflect the optimum value of each individual trait, but the optimum realisable balance of two or more traits. Though numerous trade-offs have been described (Stearns 1992), two main trade-offs have dominated the literature: that between current and future reproduction (Williams 1966; Gadgil and Bossert 1970) and that between offspring number and offspring quality (Lack 1947; Lack 1954; Williams

1966; Smith and Fretwell 1974). The latter 'quantity-quality trade-off' forms a key focus of this thesis.

Under the rubric of life history theory, parental investment can be defined as any parental allocation of resources to the benefit of one offspring at a cost to that parent's ability to invest in other components of fitness (Trivers 1972; Clutton-Brock 1991: 9). Parental investment theory, which may be seen as part of life history theory, is a collection of hypotheses concerning how parental investment should be allocated between offspring to maximise fitness. The predictions of parental investment theory complicate the seemingly simple concept of a quantity-quality trade-off as equal investment in all offspring is not always anticipated. In this thesis, I concentrate on three factors which may bias parental investment schedules: birth order, sex of offspring and biological relatedness (of father figures).

1.2.3 Methodology

Measuring parental investment and offspring quality

The simplicity of Triver's (1972) definition of parental investment masks the reality that investment, like development, is clearly multidimensional. All organisms invest qualitatively different types of resources in the production and care of offspring (Blake 1981; Rosenheim et al. 1996; Borgerhoff Mulder 1998a; Hertwig et al. 2002). For example, Hertwig et al. (2002) distinguish three separate dimensions of (postnatal) investment that characterise human parenting: (1) *material resources* such as food, healthcare and financial investments in education; (2) *cognitive resources* such as intellectual stimulation and other forms of time spent training and instructing children; and (3) *interpersonal resources* such as attention, affection and general encouragement by parents. Distinguishing dimensions of investment has value because trade-off functions and relationships between the type of invested resource and offspring outcomes (in terms of child health, education or behavioural well-being) are unlikely to be uniform.

Ultimately offspring 'quality' is defined as individual fitness by behavioural ecologists. Survival probabilities and reproductive success (measured as number of offspring or grand-offspring) are often used as proxies for fitness in both animal and human studies. Such measures are probably effective under most ecological conditions, provided mortality rates are relatively high and intergenerational transmission of resources low. However, in practice life history studies often consider a wide variety of offspring outcomes at all stages of development. Considering a range of offspring outcomes is in part recognition that long-term determinants of fitness are also likely to be multidimensional. More generally, life history theorists have a wide interest in the general application of their models to related questions of biological significance. For human behavioural ecologists, this often brings evolutionary models very close to quantitative models in related human sciences.

Identifying life history trade-offs

The study of life histories in nature is complicated by the problem of 'phenotypic correlations'. Individuals with access to a large pool of resources may be able to divert investments into multiple life history traits simultaneously, while individuals with relatively poor resource access will invest little effort in the same traits. Such variation can obscure a trade-off, leading to positive correlation between two competing functions, rather than the negative correlation predicted by the principle of allocation (van Noordwijk and de Jong 1986). Given that such phenotypic correlations are likely to be common, life history trade-offs may only be detectable by either experimental manipulation or careful use of multivariate statistics.

The first method of experimentation involves the direct manipulation of a single factor while keeping all other factors constant, or at least randomly assigned. For example in birds, the costs associated with high fertility can be demonstrated by adding additional eggs to a clutch and measuring chick survival rates against a control group (e.g. Gustafsson and Sutherland 1988; Pettifor et al. 2001). While the manipulation of single life history traits or ecological factors is not always straightforward, this method is excellent at dealing with confounding variables and so logically preferred.

The second method is to measure covariation between life history traits and fitness outcomes from unmanipulated conditions, while statistically controlling for differences in individual resource base. This method is widely acknowledged as problematic as results will be '*unreliable unless a strong case can be made that all relevant variables have been included in the analysis'* (Roff 2002: 149). Anthropologists, unable to rely on experimental methods, therefore face the difficult task of incorporating sufficient covariates into their models. Relevant heterogeneity between individuals is often difficult to measure, particularly in cases when intrinsic factors are important (such as genetic differences). Thus, methodological concerns are a recurrent issue in discussions of human life history (e.g. Sear 2007).

Evidence of life history optimisation

The behavioural ecology model predicts that observed life histories represent ecologically dependent individual optima of fitness maximisation (sometimes referred to as the 'individual optimisation hypothesis': Pettifor 2001). Observed variation in fertility is thus determined by underlying variation in the ability to raise multiple offspring without sacrificing their quality. Animal researchers often test this hypothesis with the prediction that neither the experimental removal nor addition of young will result in increased parental fitness relative to control broods (e.g. Pettifor et al. 2001). Anthropologists have focused on alternative methods. The most direct test has been to first determine the fertility level that leads to the highest fitness returns in some measurable currency (while controlling for differences in parental resources) and then to compare this to the population mode (e.g. Strassmann and Gillespie 2002). If fertility is optimised, then optimal and modal fertility should converge. A more general approach, that does not involve the calculation of precise optima, is to consider covariation in observed fertility and the strength of trade-off effects. Negative effects of competition between offspring are normally assumed to be strongest when resources are scarce (Tuomi et al. 1983; van Noordwijk and de Jong 1986). As such, positive correlations between wealth and fertility are generally anticipated by models of fitness maximisation.

1.2.4 Conceptual challenges

Alternative evolutionary models of human behaviour have raised important conceptual challenges for human behavioural ecology (Smith 2000; Laland and Brown 2002). Principal criticism has focused on the ‘phenotypic gambit’; the tendency to avoid discussions of the proximate mechanisms which guide behavioural responses to the environment and assume that such mechanisms operate relatively unconstrained by their design (Grafen 1984; Borgerhoff Mulder 2005). Evolutionary psychologists and researchers of ‘cultural evolution’ counter that a complete understanding of human behaviour requires an explicit consideration of the mechanisms of adaptation. This understanding is crucial because the true nature of such mechanisms may limit adaptive responses of an organism thereby disrupting the predictions of traditional behavioural ecology models.

Evolutionary psychologists stress that an effective withdrawal of relevant information from the environment is necessitated by ecologically contingent decision making, yet access to perfect information may often be limited, and furthermore its extraction and processing costly. They therefore suggest that it is unrealistic to assume that our cognitive architecture is able to process all environmental information rationally, or even that relevant information will be available under all conditions (Barkow et al. 1992). Instead, they are starting to explore more psychologically plausible mechanisms by which decisions are made, focusing on 'fast and frugal heuristics' (e.g. Gigerenzer et al. 1999). According to some evolutionary psychologists, the potential for this decision making apparatus to lead to maladaptive behaviour may be particularly high in conditions distinct from the environment under which they evolved (the so called 'environment of evolutionary adaptedness' or EEA). Specifically, they assume that humans are adapted to a hunter-gatherer lifestyle and that our adaptations became 'out of sync' with our environments with the onset of agriculture about 9,000 years ago (Symons 1989; Barkow et al. 1992).

Cultural evolutionary theorists argue that individual-decision based models of human behavioural ecology are misleading as humans are inherently reliant on social learning (Boyd and Richerson 1985; Richerson and Boyd 2005). Instead they focus on modelling the dynamics of social transmission biases in human behaviour. Natural selection would favour these biases as a naïve individual may often do better to imitate the behaviour of the most successful individuals in their group, or simply conform to the modal behaviour, rather than pay the costs of individual trial and error learning. As a consequence of these biases, traits may spread that are not adaptive in the strict sense of enhancing individual fitness.

Human behavioural ecologists maintain that in relation to their principal goal, to determine whether models of fitness maximisation can provide definitive explanations of behavioural variation, their traditional research methodology remains the most effective (Smith et al. 2000; Smith et al. 2001). Nevertheless, as a product of these debates, explicit consideration of the mechanisms of adaptation, which in practice has never been entirely absent in behavioural ecology studies, has been given increased weight in the literature. Recent years have seen clear signs of synthesis between alternative approaches and the emergence of integrative research frameworks (Sear et al. 2007).

1.3 Family Structure and Parental Investment

In this section I consider in more detail how family size, birth order, sex and relatedness are predicted to influence allocations of parental investment and subsequently offspring outcomes. I first introduce the main hypotheses and briefly review key studies in the animal literature (concentrating on avian and mammalian species). It is in this literature that life history theory laid its theoretical and empirical roots, and where empirical research continues to dominate, providing some of the strongest tests of each hypothesis. For each aspect of family structure, I then review the human behavioural ecology literature focusing on hunter-gatherer and agriculturalist populations. This introductory framework allows the study of modern human populations to be approached from a suitably broad comparative perspective.

1.3.1 Family size

Life history theory states that parents must balance the trade-off between fertility (family size) and the success of their offspring (Lack 1947; Lack 1954; Williams 1966; Smith and Fretwell 1974). All other things being equal, siblings are seen to dictate a division of parental resources, leading to lower individual shares per offspring, negative development outcomes and ultimately lower fitness. This simple concept of a quantity-quality trade-off, albeit without specific reference to Darwinian fitness, is also central to economic models of the human family (Becker 1981; Blake 1989; Downey 2001). A strict following of these models further predicts that increases in parental fertility will be most costly for offspring in 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 two consumers means each gets one half, three get one third, and four get one fourth, etc). However, until recently few studies have explored this related prediction (Downey 1995).

No taxon has been subject to more life history studies than birds. This bias stems historically from an enduring natural history tradition, pre-dating any theoretical framework, and from the early pioneering work of David Lack (Lack 1947; Lack 1954; Lack 1966). Avian life history is characterised by development of hatchlings from egg to full adult size and flight, often in the space of a few short weeks. This rapid transformation requires a considerable quantity of food. Parental deliveries are thus critical to a hatchling's chance of recruitment into the adult population. Brood manipulation studies provide solid evidence for a quantity-quality trade-off (reviewed in Stearns 1992; Roff 2002). Summarising the results of over 50 studies in various species, Stearns (1992) found that 82% of studies demonstrated costs of enlarged broods in offspring traits. In 28 of 44 studies, nestling survival (survival to fledging) was poorer in enlarged broods and in no study was it better. Likewise, in 27 of 40 studies reporting nestling condition, it was significantly worse in enlarged broods and in no case was it improved. In eight of 15 cases, it was suggested that chicks fledged from enlarged broods also suffered higher mortality before recruitment into the breeding population, a relationship reliably documented in Gustafsson and Sutherland (1988); Pettifor et al. (1988); Smith et al. (1989); and more recently Pettifor et al. (2001). Finally, in all three studies which assessed reproductive performance, birds reared in enlarged clutches had reduced reproductive outcomes (Stearns 1992).

Mammals, like avian species, engage in extensive parental care. However there are a number of important differences (Mock and Parker 1997). First, unlike the situation in a majority of birds (which tend towards monogamy and biparental care: Black 1996), mammals are characterised by the burden of parental care falling almost exclusively on the mother. As such, we can expect competition to focus on maternal resources. Second, whereas avian embryos subsist on segregated food supplies (yolks within shells), eutherian development begins with a lengthy gestation during which litter mates share the maternal circulatory system as common food source. As such, stronger embryos may be able to monopolize maternal resources in a way not open to avian species, which prior to hatching are less able to actively compete. Third, the non-dispersive nature of social mammals also has the interesting property of extending the potential period for sibling competition far into adulthood. These latter two factors combine so that "*mammalian sibling rivalry is likely to begin earlier (as embryos) and last longer (until adulthood) than avian versions*" (Mock and Parker 1997: 296).

Mammalian species are also relatively difficult to study; not all are open to manipulation experiments and many species are nocturnal and/or live in isolated or subterranean burrows. Nevertheless an emerging literature conducting litter size manipulations on several small mammal species provides evidence that enlarged litters show a reduced probability of survival to weaning and lower weight at weaning amongst survivors (Machin and Page 1973; Smith and McManus 1975; Fleming and Rauscher 1978; Kaufman and Kaufman 1987; Hare and Murie 1992; Genoud and Perrin 1994; Mappes et al. 1995; Koskela 1998; Humphries and Boutin 2000; Neuhaus 2000; Kiovula et al. 2003; Mappes and Koskela 2004). Correlation based studies (reviewed in Roff, 2002: 130-131) also support these negative outcomes, in addition to demonstrating lower birth weight (presumably a consequence of *in utero* resource dilution). Less work has quantified the consequences of sibling competition after weaning. Resource competition is likely to continue for many mammals beyond this stage. For example, in carnivorous species offspring may remain dependent on parental deliveries of food, while in species with low dispersal, siblings may remain in sufficiently close contact to compete directly for local resources, including mates (Clark 1978; Johnson 1988; Mock and Parker 1997).

Additional indirect evidence for a cost of siblings typical in animal populations comes from studies of sibling aggression. In extreme cases facultative and obligate systems of siblicide have evolved in birds (Simmons 1988; Mock et al. 1990; Simmons 2002) and possibly mammals (Smale et al. 1999; Leippet et al. 2000). Some species also show evidence of specialised 'sibling weaponry' to aid them in competition for resources. For example, Fraser and Thompson (1991) show evidence that pigs have evolved early erupting canines specifically to shift weaker sibling rivals off prime teats.

Negative relationships between parental fertility and individual offspring status are most obviously mediated by lowered shares of delivered food, but there are other related pathways. For example, in a number of avian species, manipulation of brood size has shown correlated changes in immune response consistent with effects of physiological stress (e.g. Gustafsson et al. 1994; Deerenberg et al. 1997; Johnsen and Zuk 1999). Parasite load also appears to be increased among larger broods (Norris et al. 1994; Richner et al. 1995). The detrimental effects of parasites on fledging success or other components of fitness have been demonstrated in a number of species (e.g. Moller 1993; Allander and Bennett 1995). In addition, large clutches may be penalised by increased predation risk because they make more noise and attract predators (Skutch 1949; Lima 1987).

Penalties to small clutch size have also been documented. Small clutches may find it hard to thermoregulate efficiently (Mock and Parker 1986). There are also cases where siblings have been suggested to aid in learning. For example, although facultatively siblicidal when young (Mock et al. 1990), osprey chicks from doubleton broods apparently learn complex hunting skills faster than singleton offspring (Edwards 1989). Older siblings from the preceding clutch may also act as ‘helpers at the nest’ assisting parents to care for younger siblings in both birds (Stacey and Koenig 1990) and mammals (Moehlam 1979; Malcom and Marten 1982). Finally, in social species, siblings may act as important cooperative allies buffering one another in times of hardship and assisting in the formation of powerful political alliances (e.g. Lee 2006). Nonetheless, given the clear survival and fertility costs demonstrated by the many studies reviewed here, it seems that in most animal species these benefits are typically outweighed by the costs of decreased parental investment.

The human behavioural ecology of family size

There is strong evidence of an early mortality cost to high parental fertility amongst traditional human societies, at least when interbirth intervals are narrow. Children from multiple births suffer substantially reduced likelihood of survival (Rutstein 1984; Gabler and Voland 1994; Sear et al. 2001) and most populations show a negative correlation between interbirth interval and child mortality (Rutstein 1984; Hobcraft et al. 1985). These costs are probably best explained by poor recovery of maternal somatic resources between births and by dilution of the particularly intense care required in the first years of infant life. Multiple births and excessively narrow birth intervals are rare in humans, a likely adaptation to avoid these high costs. Considering associations between total number of siblings and individual outcomes across the full range of observed birth intervals presents a more complex picture.

Studies of hunter-gatherer communities have not found strong evidence of quantity-quality trade-off effects. In the !Kung, an African hunter-gatherer group on which the earliest studies of human life history were carried out (Blurton-Jones 1986), researchers have failed to demonstrate higher mortality in children with many siblings (Pennington and Harpending 1988; Draper and Hames 2000). In the South American Aché, number of siblings depressed likelihood of survival between the ages of five and nine years. However, infant mortality below these ages was uninfluenced by parental fertility (Hill and Hurtado 1996). Furthermore, in both populations, large sibships failed to depress female reproductive success and were actually associated with higher fertility for males (Hill and Hurtado 1996; Draper and Hames 2000).

A larger set of studies have been conducted on agriculturalist societies. Negative relationships between family size and child survival have been demonstrated in a number of contemporary African populations including communities in Ethiopia, the Gambia, Malawi (Sear and Gibson 2007), Mali (Strassmann and Gillespie 2002) and Ghana (Meij et al. in press). Lower child survival in larger families has also been demonstrated in historical European and American datasets (Voland and Dunbar 1995; Penn and Smith 2007; Gillespie et al. 2008). However, in some cases trade-off effects appear to be quite modest, despite inclusion of controls for phenotypic quality (Sear and Gibson 2007). There are also cases where no trade-off in child survival has been detected (e.g. Kenya: Borgerhoff Mulder 1998a). Considering surviving children, there is strong evidence of an association between family size and child anthropometric status (a biomarker for health). Negative effects have been suggested in the South American Yanomamö (Hagen et al. 2001) and Shuar (Hagen et al. 2006), while in a cross-national analysis of 15 developing populations (Demographic Health Survey data), Desai (1995) finds height-for-age in children less than three years of age is significantly reduced by the presence of siblings in almost all cases. However, despite using the same set of covariates relating to parental socio-economic status for each country, effect magnitude was highly variable.

Studies of marital and reproductive success, focusing on the division of inherited capital such as land or cattle, show clear costs of resource division between siblings which survive childhood. As inheritance usually goes to males these effects are particularly visible on sons. For example, Mace (1996) found a negative effect of older brothers on male reproductive success in the Kenyan Gabbra. This resulted from smaller initial bridewealth herds and later age at marriage in comparison with their elder brothers. Number of sisters however, had a moderately positive effect on male reproductive success. Similar effects have been demonstrated on the Kenyan Kipsigis (Borgerhoff Mulder 1998a). Gillespie et al. (2008) found that large sibships reduced survival, but not fertility among survivors in 18th-19th century Finland. However, this analysis did not test for sex-specific effects. In analysis of 19th century Swedish data, Low (1991) found that both men's and women's reported reproductive success decreased as number of siblings increased, but particularly for men, and particularly with respect to number of brothers. Voland and Dunbar (1995) show that in 18th-19th century Germany, number of same-sex siblings reduced likelihood of marriage, which likely further reduces reproductive success for both sexes. Family size effects were absent in landless families, consistent with the hypothesis that the division of parental resources is the principal mechanism driving the observed relationships.

In summary, a number of lines of evidence confirm that the human family is characterised by trade-off effects in the quantity and quality of children. However, for each outcome considered, be it survival, health or reproductive success, the effects of large family size appear highly variable and in a significant number of studies trade-offs are absent or positive effects are reported. Methodological issues may account for much of this variance. In particular, trade-offs may go undetected in the absence of sufficient controls of family level resources (van Noordwijk and de Jong 1986). This may be a particular issue for studies of relatively egalitarian hunter-gathers who, unlike agriculturalist or wage-labour communities, lack obvious measures of relevant resource variation between families (Hill and Kaplan 1999; Draper and Hames 2000).

It is also important to emphasise that we shouldn't anticipate a uniform pattern of trade-off functions across cultures. In traditional societies, children often contribute significantly to economic pursuits such as foraging and may play important roles as alloparents (Kramer 2005; Sear and Mace 2008). While the benefits of these behaviours may rarely offset the net drain on family resources, engagement in these activities may modify the local costs of sibling resource competition. Wider patterns of cooperative breeding, whereby relatives share the burden of childcare may also alleviate trade-offs to varying degrees (Desai 1992; Desai 1995; Sear and Mace 2008). In many contexts, siblings may serve as valuable political allies, for example in providing an advantage in community disputes or access to neighbouring hunting or foraging territories (Draper and Hames 2000). Environmental risk factors associated with local rates of infectious disease, warfare and levels of economic development will also influence relationships between parental care and offspring development, establishing different trade-off functions (Desai 1995; Kaplan 1996; Winterhalder and Leslie 2002; Quinlan 2006). Finally, local inheritance and marriage practices will alter the relative costs and benefits of siblings with particular regard to age and sex. I consider these factors in more detail in the next two sections.

1.3.2 Birth order

Equal investment in offspring of different ages is not necessarily anticipated by evolutionary theories of parental care. This is because the returns on investment will be influenced by the condition of offspring. Two factors provide competing predictions on the direction of the bias. On the one hand, younger offspring may be favoured 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 favoured 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). Even if it is assumed that parents follow an equity heuristic in parental care, bias may ultimately form towards early-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 et al. 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. Parent-offspring conflict in investment allocations may further reinforce biased investment towards older offspring. This is because stronger, older offspring may be more able to monopolise resources subject to scramble competition between siblings (Mock and Parker 1997; Jeon 2008).

Age differences in dependent offspring are apparent in asynchronously hatching birds and some mammals. Studies of differential feeding in these species are generally supportive of later-born disadvantage. For example, a number of studies have shown younger nestlings receive less food than older nestlings, even though the former beg more intensely (reviewed in Jeon 2008). It is unclear, however, how much this pattern reflects active parental bias or the competitive advantage of older offspring. In the rare species in which siblicide has evolved, the youngest sibling is almost always killed by an elder sibling (Mock et al. 1990). Between clutches, sibling competition for parental resources is generally reduced as older siblings are usually independent of parental care. They may however provide some benefits through 'alloparenting' activities in cooperatively breeding species (Moehlam 1979; Malcom and Marten 1982; Stacey and Koenig 1990).

The human behavioural ecology of birth order

Long periods of dependence and a propensity for singleton litters often leads to much larger differences in age between dependent offspring in humans compared to other mammals, predicting particularly strong effects of birth order on parental investment (Jeon 2008). Cultural rules privileging first-born children of either sex are common in traditional societies, including more elaborate birth ceremonies and recognised authority over younger siblings (Rosenblatt and Skoogberg 1974). Daly and Wilson (1984) also point out that in the rare practice of infanticide, the victim is most often a later-born child, consistent with a preference for early-born offspring when harsh ecological conditions favour the sacrifice of one offspring for the survival of another.

Perhaps the most obvious example of actively biased parental investment towards early-born offspring in traditional societies is the widespread practice of primogeniture whereby the oldest offspring, typically sons, inherit all or most parental resources (for review: Hrdy and Judge 1993). Here, increased numbers of older brothers substantially depress male marital and reproductive success (Boone 1986; Boone 1988; Low 1990; Low 1991; Mace 1996). In some cases, later-borns may be encouraged to opt out of the competition all together. For example, in a study of 15th-16th century Portuguese nobility, Boone (1986; 1988) demonstrates higher rates of death in warfare in later-born males, and higher rates of cloistrations (i.e. becoming a nun) in later-born females, as well as lower reproductive rates among later-borns of both sexes. Of course, primogeniture is not universally practiced in traditional societies. More or less equally distributed inheritance or in rare cases ultimogeniture (i.e. biased inheritance to later-born offspring) have also been documented (Hrdy and Judge 1993). The unusual practice of ultimogeniture, while still not well understood by behavioural ecologists, may represent a strategy to ensure long-term lineage survival, by lowering the number of inheritance divisions over time, in the face of harsh economic constraints such as population saturation to available land (Beise and Voland 2008).

Studies of mortality and health in traditional societies present a more complex picture, with mixed effects of birth order at different stages of the life course. A comparative study of early-life mortality in 41 developing populations concluded that under conditions of high mortality, u or j-shaped relationships between birth order and infant mortality are common with first-borns often suffering higher mortality than second or third-borns, but mortality rising again for higher birth order offspring. In populations with relatively lower levels of mortality relationships between birth order and infant mortality tend to be positive and linear (Rutstein 1984). The apparent disadvantage of early-born offspring in conditions of high mortality may result from relatively high birthweight in later-born offspring (Fessler et al. 2006: for review). Older siblings, particularly older sisters, provided interbirth intervals are sufficiently large, may also increase chances of child survival through alloparenting activities (Sear and Mace 2008: for review of the evidence). Desai's (1995) cross-cultural study of the effects of siblings on early growth in developing countries confirms that, while negative effects of siblings are commonly found when siblings are close in age, the existence of siblings of 10 or more years older is often associated with improved anthropometric status.

Relatively few studies have considered the consequences of birth order on survival to and during adulthood. Nonetheless, currently available evidence from historical European datasets suggests that any early-life survival advantages to later-borns are typically reversed when later survival is considered (Modin 2002; Penn and Smith 2007). For example, in Modin's (2002) study of early 20th century Swedish families, higher adult mortality of later-borns was largely accounted for by adult socio-economic measures, consistent with the expectation that investment biases improve the survival and reproductive chances for early-born offspring through differential accumulation of resources. Note that while this population is partially modernised, it has high mortality rates comparable to many traditional populations.

As a conclusion to this section it is important to emphasise that many important factors, in particular parental age and overall family size, covary with birth order in most datasets. By and large, a majority of the studies reviewed here have adequately adjusted quantitative models to account for potential confounding effects. Nonetheless some variation between studies will likely originate from differences in methodology.

1.3.3 Sex-biased investment

Fisher (1930) recognised that, provided that sons and daughters are equally costly to rear, natural selection will favour equal distribution of parental investment by offspring sex, and thus a 50:50 offspring sex ratio. This is because if one sex becomes less abundant in the population, greater production of that sex will be favoured because it will, on average, out-reproduce the more abundant sex. Evolutionary biologists have since recognised important circumstances in which the costs and benefits of rearing sons versus daughters may differ, this predicts some deviations from Fisher's broader principle of equal investment in the sexes. Emerging hypotheses have stimulated a large and complex evolutionary literature on sex-biased parental investment. This work encompasses studies of both biases in the production of male and female offspring (i.e. sex ratio at birth) and biases in post-natal investment. The analyses presented in this thesis are concerned with post-natal investment. Sex ratio at birth, which has dominated the animal literature, is reviewed only very briefly here.

Much research has focused on the Trivers-Willard hypothesis which stipulates that sex-biased parental investment will be favoured when reproductive success of the sexes is differentially influenced by parental condition/invested resources (Trivers and Willard 1973). This is dramatically evident, for example, in many polygynously mating mammal species that have higher variance in male versus female reproductive success and where male reproductive success is determined largely by physical condition or social rank. Under such conditions, the fitness returns on producing a daughter will be higher for relatively poor parents, while the returns on producing a son will be higher for relatively rich parents. Thus, low maternal condition is predicted to be associated with an over-production of daughters and high maternal condition is predicted to be associated with an over-production of sons (Trivers and Willard 1973). Studies of mammalian sex ratios have produced contradictory results in relation to this hypothesis (Clutton-Brock 1991; Brown 2001; Cameron 2004). Reviewing over 400 studies, Cameron (2004) demonstrates that support is almost unanimous in studies assessing maternal condition close to the time of conception, suggesting the effect is real, albeit highly sensitive to the measure of condition under consideration.

Resource budgets are not the only factor which may influence the costs and benefits of investing in sons and daughters. If one sex of offspring has a higher mortality rate than the other, mothers may be selected to give birth to more of the low-viability sex (Fisher 1930), or to invest relatively more in each of these offspring during pre- and postnatal life (reviewed by Clutton-Brock 1991). Patterns of local resource competition may further influence the relative costs and benefits of investing in sons versus daughters. This emerges when there are sex differences in the extent to which offspring compete with parents and siblings for access to resources or mates (e.g. Clark 1978; Johnson 1988). As the logical opposite, local resource enhancement refers to situations when one sex offers a relative enhancement to the reproductive success of other kin through cooperative action, such as alloparenting (e.g. Emlen et al. 1986; Armitage 1987). Under these conditions, natural selection is predicted to lead to biased investment in favour of the less competitive/more cooperative sex.

The human behavioural ecology of sex-biased investment

In humans, males are subject to higher neonatal and infant mortality than females (Wells 2000). This is thought to underlie the slight male-bias in sex ratio at birth observed almost universally in human populations. It may also explain a number of findings implying a higher maternal energy allocation to male foetuses during pregnancy. Male foetuses have a faster rate of growth (Marsal et al. 1996), are heavier at birth (Anderson and Brown 1943; Loos et al. 2001) and pregnant women carrying a male foetus have been shown to have a higher energy intake than those carrying a female foetus (Tamimi et al. 2003). The reasons for higher early-life mortality in males remain a point of debate. Potential explanation lies in the recognition that this sex difference may in itself be understood as part of a Trivers-Willard mechanism to ensure a female-biased sex ratio when maternal condition is poor, as males have a higher likelihood of early death, and a male-biased sex ratio when maternal condition is good (Trivers and Willard 1973; Wells 2000).

Evidence for sex ratio biasing at birth in human populations is controversial. Lazarus (2002) reviewed 54 published reports considering parental status and birth sex ratio in humans and found, similar to the animal literature, considerable disagreement between studies, with roughly half rejecting the Trivers-Willard hypothesis. Following Cameron's (2004) review of the mammalian literature, this disagreement may reflect differences in methodology, with studies using more appropriate measures of physical condition more likely to support Trivers-Willard (Gibson and Mace 2003: for a recent example).

A number of human behavioural ecologists have also applied the Trivers-Willard hypothesis to post-natal investment, with poor success (reviewed in Cronk 2007). However, whether or not post-natal investment is actually predicted to follow a Trivers-Willard pattern is a point of some confusion in the literature (Hartung 1997; Keller et al. 2001). This is because the comparative fitness value of having a son versus a daughter can vary independently of the marginal fitness returns of investing in *current offspring* of either sex (Maynard Smith 1980; Keller et al. 2001). Following Trivers-Willard, a mother with poor access to resources would achieve higher fitness by rearing a daughter rather than a son. However, considering a mother of the same condition with both a son and a daughter already in her care, post-natal investments should be biased in favour of the son, because under the Trivers-Willard model, each unit of investment will have a larger impact on male reproductive success. Hence, a bias in post-natal investment favouring males is predicted independent of parental wealth (Hartung 1997; Keller et al. 2001). Complications to this argument arise because in many cases the line between sex ratio biasing and post-natal investment is blurred, such as when drastically lowering parental investment increases the risk of offspring death.

If a broad generalisation is to be made of traditional human societies, then the general pattern surely attests to higher levels of parental investment in sons relative to daughters. This is most evident in relation to wealth inheritance. As Hartung (1997:346) points out, for no society in the entire *Ethnographic Atlas*, a cross-cultural database of 1267 cultures (Murdock 1967), is wealth inherited preferentially by daughters. Even in polyandrous households, property is bequeathed to sons. Competition for wealth investment between sons explains why many studies find relatively poor offspring outcomes in the presence of brothers relative to sisters (Low 1991; Mace 1996; Borgerhoff Mulder 1998a; see also: Rickard et al. 2009). It is also well established that, where formal education is available, parents are considerably less likely to school daughters, with the gender gap in education the largest in the poorest countries (King and Hill 1993). Some studies have found that birth intervals following the birth of sons tend to be longer than those following the birth of daughters, consistent with a favoured treatment of male infants (e.g. Mace and Sear 1997). Helle et al. (2002) also showed that, in 18th-19th century Finland, number of sons is negatively correlated with female longevity, while number of daughters follows the opposite relationship. This pattern could be caused by sons enacting a relatively larger drain on parental investment over the life course. Comparative studies however suggest this relationship is not universal to pre-modern populations (Beise and Voland 2002).

There are a number of notable examples where clear investment biases favouring daughters have been documented. Many of these cases are most obviously interpreted under a local resource enhancement model, as sisters are generally more likely to behave as alloparents, and, in many populations, more likely to engage in economic activities which benefit the family as a whole (Draper and Hames 2000). For example, Margulis et al. (1993) found that North American Hutterites nurse their daughters longer than sons and that interbirth intervals following daughters are longer than those following sons. They attribute this to the fact that Hutterite daughters appear ‘cheaper’ because of the household help they provide. Similarly, Bereczkei and Dunbar (1997; 2002) found that Hungarian Gypsy daughters provide more household help and are nursed longer than their brothers. Rare cases of hypergyny, where females, but not males, can permit unique status gains to a family by marrying into a higher social class, may also explain better treatment of daughters in some cases (Dickemann 1979; Cronk 1993; Bereczkei and Dunbar 1997).

1.3.4 Relatedness and paternal care

Parental care is a form of kin assistance, predicted to occur in cases where parents can benefit their own inclusive fitness by investing in genetic offspring (Hamilton 1964; Trivers 1972; Clutton-Brock 1991). Investing in someone else's offspring is genetic altruism, and unless the offspring are also closely related (e.g. a niece or nephew), or the relationship is reciprocal, will generally not be favoured by natural selection. In most animals, internal fertilisation means that maternity is always certain, while paternity is always uncertain. Consequently, males are predicted to be particularly sensitive to cues of paternity and bias investment accordingly.

Biparental care is the norm in the majority of birds, with offspring survival often dependent on deliveries from both parents (Black 1996). Studies relating levels of paternal care to paternity certainty have been mixed. In a number of species it seems clear that when paternity of a clutch is mixed or deemed uncertain (such as when females are observed in extra-pair copulations), male provisioning is reduced (e.g. Ewen and Armstrong 2000). In others species, this relationship appears weak or variable (e.g. Bouwman et al. 2005), perhaps because males have difficulty assessing paternity (see also: Kempenaers and Sheldon 1997). Comparative studies are more supportive of a coevolution of paternity certainty and paternal care, as male provisioning is the highest in species with relatively low rates of cuckolding (Moller and Birkhead 1993; Moller and Cuervo 2000).

In mammals, internal gestation and obligate post-natal suckling dictates that females pay the bulk of reproductive costs and direct male provisioning of offspring is very rare, occurring in less than 10% of species (Clutton-Brock 1991). In species where paternal care does occur, most notably in carnivores and some primates, there is accumulating evidence that investment is discriminate in relation to paternity certainty, although, as in birds, not all studies are in agreement (see: Charpentier et al. 2008 for a discussion of recent evidence). In many mammals the pattern of extensive maternal care and overlapping partnerships over the life course leaves vulnerable offspring at risk of infanticide from unrelated males, which benefit from this behaviour because it opens up reproductive opportunities with lactating females (for review: van Schaik and Janson 2000).

The human behavioural ecology of relatedness and paternal care

Levels of paternal care in traditional human societies are relatively high in mammalian terms, although decidedly variable cross-culturally (for reviews: Geary 2000; Sear and Mace 2008). Culturally widespread practices surrounding the ‘protection’ of female chastity, including such traditions as the obligation of ‘modest’ female dress (for example, under Islamic law), or the cloistrations of females in harems, have been interpreted as clear socially recognised concerns regarding the synchronisation of paternity and paternal care (Dickemann 1979). In many cultures, suspicion of female infidelity is a commonly cited reason for divorce, and in some cases infanticide or uxoricide (the murder of one’s wife) (Daly et al. 1982; Daly and Wilson 1988; Betzig 1989).

Comparative studies have also found that cultures estimated to have low paternity confidence are characterised by relatively low levels of paternal involvement and inheritance from paternal relatives in general (Gaulin and Schlegel 1980; Flinn 1981; Hartung 1985). Nevertheless, social and biological fatherhood does overlap significantly in many traditional societies. Where empirical studies of these populations have been conducted, results confirm that father figures allocate less time, and interact more antagonistically, with step-children relative to biological children (Flinn 1988; Marlowe 1999).

1.4 *Evidence of Fertility Optimisation*

It is generally assumed that food availability and body condition are the principal regulators of animal fertility (Boutin 1990; Dobson and Oli 2001; Wade and Schneider 1992). Similarly, in human communities where parental investment consists mainly of lactation, direct childcare and foraging, physiological pathways like lactational amenorrhea and maternal depletion clearly play important proximate roles in adjusting the timing and number of births (Bentley 1999). At the psychological level, we can expect reproductive decision-making to be further regulated by cognitive mechanisms which utilise observed or expected relationships between parental investment and offspring development (Kaplan 1996; Kaplan and Gangestad 2005). Experimental studies show that such cognitive mechanisms are important regulators of fertility behaviour in many animal taxa. For example, Eggers et al. (2006) have demonstrated that Siberian jays exposed to playbacks of predator calls seek out nests offering more protective covering and reduce current clutch size, even when predation itself is not increased. In humans, behavioural pathways of fertility regulation may often be institutionalised in cultural systems, such as marriage and inheritance practices, contraception and celibacy rules (Kaplan 1996).

Behavioural ecologists assume that mechanisms of fertility regulation have evolved to optimise life history strategy at the individual level to local ecological conditions. In this section, I review the three main lines of evidence for this hypothesis with regard to family size: 1) clutch manipulation studies, which are uniquely applied to animal populations; 2) anthropological studies estimating the convergence between modal and optimal fertility; and 3) studies considering covariation in wealth and fertility.

1.4.1 Clutch manipulation studies

A number of avian studies have demonstrated a peak in recruitment rates for unmanipulated broods compared to those which have been experimentally enlarged or reduced (Perrins and Moss 1975; Gustafsson and Sutherland 1988; Pettifor et al. 1988; Daan et al. 1990; Tinbergen and Daan 1990; Pettifor et al. 2001). In a majority of litter manipulation studies of small mammals to investigate survival to weaning, natural litter sizes led to a higher number of surviving offspring, and in no case did enlargement increase survival rate (Hare and Murie 1992; Koskela 1998; Humphries and Boutin 2000; Neuhaus 2000; Kiovula et al. 2003). These studies have been presented as evidence of individual fertility optimisation.

Other studies have found a lack of negative fitness consequences to enlarged clutch size (Tinbergen and Both 1999; Tinbergen and Sanz 2004; Török et al. 2004). This suggests that higher parental fitness could have been achieved by reproducing beyond naturally observed fertility. Methodological problems inherent to manipulation studies could account for these negative results. For example, manipulation experiments ignore potential costs of siblings which occur through the depletion of maternal resources in egg making, yet there is strong evidence that this is costly in several species (Monaghan and Nager 1997; Visser and Lessells 2001). Furthermore, few studies have tracked subjects for sufficient time to measure long-term fitness measures such as the number of grand-offspring. Many studies also fail to take into account the survival and future reproductive outputs of mothers beyond the observed clutch. As such, the true costs of over-reproduction may often be underestimated.

There are also cases where clutch size reduction has apparently increased fitness (Verhulst 1995; Blondel et al. 1998) leading to the conclusion that clutches were *larger* than optimal.

It remains possible that inherent limitations in evolved regulators of fertility are responsible for these negative results. In relation to avian studies, a number of authors support this hypothesis. For example, Török (2004) suggests that future ecological conditions will be too difficult to predict in many environments leading to high rates of unavoidable error. Tinbergen and Sanz (2004) on the other hand, note that many of the tit studies that failed to find optimisation took place outside of ancestral woodland environments, positing that fertility regulation in these populations may be subject to adaptive lag.

1.4.2 Modal and optimal fertility

Unable to perform manipulation studies, human behavioural ecologists have focused on demonstrating convergence between the observed population mode in fertility and calculated optima. This work has produced mixed evidence of fertility optimisation. Studies of the !Kung (Pennington and Harpending 1988; Draper and Hames 2000) and Aché (Hill and Hurtado 1996) reveal positive linear relationships between number of children, and the lifetime reproductive success of the mother, with a substantial slope. This implies that both groups of hunter-gatherers failed to optimise family size as higher fitness could have been achieved by increasing fertility beyond observed levels.

Tests on agricultural societies have been more suggestive of a convergence between modal and optimal fertility. Borgerhoff Mulder's (2000) study of the Kipsigis identified a quantity-quality trade-off in family size, with intermediate numbers of children maximising grandchildren for women, but not for men. For women, the calculated optima corresponded with the population mode. In the Dogon, Strassmann and Gillespie (2002) found family size had a clear negative effect on child survival rates, so that an intermediate level of fertility (eight offspring) optimised this measure of reproductive success. A large majority of women had a completed fertility within the confidence limits of this estimate, leading the authors to conclude that observed family size optimised parental fitness. However, more recent studies of child survival attempting to replicate the results of Strassmann and Gillespie (2002) have found little evidence that intermediate levels of fertility maximise number of surviving children (Sear and Gibson 2007; Meij et al. in press).

The generally poor success of these studies most likely results from two key methodological problems well recognised in the literature – the failure to adequately adjust for phenotypic correlations and the difficulty involved in calculating precise fertility optima with available data (van Noordwijk and de Jong 1986; Hill and Hurtado 1996). Problems of phenotypic correlations are most evident in the hunter-gatherer studies which did not include many controls for maternal condition or parental wealth. Studies focusing on child survival alone, will not detect negative effects of large family which become apparent in later life, or in future generations (McNamara and Houston 2006). Hence, it is likely that these studies have systematically overestimated optimum family size. This is consistent with the fact that all studies that have failed to demonstrate a convergence between modal and optimal fertility have suggested that observed levels lie below the optimum.

1.4.3 Relationships between wealth and fertility

Traditional models of life history theory assume that quantity-quality trade-off effects are relieved when resources are relatively abundant, as parents do not need to limit family size to ensure the production of competitive offspring (Tuomi et al. 1983; van Noordwijk and de Jong 1986). Empirical support for this position has been demonstrated in a number of animal studies (e.g. Boyce and Perrins 1987; Risch et al. 1995). In humans, costs of high parental fertility to individual offspring have been shown to be less pronounced in relatively wealthy strata in both contemporary African (Borgerhoff Mulder 2000; Meij et al. in press) and 18th-19th century European agriculturalists (Lummaa et al. 1998; Gillespie et al. 2008).

Hence, following the optimisation of fertility, behavioural ecologists generally anticipate positive relationships between measures of individual wealth and fertility. Animal studies of food supplementation strongly support this hypothesis, revealing positive relationships between levels of food availability and clutch size (Boutin 1990; Dobson and Oli 2001). In humans, strong positive correlations between measures of socio-economic status and fertility have been documented in practically all traditional societies where such relationships have been considered (Borgerhoff Mulder 1987; Cronk 1991b; Hopcroft 2006: for review).

1.5 The Modern Human Family

The aim of this thesis is to explore how the research questions identified in the previous sections apply to parental investment and child development in modern human families. In this final section of the introduction, I first summarise the key features of the demographic transition leading to the remarkably low levels of fertility that characterise modern populations. I then cover some general points about the socioecology of modern parenting. A summary of the current theories of modern fertility decline concludes the section.

1.5.1 The demographic transition

Demographic transition refers to the population shift from high mortality and fertility to low mortality and fertility which typically occurs in the economic development of a population from a pre-industrial to an industrialised economy. In classic models this is a multi-stage process starting with a fall in death rates, followed in time by reduced birth rates, leading to an interval of first increased and then decreased population growth (Coale and Watkins 1986; Lee 2003). The first demographic transitions occurred in northwest Europe, where mortality began a secular decline around 1800. It has now spread to all areas of the world, with most developing populations in at least the early stages of transition, and the completion of a 'global demographic transition' projected by 2100 (Lee 2003).

Initial mortality declines in modernising countries were largely driven by innovations in healthcare along with advancements in food storage and transportation which reduced rates and susceptibly to infectious disease and famine. Changes in mortality were mostly focused on infants and children, with death becoming increasingly concentrated in a relatively narrow band of older age (Omran 1977). Following these advancements, fertility began to decline in most European countries between 1890 and 1920 (Coale and Treadway 1986). However, there are notable cases where fertility decline has commenced without prior shifts in mortality, presenting a challenge to transition theories that envisage fertility decline as a direct response to mortality shifts. Less developed countries began to reduce fertility from around the 1960s, with fertility decline typically occurring more rapidly than for those in current developed countries (Lee 2003). Total fertility rate (TFR) has now fallen to below replacement level in practically all industrialised populations and many countries in East Asia. The United Kingdom reached its lowest recorded TFR of 1.6 in 2001. In 2007 UK fertility was estimated at 1.9 with immigration indicated as a causal factor for recent increases (UK Office for National Statistics).

Despite differences in timing, speed and magnitude across societies, fertility decline within societies is generally characterised by markedly larger reductions of fertility in wealthy families compared to the rest of the population (Livi-Bacci 1986). As a consequence, modern fertility is not only dramatically reduced in comparison to traditional populations but is also typified by relative socio-economic levelling (Nettle and Pollet 2008). Thus contrary to adaptive predictions, relationships between wealth and fertility are typically recorded as null or negative in demographic surveys (Kaplan et al. 1995; Kaplan et al. 2002). Some studies have suggested that when education is held constant, positive relationships between income and fertility persist, at least for males (Hopcroft 2006; Weeden et al. 2006; Fieder and Huber 2007; Nettle and Pollet 2008). However, these relationships appear to operate on mating success, rather than reproductive success per se (i.e. influencing levels of childlessness, rather than family size amongst reproducing individuals) and remain in stark contrast with the strong positive relationships between wealth and fertility common to pre-transition societies.

1.5.2 The socioecology of modern parenting

In addition to increased levels of personal and societal wealth, as well as decreased mortality and fertility, a number of novel factors can be ascribed to the socioecology of modern parenting. On the one hand the direct costs of child-rearing faced by parents have increased. Modernisation typically coincides with a fragmentation of kin networks caused by individuals dispersing longer distances to work and establish homes. A ‘nuclearisation’ of the human family has therefore occurred with relatively low levels of extended kin involvement in child-rearing (Turke 1989). Older siblings are also less likely to assist parents partly because low fertility dictates their common absence, but also because current cultural systems deem child-minding by minors inappropriate, and children spend much time engaged with school. In the absence of such alloparents, modern families often partly rely on costly formalised childcare systems, particularly when mothers are engaged in employment. Perhaps as a consequence of this shift, direct paternal involvement in childcare has increased in recent decades (Bianchi 2000).

On the other hand, the establishment of the modern welfare state has reduced some responsibilities of parents in rearing children. Basic levels of healthcare, schooling and social welfare are now guaranteed to children in many countries, regardless of the direct investment made by parents. It is important to note that while these ‘base investments’ are typically higher than those provided even to the wealthiest members of most traditional populations, significant socio-economic gradients remain. In fact, modern populations offer almost no upper limit to conceivable levels of parental investment through expensive private healthcare, schooling, cultural activities or simply direct transfers of wealth (Mace 2007). Such scope for parental investment is simply not available in populations without developed health and education systems or established cash economies.

1.5.3 Theories of modern fertility decline

Economic models of demographic transition suggest that fertility decline can be explained by increasing perceived or real costs of raising children. Following Becker (1981), many demographers view children, who are assumed to provide some inherent pleasure to parents, as a consumer durable which can be 'purchased' amongst a set of alternatives such as, for example, a new house (see also Cigno 1991). At its simplest, this perspective sees modernity as invoking fertility decline because it raises the costs of producing children of a desirable quality, which require increasingly expensive competitive education to obtain good jobs. Alternatively, Caldwell (1976; 2005) proposes that modern parents favour smaller families because cultural modernisation reverses the transfer of wealth between parents and children, turning children from a relative economic asset into a liability. In traditional societies, where production typically occurs in the context of the family unit, it is suggested that net wealth often flows from child to parent. While in modern economies since children engage in productive activities relatively independent of the family budget, and only at later ages, they fail to offset their own expense.

To a large extent behavioural ecology models of the family offer much scope for integration with such economic perspectives; both emphasise the importance of limited resource budgets and inherent trade-offs in reproduction (Kaplan 1994). However, 'evolutionary demographers' insist that adaptive models provide a more definitive explanation for the human desire to raise competitive offspring and that, ultimately, the costs and benefits of raising children should be analysed in terms of Darwinian fitness. Furthermore, while it is agreed that variation in children's contribution to family resource budgets may alter fertility optima, net economic gain to raising children is unlikely to represent an evolutionarily stable strategy as natural selection ultimately favours maximum production of descendants. Indeed, quantitative studies of wealth transfers show that children very rarely provide a net source of income for parents even in traditional societies (Turke 1989; Kaplan 1994), a fact increasingly acknowledged by economic demographers (Caldwell 2005).

Adaptive models, however, immediately appear at odds with modern fertility decline because of its concurrence with unprecedented levels of material well-being (Vining 1986; Borgerhoff Mulder 1998b). Current levels of resource abundance also appear to buffer out any evolutionarily relevant costs of high fertility on offspring survival or reproduction. This is demonstrated by a number of studies applying traditional life history models to modern fertility. In all cases researchers have failed to detect a trade-off between number of children and grandchildren, even in very large families (Kaplan et al. 1995; Mueller 2001). Alternative models of modern fertility decline, emphasising inherent limitations in evolved mechanisms of adaptation, have consequently gathered popularity.

Maladaptation to novel contraceptive technologies

Evolutionary psychologists have stressed that maladaptive fertility patterns, such as the lack of clear positive relationships between wealth and fertility, may be explained by the interaction of ancestrally formed adaptations and novel socioecological factors. As such, it has been argued that the widespread availability of efficient birth control technology in modern environments negates the ancestral association between sexual intercourse and reproduction (Barkow and Burley 1980). In support of this model, Pérrusse (1993) has shown that wealthier men achieve higher copulation rates than their poorer counterparts, proposing that without the availability of contraception the wealthy would outreproduce the poor (see also Kanazawa 2003).

The importance of contraception in regulating fertility behaviour is contested by evolutionary and economic demographers, not least because European demographic transition was apparently initiated by *coitus interruptus* and because such models fail to explain the demand driving the invention and accessibility of modern contraceptive technology (Borgerhoff Mulder 1998b; Lee 2003). Studies documenting strong, socially recognised motivations for reproduction and the care of children distinct from sexual activity further dissuade from the simplicity of this hypothesis (Foster 2000; Rotkirch 2007).

A cultural evolution of modern fertility decline

Researchers of cultural evolution have also promoted their own accounts of modern fertility behaviour. These models have much in common with a rising number of social demographers who reject the rational choice perspective of economic demography in favour of models of cultural diffusion and social influence (see Bongaarts and Watkins 1996; Montgomery and Casterline 1996; Kohler 2001). Boyd and Richerson (1985), for example, suggest that throughout our history, imitating behaviour associated with social prestige offered an efficient mechanism to enhance individual fitness. In traditional societies, imitation of esteemed patriarchs and matriarchs would thus cause individuals to strive to attain similar high fertility. Modernisation offers novel social roles of high prestige such as teachers and heads of organised workforces. Competition for such positions is advanced by increased investments in education and production away from the family, at the cost of limited fertility. Thus imitation of prestigious individuals could consequently lead fertility levels to diverge from individual optima, sparking fertility decline. This hypothesis however fails to provide an effective explanation for why the first individuals decided to limit fertility in the early stages of demographic transition (Borgerhoff Mulder

1998b), nor does it take into account the fact that social prestige is itself constructed by societal norms and values (Newson et al. 2005).

A more considered perspective, combining models of social learning and the importance of extended kin in human life history, has been offered by Newson et al (2005). Here it is suggested that kin can be expected to place social pressure and rewards upon reproduction, at least when conditions are favourable, as this would lead to inclusive fitness benefits. Thus, traditional societies which are characterised by frequent and sustained interaction with kin, lead to high fertility norms consistent with fitness maximisation. However, cultural modernisation dramatically changes the nature of social networks through the fragmentation of the extended family. Non-kin have less inclination to support our reproductive interests and therefore high fertility strategies are less likely to become socially favoured, encouraging low and potentially maladaptive fertility norms. In support of this model, Newson et al. (2007) demonstrate that in role-playing experiments individuals adopting the role of friends, in contrast to relatives, are less likely to offer favourable advice about reproduction.

New parental investment models of modern fertility

Behavioural ecologists remain resistant to the view that modern reproductive decisions have become uncoupled from the costs and benefits of rearing children (Kaplan et al. 2002; Mace 2007; Mace 2008). For example, while low fertility may not provide obvious survival or reproductive advantages to offspring, there is some evidence of benefits to other aspects of offspring status. It is therefore possible that modern low fertility remains adaptive if we take into account that immediate deficits in reproductive success may eventually be offset by acquired benefits to wealth inheritance or other predictors of long-term lineage survival. Such a scenario has been formally modelled as theoretically possible by a number of researchers (Mace 1998; Boone and Kessler 1999; Hill and Reeve 2005; McNamara and Houston 2006).

Alternatively, Kaplan (1996) argues that modern low fertility is maladaptive, but nevertheless the product of an evolved psychology which regulates reproduction in balance with the local effects of parental investment on offspring status. This psychology fails to function adaptively in modern contexts because novel factors, such as the establishment of skill-based wage economies, offer radically extended scope for status competition between individuals at levels which now fail to translate into significant survival or reproductive benefits (Kaplan 1996; Kaplan et al. 2002).

Distinguishing between these new models of parental investment at an empirical level is currently limited by a lack of sufficient multigenerational data. However, both perspectives share a fundamental, but rarely tested, prediction – In order to explain null or negative relationships between wealth and fertility, cultural modernisation must establish a reversal of the traditional life history model of quantity-quality trade-offs; creating unusually intense resource competition between offspring when resources are relatively abundant rather than scarce. I recognise three socioecological developments associated with modernisation as responsible for this hypothesised shift.

First, in traditional human societies, factors such as high infectious disease rates, famine and warfare leads offspring quality to be significantly determined by external risk factors beyond the grasp of parental control under feasible ranges of investment. As a consequence there may be substantial diminishing returns to parental effort, with a saturation point beyond which 'chance' becomes the principal determinant of offspring success (Quinlan 2006). As the traditional life history model assumes, this pattern is associated with reduced levels of resource competition between offspring when resources are relatively abundant, favouring high fertility norms. Cultural modernisation, through the relative abolishment of these risk factors, buffers populations from environmental instability and may therefore create a higher degree of reliability in investment returns (Winterhalder and Leslie 2002). As such, higher levels of wealth can lead to a closer association between parental investment and offspring quality, and subsequently increased costs to resource competition between offspring (Kaplan 1996; Kaplan et al. 2002). Supportive of this argument, in a sample of 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 on height. Thus, it seems that the improved ability of parents to control the determinants of their children's development increases the intensity of sibling resource competition.

Second, Kaplan and colleagues have emphasised that the establishment of skill-based wage economies in industrialised nations may reinforce exponential returns to parental investment; with high investment strategies bringing about disproportionately large benefits to offspring status and consequently increasing the magnitude of trade-off effects. This is because direct financial allocations to offspring, along with investments in skill acquisition through formal education, may doubly advantage offspring by increasing their ability to generate new wealth during the life course (Kaplan 1996; Kaplan et al. 2002; Rogers 1990).

Finally, the construction of the modern welfare state may selectively reduce the costs of resource competition between offspring in impoverished relative to wealthy strata. Downey's (2001) categorisation of parental investment into the transfer of 'base' and 'surplus' level resources is useful in understanding this point. Base resources are those necessary for survival and essential social functioning, and are invested by both poor and wealthy parents alike. Surplus resources, however, require a qualitatively higher level of parental investment which is exclusively available in relatively rich families. In traditional populations, following a quantity-quality trade-off model, both base and surplus level resources will be diluted by large family size. However, under a welfare state, competition for base level resources may be relatively eliminated through guaranteed provisioning of basic schooling, healthcare and social opportunity. As such, family size may hold more influence over the success of offspring in wealthy compared to relatively impoverished families in modern populations with strong welfare states, favouring null or negative relationships between wealth and fertility.

1.6 Outline of Thesis

Chapter 2 introduces the British cohort data which are analysed in this thesis. The statistical techniques which are used to deal with this longitudinal data are also described in this chapter. Chapters 3 – 7 are data analysis chapters which tackle the research questions identified in the Introduction. Relevant supporting literature is reviewed at the beginning of each chapter, results are presented and their implications are discussed. This thesis is unique in its exploration of a broad range of family structure effects on parental investment and child development within a single study population.

Chapters 3-4 examine family structure (family size, birth order, sex and relatedness of father figures) as a determinant of parental investment. Chapter 3 considers family structure effects on maternal and paternal involvement in childcare. Chapter 4 considers family structure effects on maternal perceptions of economic hardship, a proxy measure for access to material resources in childhood. Chapters 5 –7 examine family structure as a determinant of a series of child development outcomes. Chapter 5 considers family structure effects on physical development, focusing on height measurements. Chapter 6 considers family structure effects on repeated assessments of cognitive development. Chapter 7 considers family structure effects on a series of child mental health measures (behavioural development).

Chapter 8 concludes the thesis. Comparisons are made between the findings of each chapter and conclusions formed on trade-offs and biases in parental investment and child development that characterise the modern family. Findings on the interaction between socio-economic status and family size trade-offs are then discussed in relation to evolutionary theories of modern low fertility.

Chapter 2. Data and Methods

2.1 Study Population

All data in this thesis are sourced from the Avon Longitudinal Study of Parents and Children (ALSPAC). ALSPAC is an ongoing, uniquely detailed cohort study designed to examine environmental and genetic influences on the health and development of British children (Golding et al. 2001). Study recruitment started in 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 (14,676 foetuses) recruited into the initial sample (an estimated 80-90% of the known births from the defined area). Avon has a predominantly white population, a mixture of rural and urban communities and a socio-economic mix similar to the rest of the UK. A major advantage of ALSPAC is the exceptional frequency of data collection. Mothers complete up to three postal surveys a year, one relating to the characteristics of herself and the household in general and two relating to the child. In addition, mothers answered four questionnaires during pregnancy. The ALSPAC survey also contains data from other surveys, including extraction from clinical records and school-based assessments and direct examination of children at specifically designed research clinics. Further methodological details of the study can be found in Golding et al. (2001).

There were 14,062 live births amongst the recruited mothers, 13,988 surviving to one year. This thesis uses all relevant data currently available (some data has not yet been released for study) up until questionnaires aimed at assessing ALSPAC families at a study child age of 10 years. A number of exclusion criteria define the study sample used in the analysis chapters which follow. These exclusion criteria remove relatively rare family structures. Families where the study child is from a multiple birth (i.e. a twin or triplet), families recorded as experiencing the death of a child and families containing 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 study child's live in 'mother figure' is ever recorded as other than the biological mother, as absent or in a same-sex 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 the key study sample contained 13,176 different families each containing a single study child.

2.2 Independent Variables

This section describes the independent variables used in each of the data analysis chapters which follow. Where appropriate, categorical codings are used to enable the identification of threshold effects. ALSPAC was not designed specifically for the purpose of this study and hence a number of variables, particularly in the case of family structure, had to be derived from the original data. All independent variables are sourced from questionnaire data collected at eight points over the study period.

2.2.1 Family structure

Family structure data (Table 2.1) was collected at six unevenly spaced 'key points' in the mother-based questionnaires (collected in pregnancy, at one year nine months, two years nine months, three years 11 months, seven years one month and 10 years). Data on the number, residence and relatedness of the mother's children were used to code the family size of the study child. For the purpose of this thesis, siblings are defined as maternally related siblings (i.e. including siblings from different biological fathers, but excluding siblings with different mothers) resident with the study child. This definition objectifies siblings as those related through the study child's mother and currently dependent on the study child's mother and her current partner. Non-resident siblings were rare in the study sample (only 1.8% of mothers had a non-resident child in pregnancy, rising to 3.4% by the end of the study period). A significant proportion of ALSPAC mothers recorded children unrelated to themselves but related to their current partner (8.9% in pregnancy and 6.9% by the end of the study period), but only in a very small percentage of families were such children coresident (1% and 1.1% respectively). Collected data does not determine if non-resident children were independent or resident with another family.

Table 2.1 Family structure data (percentage of cases at each study wave)

		Child Age							
		0y0m	*0y8m*	*1y9m*	*2y9m*	*3y11m*	*5y1m*	*7y1m*	*10y0m*
Family Size	1	51	-	39	24	16	-	10	9
(n*=12,349 – 7,038)	2	33	-	41	52	57	-	55	54
	3	12	-	15	17	20	-	26	27
	4	2.9	-	3.8	4.9	6	-	7	8
	5+	1.0	-	1.4	1.7	1.8	-	1.9	2.4
Number of Older	0	51	-	-	-	-	-	-	-
Siblings	1	33	-	-	-	-	-	-	-
(n=12,349)	2	12	-	-	-	-	-	-	-
	3+	4	-	-	-	-	-	-	-
Number of	0	100	-	84	65	53	-	44	41
Younger Siblings	1	0	-	15	32	41	-	43	43
(n=13,176 – 6,738)	2+	0	-	1.5	2.8	2.9	-	13	16
Number of Brothers	0	73	-	68	58	52	-	46	45
(n=11,330 – 5,169)	1	21	-	27	35	40	-	43	44
	2+	5	-	6	7	8	-	11	11
Number of Sisters	0	75	-	69	59	53	-	47	45
(n=11,330 – 5,169)	1	21	-	26	34	39	-	44	45
	2+	4	-	5	6	8	-	10	10
Sex of Child	Male	52	-	-	-	-	-	-	-
(n=13, 060)	Female	48	-	-	-	-	-	-	-
Father Figure Status	Biological Father	97	-	93	91	88	-	85	82
(n=12,479 – 9,022)	Mother Alone	2.6	-	6	7	9	-	10	10
	New Partner	0	-	1.0	1.7	3.1	-	5.0	7
Mother's Age	<25	24	-	-	-	-	-	-	-
(n=13,107)	25-29	39	-	-	-	-	-	-	-
	30-34	27	-	-	-	-	-	-	-
	35+	10	-	-	-	-	-	-	-
Father's Age	<25	12	-	-	-	-	-	-	-
(n=10,902)	25-29	34	-	-	-	-	-	-	-
	30-34	33	-	-	-	-	-	-	-
	35+	22	-	-	-	-	-	-	-

* Sample size at first and last time point available over the study period.
Note that these values refer to the sample available at each study wave. They should not be directly interpreted as evidence of change over time due to selective attrition.

Number of older siblings is treated as a time-invariant measure in each analysis and is calculated as equal to the total number of siblings at the first key point (which took place during the mother's pregnancy). Total number of siblings and number of younger siblings are time-varying measures. Number of younger siblings at birth is zero and derived at future key points by subtracting number of older siblings from the total number of siblings. Half (51%) of the study children were first-borns, around a third (33%) were second-borns, and a significant number (16%) were third or later born. By age 10, a majority (59%) of study children had experienced the arrival of at least one younger sibling, and 16% the arrival of two or more. 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. Data on the sex of siblings was collected at different times to the key point data and did not simultaneously code relatedness. However, it was possible to match across this information to the key points allowing the number of younger and older brothers and sisters with the same relatedness assumptions to be imputed in most cases. Mean number of brothers and sisters is equal across the study period.

Three quarters (76%) of mothers were married to the biological father at recruitment, and 16% were unmarried but cohabiting. The average length of prior cohabitation for these couples was 4.8 years (SD: 3.5). Out of the remaining mothers, 6% were in non-cohabiting relationships and 2.6% of mothers recorded themselves as not in any relationship. This data enabled subsequent presence of fathers to be coded throughout the study period. In most cases it also provides information on new 'father figures' which may adopt the role of an absent biological father. Biological fathers are coded as present provided the mother states the child has a biological live-in 'father figure' at the time of the questionnaire. In cases were 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 by the end of study period, with 40% (589/1457) of these children acquiring new live-in father figures. This method of coding father presence is preferable to measures of the mother's relationship status (married, divorced, etc.) which is unsuitable for relationships outside of marriage. However, this data does not distinguish between different partners of the mother subsequent to the biological father of the study child. A majority of parents were aged between 25-29 years at the birth of their study child, with a mean maternal age of 28.0 years (*SD: 5.0*) and paternal age of 30.7 (*SD: 5.7*).

2.2.2 Socio-economic profile

Table 2.2 Socio-economic data (percentage of cases at each study wave)

		Child Age							
		0y0m	*0y8m*	*1y9m*	*2y9m*	*3y11m*	*5y1m*	*7y1m*	*10y0m*
Mother's Education (n*=11,589)	<O-level	30	-	-	-	-	-	-	-
	O-level	35	-	-	-	-	-	-	-
	A-level	23	-	-	-	-	-	-	-
	Degree	13	-	-	-	-	-	-	-
Household Income (n =8,210 – 7,020)	<£200	-	-	-	27	24	-	15	-
	£200 – 299	-	-	-	29	27	-	18	-
	£300 – 399	-	-	-	21	22	-	23	-
	£400+	-	-	-	24	28	-	44	-
Home Ownership (n =11,789 – 7,129)	Rented	24	21	19	-	-	-	15	12
	Mortgaged /Buying	74	77	78	-	-	-	81	82
	Owned	2.2	2.3	2.1	-	-	-	5	7
Neighbour-hood (n =11,993 – 7,239)	<V. Good	59	56	55	53	-	48	-	43
	V. Good	41	44	45	47	-	52	-	57

* Sample size at first and last time point available over the study period.
Note that these values refer to the sample available at each study wave. They should not be directly interpreted as evidence of change over time due to selective attrition.

Multiple measures of family socio-economic profile (Table 2.2) are available in ALSPAC. I include mother's educational attainment coded at the time of pregnancy as a time invariant measure (educational status rarely changes during motherhood). The majority of ALSPAC mothers obtained less than O-level (30% - including Vocational and Certificate of Secondary Education (CSE) qualifications) or O-level only qualifications (35%). The highest obtained qualification for around a quarter (23%) of mothers was A-levels and 13% of mothers had university degrees. In the UK, O-level and A-level qualifications correspond to 16 and 18 years of formal education respectively. In addition, I use three measures of wealth coded at repeated points over the study period - 'take-home' household income, home ownership and neighbourhood quality. Take home household income was coded into four bands by ALSPAC questionnaires. At the first assessment 27% earned under £200 and a quarter (24%) of families earned over £400 pounds a week, while the majority of families (74%) lived in mortgaged accommodation, with 24% renting and 2% owning their house. Neighbourhood quality was self-rated by the mother on a four point scale with the highest being ‘very good’, followed by ‘fairly good’ (with 92.2%-97.4% of ratings within these top two codings), followed by ‘not very good’ and then ‘poor’. This variable was converted into an almost evenly split dichotomous measure coded as either less than very good or very good. For all time varying measures, codings of low level socio-economic status are less common in later assessments due to both selective attrition and a tendency for socio-economic status to increase with parental age. Multicollinearity between socio-economic variables 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).

2.2.3 Social support

Table 2.3 Social support data and other covariates (percentage of cases at each study wave)

		Child Age							
		0y0m	*0y8m*	*1y9m*	*2y9m*	*3y11m*	*5y1m*	*7y1m*	*10y0m*
Social Network Score (n* = 11,581)	Low (<23)	38	-	-	-	-	-	-	-
	Med (23-25)	32	-	-	-	-	-	-	-
	High (26+)	31	-	-	-	-	-	-	-
Social Support Score (n = 11,474)	Low (<19)	38	-	-	-	-	-	-	-
	Med (19-22)	30	-	-	-	-	-	-	-
	High (23+)	32	-	-	-	-	-	-	-
Ethnicity of Child (n = 11,308)	White	95	-	-	-	-	-	-	-
	Non-white	4.9	-	-	-	-	-	-	-
Maternal Employment (n = 9,362–7,275)	Unemployed	59	-	53	-	45	-	33	28
	Employed	41	-	47	-	55	-	67	72
Maternal Height in cm (n = 11,534)	Continuous Mean *(SD)*	163.9 *(6.7)*	-	-	-	-	-	-	-
Maternal Emotional Problems (n = 9,023)	Low (<4)	36	-	-	-	-	-	-	-
	Med (4-8)	36	-	-	-	-	-	-	-
	High (8+)	28	-	-	-	-	-	-	-

* Sample size at first and last time point available over the study period.
Note that these values refer to the sample available at each study wave. They should not be directly interpreted as evidence of change over time due to selective attrition.

Two time-invariant measures of social support (Table 2.3) were also incorporated, both based on questionnaires distributed to the mother in pregnancy. Further assessment of these measures has not yet been made in the ALSPAC survey. The social network score comprises ten 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 ten items specifically designed for ALSPAC. The item presents statements relating to emotional, financial and instrumental support, with a summed overall score also ranging between 0-30. This measure shows a strong association with the mother's emotional well-being during pregnancy (Thorpe et al. 1992). Both measures were banded into three groups of equal size, coded as 'low', 'medium' and 'high'.

2.2.4 Other covariates

Ethnicity of the study child is included as a covariate in all analysis chapters, coded as either white (95%) or non-white (4.9%). Amongst non-white groups, most common are mixed black Caribbean-white (19.5%), black Caribbean (8.7%) and Indian (8.7%), with the remainder made up of a broad mix of ethnicities.

Maternal employment is included as a covariate in Chapters 3 (parental care), 4 (economic hardship), 6 (cognitive development) and 7 (mental health), following previous studies' indication of the potential relevance of this factor. Maternal employment is coded as a dichotomous variable (employed or unemployed) at five points over the study period, with employment more common in later years. In pregnancy 41% of mothers were employed (including maternity leave), while at the end of the study period 72% were employed.

Self reported maternal height (recorded in pregnancy) is included as a covariate in Chapter 5, which considers family structure effects on height. A banded measure of maternal emotional problems (assessed in pregnancy by the Edinburgh Post-Natal Depression Score) is included in Chapter 7, which considers childhood mental health.

2.3 Methods

2.3.1 Longitudinal analysis

The current literature on the family structure determinants of parenting behaviour and child development is dominated by cross-sectional research methodologies. In these studies, single measurements of independent and dependent variables per individual are used to model relationships of interest. However, as Tables 2.1 – 2.3 illustrate, families are dynamic environments in which variables such as number of siblings, father presence, and socio-economic factors demonstrate significant change, even over short time periods. Longitudinal analysis techniques enable researchers to incorporate repeated 'time-varying' measures of both independent and dependent variables. This advancement offers a substantially improved ability to control for associations in the data which may confound relationships of interest (Singer and Willett 2003). While this feature of longitudinal methods is well known, many researchers still opt for the simplicity of cross-sectional research designs, even when longitudinal analysis is possible. However, the publication of subtle longitudinal and within-family studies which specifically challenge the popular conclusions of this literature (e.g. Guo and VanWey 1999; Rodgers et al. 2000; Wichman et al. 2006), is placing increasing pressure on researchers to embrace more powerful statistical methods when possible.

Longitudinal methods also provide the techniques to define and illustrate changing status and relationships over time. This allows us to consider, for instance, if biases or trade-off functions in parental investment are relatively uniform across childhood or if they change in magnitude as children age. This ultimately offers us a more complete picture of human parenting and further assists the interpretation of differences in results across studies (Holden and Miller 1999).

In all data analysis chapters that follow, with the exception of Chapter 6, outcome measures are recorded at several points over the study period enabling longitudinal analysis. In Chapter 6, which considers three one-off measures of cognitive development, standard regression techniques are used to estimate cross-sectional relationships in the data.

2.3.2 Multi-level models for change over time

In Chapters 3, 4, 5 and 7 study questions are addressed using multi-level models for change over time (Singer and Willett 2003). All analyses are carried out using MLwiN 2.02 (Rasbash et al. 2005). These models can be used to estimate multivariate relationships between time-varying categorical or continuous independent variables and a continuous dependent variable over time. Dependent measures must be measured on the same metric over time or be transformed to meet this criterion. Individuals are treated as level-two units and the timing of measures as level-one units.

Modelling data in this way also requires contemporaneous data on independent and dependent variables. This feature is not strictly met by the temporal distribution of variables in each analysis. To overcome this issue it is assumed that time-varying independent variables are equal in value to the mid-points between each coding, imputing their value at the months when outcome data was recorded. Given the relatively small gaps in convergence between measures, and the relatively short total study period, this serves as a reasonable approximation for the purpose of this thesis.

The major advantage of a multi-level modelling strategy is that it enables incorporation of all available outcome data, rather than restricting analysis to individuals with complete assessments at a specific subset of time points. Large sample analysis is particularly useful in studies of modern family structure because variation in family size is relatively low. 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 outcome measure being missed may depend on observed, but not unobserved, measures (Little and Rubin 1987). Although this issue is not formally investigated in this thesis, given the large range of relevant independent variables considered in each model, it is likely that presented analyses conform to the MAR assumption.

In a multi-level model for change, total outcome variation is partitioned into several within and between-person variance components. For each of these components a pseudo-R^2 statistic can be calculated based on the reduction of this term from 'unconditional models' (see below) containing only a constant and age terms (Singer and Willett 2003). These pseudo-R^2 statistics are used to estimate the fit of final models to the data.

2.3.3 Analysis strategy

Chapters 3, 4, 5 and 7 all follow an identical analysis strategy. To avoid repetition I provide a general summary of this method here and cover only the unique details of each individual analysis in later chapters. Firstly, for each outcome variable I determine an 'unconditional growth model' which establishes the overall relationship of the outcome with time (age of the study child in years). Linear and higher order functions are compared and the form which provides the best fit is then chosen as the relationship function specified in further models.

The second stage of analysis is then to specify the 'univariate associations' between each independent variable and the outcome to get a general sense of the relationships in the data. These univariate models only include adjustment for the relationship between time and the outcome. For each independent variable, effects are estimated by both a main effect term (effect on 'initial status' i.e. point of first measurement) and an interaction term with time (effect on rate of change per year). Higher order interaction terms can also be specified. In order to keep models relatively simple to compute and interpret, I only estimate linear deviations away from each reference category associated with each rate of change coefficient. Statistical significance of each predictor term is assessed (as in standard linear regression) by dividing the regression coefficient by its standard error and 95% confidence intervals are calculated. For each Chapter, univariate associations are summarised in Appendix tables and referred to in the relevant chapters where appropriate.

Three multivariate models are then constructed to assess the effects of family structure. A primary model, referred to as the 'main model', is used to examine the effects of family size, relatedness of father figures and covariates relating to parental resources. This model is constructed in a stepwise fashion. All variables relating to family structure (except sibling sex and age) are entered in the initial block. This model is then reduced down by a backwards procedure removing predictor terms that did not reach significance at the $p<0.05$ level. All family structure variables maintained in the model at this stage are then carried forward to a final presented model. The second block enters all remaining variables. Predictor terms are maintained if $p<0.05$ or their presence affects notable change on any of the family structure coefficients. Two alternative versions of the main model are then constructed to consider the effects of sibling age and sex configuration. The main model is used as a template, with sibling age and sex models specified by replacing the predictor terms for total number of siblings with first number of older and younger siblings, and then number of brothers and sisters.

Finally, variation in family size effects are explored by running separate versions of the main model for low, medium and high socio-economic status subgroups. These groups are categorised first by household income (low: <200/week, middle: 200-<400/week, high: 400+/week) and then maternal education levels (low: <O-level, middle: 0-level/A-level, high: degree). Therefore, in total, six separate models are fit to explore socio-economic variation in family size effects. Comparison of effect sizes between socio-economic status groups is then 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 socio-economic status may vary at different family size thresholds.

Chapter 3. Parental Care

3.1 Introduction

The aim of this chapter is to model associations between family structure and parental allocations of care time to the study child in the ALSPAC sample (see also: Lawson and Mace in press). ALSPAC offers a uniquely thorough record of parent-child activities over the first decade of life, providing an ideal dataset to test the predictions of life history and parental investment theory in the context of modern child-rearing. There is widespread recognition that high quality parenting plays an important role in ensuring positive child outcomes across multiple domains of development in modern populations (Downey 1995; Hoghughi 1998; Williams et al. 2002; Flouri and Buchanan 2004; Gullotta and Blau 2008; Nettle 2008; Rogers et al. 2008; Stewart-Brown 2008; Waylen et al. 2008). A small evolutionary literature and a more extensive literature in sociology and economics already provide some strong indications of family structure effects on parental care. Few studies have, however, been able to model how effects change over time, and those that have tend to be limited to very short intervals (Holden and Miller 1999). ALSPAC data are also relatively unique in that measures of both maternal and paternal behaviours are available – enabling their comparison. This is important because conclusions based on a single parent may lead to a distorted view of parental investment strategies as increases or deficits in parental care by one individual may be cancelled out by the compensatory action of other carers.

Family size and parental care

Sociologists and economists of the family have documented a range of evidence suggestive of a reduced quality of parenting for children in larger families, even in the presence of controls for family-level socio-economic measures. Studies of US family databases by Blake (1989) and Downey (1995), exploring the dilution of a range of *interpersonal* and *cognitive resources* by family size, provide the most comprehensive analyses to date. For practically all measures considered, a quantity-quality trade-off between number of children and investment is observed. Thus, children in large families are less likely to recall being read to as a pre-schooler (Blake 1989), engage in fewer cultural activities (Blake 1989) and lower frequencies of talk with parents (Downey 1995). They are also more likely to have parents with poor knowledge of their social networks in childhood (Downey 1995). Further 'time diary' studies confirm that as family size increases, parents record devoting less time to childcare per child (Hill and Stafford 1974; Hill and Stafford 1980). Large family size has also been associated with higher chances of parental neglect and abuse, even when controlling for a range of socio-economic and demographic measures, particularly if births are unplanned (Zuravin 1991).

I am not aware of any studies that have examined socio-economic variation in the effect of family size on parental care. This chapter therefore provides the first assessment of this important question.

Birth order and parental care

In comparison to family size, few well controlled studies have considered the importance of birth order in parenting behaviour. For example, Rohde et al (2003) examined a university student sample, collected across six modern populations, to explore perceptions of parental favouritism and closeness to kin. In sibships of two, first-borns and last-borns were both more likely to report the last-born child in their family as the parental favourite. In contrast, first-borns were more likely than last-borns to report a parent as the person to whom they were closest. It is difficult to draw a conclusion from this analysis because the study design asks respondents to compare themselves to their siblings who will not only differ by birth order, but also by age. As such, a general pattern of reduced support as children age could explain, in the absence of a genuine birth order effect, why later-borns are seen as parental favourites. This study also lacks any real measure of parental investment, relying on self-reports of favouritism which may be open to bias from other sources.

A recent study by Price (2008) presents a more informative analysis. Using data from a large American time use survey, Price demonstrates that while parents tend to equalise quality time with their children at any particular point in time, overall levels of care decrease as the age of the children, particularly the oldest child, increases, leading to a significant disadvantage to later-born children when age-specific levels of time allocation are considered. An interesting point about this study is that it demonstrates how parental time investment may appear equalised to both parents and children, and yet simultaneously be subject to a strong bias (see also: Hertwig et al. 2002).

Sex and parental care

A number of researchers have explored sex-biases in parental care in the context of modern societies. Those studies framed in parental investment theory have principally been concerned with tests of the Trivers-Willard hypothesis (Trivers and Willard 1973); for which there is inconsistent evidence (reviewed in: Keller et al. 2001). Sociological literature on the family has emphasised overall biases in parental care favouring male offspring, although the effects appear modest in comparison to the situation in many traditional societies (Lundberg 2005 for review). These effects appear particularly evident in the care involvement of fathers (Lundberg and Rose 2003; Dahl and Moretti 2004; Lundberg 2005; Nettle 2008; Price 2008). For example, male offspring are associated with higher levels of marital stability than female offspring in US families (Lundberg and Rose 2003; Dahl and

Moretti 2004). As discussed in Chapter 1, this apparent bias is consistent with evolutionary models if the marginal benefits of parental investment are greater for sons relative to daughters (Keller et al. 2001). Using ALSPAC data, I test for biases in investment in maternal and paternal behaviours. I 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.

Relatedness and parental care

Daly and Wilson drew much attention to evolutionary models of parental investment with their classic studies of child abuse and homicide (Daly and Wilson 1981; Daly and Wilson 1985; Daly and Wilson 1998). Here they showed considerably elevated risks of children being abused or murdered when co-resident with a step-parent (usually step-fathers). Many studies have also demonstrated that step-children receive lower levels of paternal care than genetic offspring (Amato 1987; Marsiglio 1991; Cooksey and Fondell 1996; Anderson et al. 1999) and in a retrospective study, Anderson et al. (2007) found that men who report low paternity confidence are more likely to divorce their wife and are less involved in childcare. ALSPAC data enable a further assessment of the relative contribution of biological versus unrelated father figures. Furthermore, I am able to consider the impact of paternal presence and relatedness on maternal behaviour; an issue largely neglected in previous studies. We might predict that, in order to compensate for reduced paternal investment, maternal care will be increased when a father figure is absent or unrelated. Alternatively, single mothers or those partnered with a new male may face additional constraints as they have to trade parental investment with 'mating effort' in obtaining or retaining a new partner with no biological relationship to her children.

3.2. Data and Methods

3.2.1 Parent scores

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 one year six months, to nine years (Table 3.1). 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 standardised measures, which I refer to as the mother and partner parent scores, were calculated at each time point from this data, ranging from zero to 10. Frequency of each parenting activity was ranked on a scale between zero and three/four. This measure was summed for each time point and standardised to a maximum value of 10. Thus, a score of zero indicates 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, 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 3.1). In all reported analyses I 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. I compared all final models using the full sample with that when the parent figure only is involved in the calculation of the parent scores. While the involvement of other adult carers had a positive main effect, in no case did this exclusion affect notable changes on other covariates. Therefore, in all reported analyses I use the full dataset, retaining maximum sample size, but including a dichotomous covariate term (‘Question Reference’) to take into account the significant main effect of this term on each parent score.

3.2.2 Data analysis

The relationship of family structure and resources to parental care during the study period was examined using multivariate multi-level models for change (Chapter 2). In addition to the independent variables listed in Chapter 2, I also include the mother score as an independent variable in analysis of the partner score in order to assess the covariation between levels of maternal and paternal investment. I do not include partner score as an independent variable in the mother score model as this would exclude cases of father absence from the sample.

Table 3.1 Standardised parent scores and percentage of parents engaging in each parenting activity at the highest specified frequency †

	Child Age													
	1yr 6m		3yr 2m		3yr 6m		4yr 9m		5yr 5m		6yr 9m‡		9yr 0m‡	
	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 *(between person)*	***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*	*9,550*	*9,416*	*8,804*	*9,339*	*8,723*	*8,759*	*8,129*	*8,308*	*7,545*	*7,225*	*7,282*	*6,614*	*6,709*
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
Preparation for school	-	-	-	-	-	-	-	-	-	-	75	12	65	10

† : Frequency measures – 1yr 6m, 3y 6m – never(0), <1/week(1), 1-2/week(2), 3-5/week(3), nearly every day(4)
3yr 2m, 4yr 9m, 5yr 5m– never(0), rarely(1), sometimes(2), often(3)
6yr 9m, 9yr 0m – never (0), <1/week(1), 1/week(2), 2-5/week(3), nearly every day(4)

‡ : Refers to adult females/males, not specifically the parent.

Total N: Mother Score – 59,710 for 11,142 individuals; Partner Score – 56,742 for 10,969 individuals

3.3. Results

3.3.1 Parental care over the study period

Across the study period mean mother scores are higher and have a smaller standard deviation than mean partner scores (Table 3.1). Unconditional growth models, containing 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), estimate overall relationships with child age. For each parent score, a negative linear relationship is not significantly improved upon by any higher order function (Figure 3.1). 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<0.001*) decreasing at -0.85 units per year (*CI: -0.86 – -0.84, p<0.001*). In the partner score model, initial status was estimated at 5.62 (*CI: 5.55 – 5.69, p<0.001*) decreasing at -0.56 units per year (*CI: -0.58 – -0.54, p<0.001*). The higher rate of decline for the mother score indicates that the difference between mother and partner scores attenuates over time.

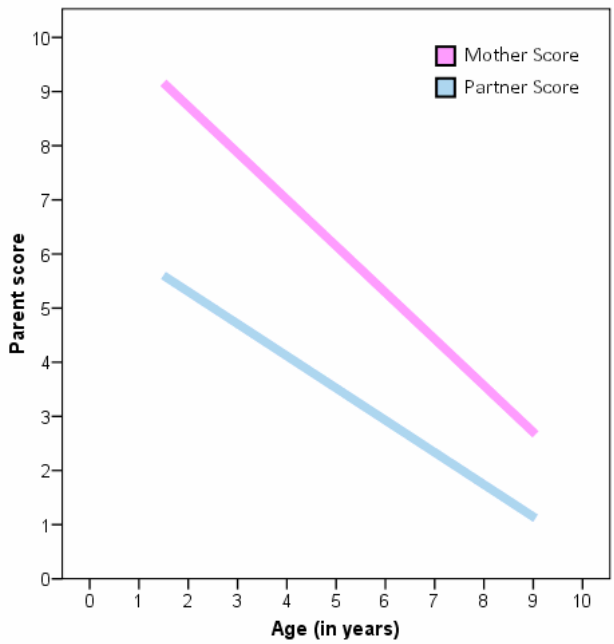

Figure 3.1 Change in parent scores over the study period (1.5 years – 9 years).

Univariate associations

Univariate associations between each independent variable and parent score can be consulted in the Appendix (Tables A1 – A2). A large majority of independent variables are associated with both the mother and partner scores at high levels of significance.

Final multivariate models

Tables 3.2 and 3.3 summarise 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 is accounted for by the independent variables. In the partner score model these values are 57%, 28% and 39% respectively.

3.3.2 Family size

Family size was negatively related to the mother and partner scores (Tables 3.2 and 3.3). Each additional sibling markedly reduces the amount of care that both mother and father give to each child. At the largest comparisons (i.e. single child families versus family sizes of five or more), the effects of family size are the largest estimated effects in each model. The magnitude of the family size effect 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 in the largest families. Figure 3.2 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.

Table 3.2 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†			8.62 ***	*8.52 – 8.72*	-0.77 ***	*-0.75 – 0.79*
Family Structure	Family Size *(Ref: 1)*	2	-0.09 ***	*-0.12 – -0.06*	-	-
		3	-0.20 ***	*-0.24 – -0.16*	-	-
		4	-0.28 ***	*-0.34 – -0.22*	-	-
		5+	-0.27 ***	*-0.37 – -0.17*	-	-
	Sex *(Ref: Male)*	Female	0.06 ***	*0.02 – 0.10*	-	-
	Mother's Age *(Ref: <25)*	25-29	-	-	0.00 ns	*-0.01 – 0.01*
		30-34	-	-	-0.01 ns	*-0.02 – 0.00*
		35+	-	-	-0.02 **	*-0.03 – -0.01*
	Father's Age *(Ref: <25)*	25-29	-	-	-	-
		30-34	-	-	-	-
		35+	-	-	-	-
	Father figure Status *(Ref: Biological Father)*	Mother Alone	0.09 ***	*0.04 – 0.14*	-	-
		Unrelated Male	-0.16 ***	*-0.23 – -0.09*	-	-
Socio-economic Measures	Maternal Education *(Ref: <O-level)*	O-level	0.07 *	*0.01 – 0.13*	-0.01 *	*-0.02 – 0.00*
		A-level	0.25 ***	*0.19 – 0.31*	-0.03 ***	*-0.04 – -0.02*
		Degree	0.17 ***	*0.10 – 0.24*	-0.05 ***	*-0.06 – -0.04*
	Household Income *(Ref: <£200/week)*	£200-299	0.03	*-0.01 – 0.07*	-	-
		£300-399	0.04 *	*0.00 – 0.08*	-	-
		£400+	0.06 **	*0.01 – 0.11*	-	-
	Neighbourhood *(Ref: <V. Good)*	V. Good	-	-	-	-
	Home Ownership *(Ref: Renting)*	Mortgaged /Buying	0.07 *	*0.01 – 0.13*	-0.03 ***	*-0.04 – -0.02*
		Owned	0.22 ***	*0.10 – 0.34*	-0.05 ***	*-0.08 – -0.02*
Social Support	Social Network Score *(Ref: Low)*	Med	0.16 ***	*0.09 – 0.23*	-	-
		High	0.29 ***	*0.22 – 0.36*	-	-
	Social Support Score *(Ref: Low)*	Med	0.10 ***	*0.08 – 0.12*	-	-
		High	0.21 ***	*0.19 – 0.23*	-	-
Other	Maternal Employment *(Ref: No)*	Yes	-0.05 ***	*-0.07 – -0.03*	-	-
	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-	-
	Question Style *(Ref: Objective)*	Subjective	-0.30 ***	*-0.34 – -0.26*	0.35 ***	*0.34 – 0.36*
	Question Reference (*Ref: Parent Only*)	Additional adults	0.19 ***	*0.17 – 0.21*	-	-

† - 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.
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Model Fit (Pseudo R^2): Within-Person (over time) – 0.63 ; Initial Status – 0.19; Rate of Change – 0.20
Final N – 37,658

Table 3.3 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†			1.57 ***	*1.39 – 1.75*	-0.18 ***	*-0.20 – -0.16*
Family Structure	Family Size *(Ref: 1)*	2	-0.24 ***	*-0.29 – -0.19*	0.04 ***	*0.02 – 0.06*
		3	-0.46 ***	*-0.54 – -0.38*	0.06 ***	*0.04 – 0.08*
		4	-0.61 ***	*-0.74 – -0.48*	0.09 ***	*0.06 – 0.12*
		5+	-0.71 ***	*-0.93 – -0.49*	0.11 ***	*0.07 – 0.15*
	Sex *(Ref: Male)*	Female	-	-	-0.04 ***	*-0.05 – -0.03*
	Mother's Age *(Ref: <25)*	25-29	-	-	-	-
		30-34	-	-	-	-
		35+	-	-	-	-
	Father's Age *(Ref: <25)*	25-29	0.01 ns	*-0.09 – 0.11*	-	-
		30-34	-0.07 ns	*-0.17 – 0.03*	-	-
		35+	-0.19 ***	*-0.30 – -0.08*	-	-
	Father figure Status *(Ref: Biological Father)*	Mother Alone	N.A.	N.A.	N.A.	N.A.
		Unrelated Male	-0.33 ***	*-0.47 – -0.29*	-	-
Socio-economic Measures	Maternal Education *(Ref: <O-level)*	O-level	0.09 ns	*0.00 – 0.18*	-0.02 *	*-0.04 – 0.00*
		A-level	0.30 ***	*0.20 – 0.30*	-0.04 ***	*-0.06 – -0.02*
		Degree	0.55 ***	*0.43 – 0.67*	-0.07 ***	*-0.09 – -0.05*
	Household Income *(Ref: £200/week)*	£200-299	0.10 ***	*0.05 – 0.15*	-	-
		£300-399	0.12 ***	*0.06 – 0.18*	-	-
		£400+	0.10 **	*0.04 – 0.16*	-	-
	Neighbourhood *(Ref: <V. Good)*	V. Good	-	-	-	-
	Home Ownership *(Ref: Renting)*	Mortgaged /Buying	-	-	-	-
		Owned	-	-	-	-
Social Support	Social Network Score *(Ref: Low)*	Med	0.24 ***	*0.23 – 0.25*	-	-
		High	0.32 ***	*0.31 – 0.33*	-	-
	Social Support Score *(Ref: Low)*	Med	0.44 ***	*0.35 – 0.53*	-0.03 ***	*-0.04 – -0.02*
		High	0.64 ***	*0.55 – 0.73*	-0.03 ***	*-0.04 – -0.02*
Other	Maternal Employment *(Ref: No)*	Yes	0.18 ***	*0.13 – 0.23*	-0.01 **	*-0.02 – 0.00*
	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-	-
	Question Style *(Ref: Objective)*	Subjective	1.04 ***	*1.02 – 1.06*	-	-
	Question Reference (*Ref: Parent Only*)	Additional adults	0.08 ***	*0.04 – 0.12*	-	-
	Mother Score	Continuous (0-10)	0.37 ***	*0.35 – 0.37*	-	-

† - 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.

ns – non significant, * - $p<0.05$, ** - $p<0.01$, *** - $p<0.001$

Model Fit (Pseudo R^2): Within-Person (over time) – 0.57 ; Initial Status – 0.28; Rate of Change – 0.39

Final N – 37,296

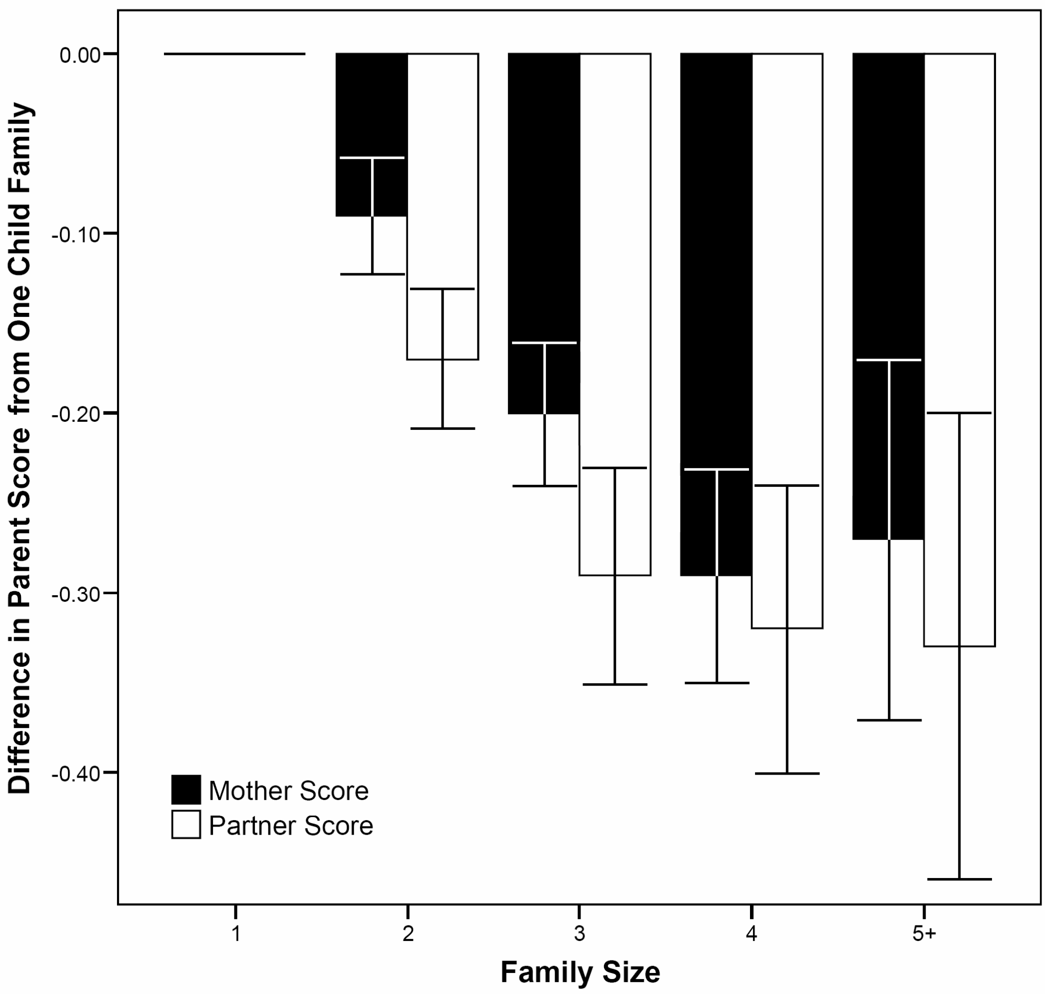

Figure. 3.2. Family size and parent scores over the study period (main effects of family size only). *Family size is negatively associated with levels of maternal and paternal time investment over the study period (1.5 years to 9 years, all contrasts p<0.001). Final models control for time of measurement, sex of study child, parental age, father figure status, 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 3.4 and 3.5 for full models).*

.

3.3.3 Birth order

Table 3.4 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	Number of older siblings *(Ref: 0)*	1	-0.24 ***	*-0.28 – -0.20*	-	-
		2	-0.27 ***	*-0.33 – -0.21*	-	-
		3+	-0.42 ***	*-0.52 – -0.32*	-	-
	Number of younger siblings *(Ref: 0)*	1	-0.03 *	*-0.06 – 0.00*	-	-
		2+	-0.10 ***	*-0.15 – -0.05*	-	-
(*b) Partner Score*	Number of older siblings *(Ref: 0)*	1	-0.54 ***	*-0.62 – -0.46*	0.07 ***	*0.06 – 0.08*
		2	-0.81 ***	*-0.92 – -0.70*	0.09 ***	*0.07 – 0.11*
		3+	-0.98 ***	*-1.19 – -0.77*	0.12 ***	*0.08 – 0.16*
	Number of younger siblings *(Ref: 0)*	1	-0.03 ns	*-0.07 – 0.01*	-	-
		2+	-0.07 *	*-0.14 – 0.00*	-	-

Models contain control variables for additional aspects of family structure and parental resources (see Tables 3.2 and 3.3)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final N – Mother Score – 37,658; Partner Score – 36,691

Re-running the main models, but replacing family size with number of older and number of younger siblings, revealed that for both parent scores the presence of older siblings led to larger reductions in parental care than the presence of younger siblings (Table 3.4). 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.

3.3.4 Sex

Table 3.5 Final parent score models for sibling sex 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	Number of brothers	1	-0.09 ***	*-0.12 – -0.06*	-	-
	(Ref: 0)	2+	-0.23 ***	*-0.29 – -0.17*	-	-
	Number of sisters	1	-0.09 ***	*-0.12 – -0.06*	-	-
	(Ref: 0)	2+	-0.24 ***	*-0.30 – -0.18*	-	-
(b) Partner Score	Number of brothers	1	-0.29 ***	*-0.35 – -0.23*	0.04 ***	*0.03 – 0.05*
	(Ref: 0)	2+	-0.49 ***	*-0.62 – -0.36*	0.06 ***	*0.04 – 0.08*
	Number of sisters	1	-0.24 ***	*-0.30 – -0.18*	0.03 ***	*0.02 – 0.04*
	(Ref: 0)	2+	-0.53 ***	*-0.63 – -0.43*	0.07 ***	*0.05 – 0.09*

Models contain control variables for additional aspects of family structure and parental resources (see Tables 3.4 and 3.5)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final N – Mothers Score – 33,575; Partners – 32,798

Girls had consistently slightly higher mother scores than boys (Table 3.2), but had lower partner scores particularly in later years (with no main effect but a rate of change effect – Table 3.3). Re-running the main models, but replacing family size with number of brothers and number of sisters, 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 (Table 3.5).

3.3.5 Relatedness

Single motherhood was associated with consistently higher mother scores relative to children with biological fathers present (Table 3.2). However, children with non-biological father figures had consistently lower mother scores (Table 3.2) and lower partner scores (Table 3.3) across the study period. Hence, mothers are reducing investment in offspring from former partners, only if a new partner is present.

3.3.6 Parental resources

Relatively high socio-economic status was associated with higher parent scores particularly in the earliest years of the cohort (Tables 3.2 and 3.3). Compared to low level qualifications (CSE), children of more educated mothers scored higher initial status for both parent scores. 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 income 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 those in rented accommodation. However, negative rate of change effects per year reverse this effect by the end of the study period. Neighbourhood quality did not influence levels of parental investment in the presence of other socio-economic variables.

Higher maternal social support and social network scores were associated with higher parent scores for both mothers and partners (Tables 3.2 and 3.3). Maternal employment was associated with a modest reduction in the mother score consistent across the study period. The effect was the opposite on 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 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. However, the effects of parental age are of lower magnitude and significance in sibship age configuration models (Tables 3.4 and 3.5: full models not shown). This suggests that parental age effects reflect co-varying birth order patterns, rather than independent effects.

Including mother score as a covariate in the partner score model, we can estimate the association between parent scores controlling for each of the independent variables considered (Table 3.3). 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.

3.3.7 Interaction of socio-economic status and family size

Finally, I refit the main models separately for low, middle and high socio-economic status families categorised first by household income and then by maternal education levels (see Chapter 2). 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 3.2 and 3.3), with the exception that I do not estimate the effect of mother score in partner score models (in order to retain maximum sample size). In total, 12 separate models were fit to explore socio-economic variation, six for each parent score (summarised in Table 3.6).

Figure 3.3 graphically contrasts the incremental effects of increasing family size by household income. For the mother score, the transition from one to two children shows a clear socio-economic gradient with high income associated with the lowest costs of increasing family size (not significantly different from one child). 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 3.6).

Table 3.6 Final parent score models for family size by socio-economic strata: **(a)** household income strata **(b)** maternal education strata

(a) Income Strata					**(b) Education Strata**				
Fixed Effects			Coefficient (B)	*95%CI*				Coefficient (B)	*95%CI*
Mother Score	Low Income (n = 8,179)	2 *(Ref: 1)*	-0.19 ***	*-0.26 – -0.12*	Mother Score	Low Education (n = 10,218)	2 *(Ref: 1)*	-0.19 ***	*-0.26 – -0.12*
		3 *(Ref: 2)*	-0.11 **	*-0.19 – -0.03*			3 *(Ref: 2)*	-0.06 ns	*-0.13 – 0.01*
		4+ *(Ref: 3)*	-0.00 ns	*-0.11 – 0.11*			4+ *(Ref: 3)*	-0.09 ns	*-0.18 – 0.09*
	Middle Income (n = 25,807)	2 *(Ref: 1)*	-0.13 ***	*-0.17 – -0.09*		Middle Education (n = 27,734)	2 *(Ref: 1)*	-0.10 ***	*-0.14 – -0.06*
		3 *(Ref: 2)*	-0.14 ***	*-0.18 – -0.10*			3 *(Ref: 2)*	-0.13 ***	*-0.17 – -0.09*
		4+ *(Ref: 3)*	-0.12 ***	*-0.19 – -0.01*			4+ *(Ref: 3)*	-0.12 ***	*-0.19 – -0.05*
	High Income (n = 13,499)	2 *(Ref: 1)*	-0.01 ns	*-0.14 – 0.12*		High Education (n = 7,592)	2 *(Ref: 1)*	-0.05 ns	*-0.12 – 0.02*
		3 *(Ref: 2)*	-0.11 **	*-0.16 – -0.06*			3 *(Ref: 2)*	-0.10 ***	*-0.16 – -0.06*
		4+ *(Ref: 3)*	-0.13 **	*-0.22 – -0.06*			4+ *(Ref: 3)*	-0.03 ns	*-0.15 – 0.09*
Partner Score	Low Income (n = 6,163)	2 *(Ref: 1)*	-0.11 ns	*-0.25 – 0.03*	Partner Score	Low Education (n = 9,032)	2 *(Ref: 1)*	-0.18 ***	*-0.28 – -0.08*
		3 *(Ref: 2)*	-0.17 **	*-0.31 – -0.03*			3 *(Ref: 2)*	-0.03 ns	*-0.13 – 0.07*
		4+ *(Ref: 3)*	-0.04 ns	*-0.23 – 0.15*			4+ *(Ref: 3)*	-0.01 ns	*-0.15 – 0.14*
	Middle Income (n = 24,546)	2 *(Ref: 1)*	-0.14 ***	*-0.20 – -0.08*		Middle Education (n = 27,554)	2 *(Ref: 1)*	-0.21 ***	*-0.26 – -0.16*
		3 *(Ref: 2)*	-0.23 ***	*-0.32 – -0.14*			3 *(Ref: 2)*	-0.19 ***	*-0.25 – -0.13*
		4+ *(Ref: 3)*	-0.13 **	*-0.22 – -0.04*			4+ *(Ref: 3)*	-0.14 **	*-0.13 – -0.05*
	High Income (n = 13,132)	2 *(Ref: 1)*	-0.20 ***	*-0.27 – -0.13*		High Education (n = 7,255)	2 *(Ref: 1)*	-0.23 ***	*-0.32 – -0.14*
		3 *(Ref: 2)*	-0.16 ***	*-0.23 – -0.09*			3 *(Ref: 2)*	-0.18 ***	*-0.28 – -0.08*
		4+ *(Ref: 3)*	-0.10 ns	*-0.22 – 0.02*			4+ *(Ref: 3)*	-0.01 ns	*-0.17 – 0.15*

Models contain control variables for additional aspects of family structure (see Tables 3.2 and 3.3)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

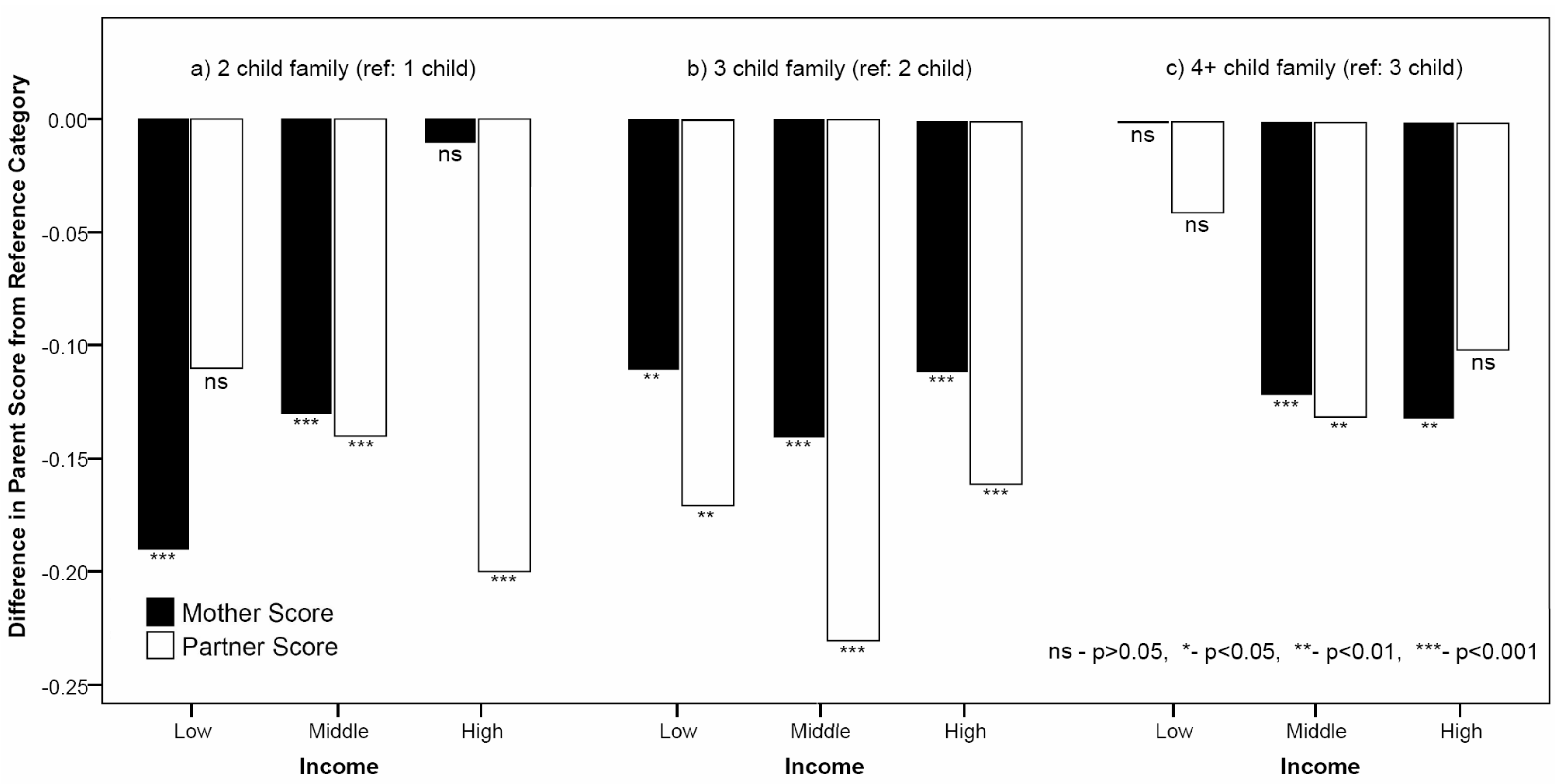

Figure 3.3 Incremental differences in parent score values as family size increases, by household income strata: a) caring for two relative to one child, b) caring for three relative to two children, c) caring for 4+ relative to three children. *In most cases, relatively higher household income is associated with comparative or stronger trade-offs between family size and parental care. Final models control for time of measurement, sex of study child, parental age, father figure status, 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 3.6 for confidence intervals).*

3.4 Discussion

In this chapter, I used ALSPAC data to examine the parental investment schedules which characterise childhood in contemporary British families. I measured parental investment as reported frequencies of parental engagement in childcare activities. I 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 behaviours, for only one activity (physical play) was maternal involvement lower than paternal involvement (Table 3.1). This asymmetry of investment likely also reflects a division of parental investment forms, with mothers being more likely to stay 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 the 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 not of comparable magnitude to the overall gap between the sexes.

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, the results also indicate signs of cooperative replacement in parental care. 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 (see also: Bianchi 2000).

Family size and parental care

All aspects of family structure showed strong associations with parental care. Most importantly, both mothers and fathers can only achieve large family size at a significant cost to the quality of care provided to individual children. (Figure 3.2). In fact, family size was the strongest explanatory variable considered in the presented analyses. I also find that the costs of each additional child tailed-off in the largest families, a pattern predicted from a resource dilution perspective, but that has rarely been subject to empirical testing (Downey 1995). Assuming that quality of parenting influences child well-being in modern societies, negative relationships between family size and child development outcomes are therefore to be anticipated.

Birth order and parental care

For both parents, time investments decreased linearly with increasing child age (Figure 3.1). While investment levels over time cannot be interpreted directly due to the inclusion of age-specific activities, 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 by evolutionary models (Jeon 2008), I find clear evidence of a later-born disadvantage with the presence of older siblings impacting a larger deficit in parental care (Table 3.4).

Further to the recent work of Price (2008) this suggests that differences in parental care may be an important mediating factor in the production of relatively negative outcomes for later-born children. The magnitude of birth order effects, while large in comparison to other covariates, are difficult to interpret directly using the measure of parental care in this thesis. Price, using time diary data on contemporary American families, estimates that a first-born child in a two child family spends between 20-25 more minutes engaging in quality-time activities each day with his or her father, and 25-30 with his or her mother, than the second-born child (Price 2008).

Sex and parental care

A 'gendering' of parenting activities characterised the study population with each parent investing relatively more in same-sex offspring (see also Zick and 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). I also predicted that the preferred sex (in this case girls for maternal investment, and boys for paternal investment) would make for more costly siblings. There is little evidence that sex of siblings influences individual levels of parental care from either parent (Table 3.7).

Relatedness and paternal investment

Following previous studies of paternal investment (Amato 1987; Marsiglio 1991; Cooksey and Fondell 1996; Anderson et al. 1999) unrelated father figures invested less in offspring. Considering maternal behaviour towards the same child, I also find maternal investment is negatively influenced when unrelated father figures are present. This result is consistent with 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 favour of the new partner or future offspring. Single mothers, however, invest more than mothers partnered with the biological father of the study child, indicating some level of care replacement in the absence of any father figure. The methodological advancements of this study provide particularly strong confidence that these findings are not confounded by socio-economic or demographic differences between families.

Socio-economic status and family size trade-offs

Strong socio-economic gradients characterised 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 (Hill and Stafford 1980; Zick and Bryant 1996; Bianchi 2000). In addition, some of the activities included in this study, such as taking the study child to watch sports, 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 the care measures did not involve monetary outlay. Positive effects of socio-economic status were particularly strong on paternal care, indicating that the relative involvement of fathers to mothers increases with socio-economic status (see also: Nettle 2008). Higher levels of social support and larger social networks may free up more time for childcare activities (Ceballo and McLoyd 2002). Alternatively, these effects may be mediated through improving the emotional well-being of the parents (Thorpe et al. 1992).

Contrary to the expectations of traditional models of life history, reductions in parental care associated with large family size were generally not alleviated in high income or well educated families. In fact, the results of this chapter suggest, particularly in relation to paternal investment, that middle or high socio-economic status may actually increase the magnitude of trade-off effects relative to low socio-economic status families (Figure 3.3).

One possible explanation for the particularly striking pattern for paternal care is that it better fits the conditions of a 'base-surplus model' (Downey 2001), with low socio-economic status fathers investing such minimal base level investment that they literally have limited room to invest any less as sibship sizes increases. This explanation is consistent with the overall lower levels of paternal relative to maternal care (Figure 3.1) and the particularly low levels of investment by low socio-economic status father figures. It is also consistent with the finding that negative sibship size effects on paternal investment attenuate over time (Table 3.3), as in the later periods of the study average paternal care levels are extremely low. Maternal investment on the other hand, with higher overall levels of investment and weaker effects of socio-economic status, may be more open to resource competition costs across childhood.

Chapter 4. Economic Hardship

4.1 Introduction

The aim of this chapter is to model associations between family structure and the living conditions of the study child as evidenced by maternal perceptions of economic hardship. ALSPAC mothers were asked at several occasions over the study period to rate their difficulty affording key household expenses, including food, rent and items for the study child. A summary score based on these data is used as a proxy for financial dimensions of parental investment, which is otherwise difficult to assess directly during childhood (as household resources are pooled). The abolition of child poverty, due to its demonstrated negative effects on successful outcomes in later life, is currently a key area of social policy driven research in developed countries, including the UK (Bradshaw et al. 2006; Iacovou and Berthoud 2006). This literature in particular provides some strong evidence of family size effects on economic hardship. It is also useful to consider studies of household expenditure and parental contribution to educational expenses in late childhood/early adulthood. This parallel research is suggestive of important dilution effects and potential biases in financial allocations to children. ALSPAC data provide an opportunity to further this research, and consider neglected hypotheses, with the added methodological advantage of longitudinal analysis and inclusion of a wide range of relevant covariates not always considered in past research.

Family size and economic hardship

A number of social policy focused studies have reported that children in large sibships are substantially overrepresented in families coded as experiencing conditions of poverty (reviewed in: Bradshaw et al. 2006; Iacovou and Berthoud 2006). ‘Poverty’ in these studies is generally indexed by ‘hardship’ or ‘deprivation scores’, very similar to the dependent variable analysed in this chapter. Recent work confirms that while large families are more likely to be of low socio-economic status, the association between large family size and poverty measures remain after adjustment for a range of factors including income, education, employment and ethnicity (Iacovou and Berthoud 2006).

Studies of financial investments in education in modern US families further indicate a dilution of *material resources* in large sibships. In large relative to small families, parents are less likely to save for college expenses during childhood (Downey 1995), and children receive lower financial assistance and are relatively more dependent on loans and scholarships (Steelman and Powell 1989). Children in large families are also less likely to have computers or educational objects (such as a dictionary or calculator) present in their home (Downey 1995).

Whether or not family size effects on financial investment vary by socio-economic status has rarely been considered. Downey (2001:499) cites unpublished work which apparently demonstrates that low income families are subject to relatively weak trade-offs between family size and parental savings for college.

Birth order and economic hardship

Although it is recognised that the age of children is an important factor in the costs of parenting, child poverty research has paid relatively little attention to how relative birth order may alter the risks of experiencing economic hardship (Iacovou and Berthoud 2006). Steelman and Powell (1989) considered the issue in relation to financial contributions to education. They reported that number of younger siblings had a larger negative effect than number of older siblings (suggesting an early-born disadvantage). Methodological issues detract from a clear interpretation of this result, because, as the authors note, this pattern may represent associated differences in the age of parents (socio-economic status tends to increase with age), rather than an independent effect of birth order. As outlined in the introduction (Chapter 1), life history and resource dilution models of the family predict a later-born disadvantage in parental investment. In the analyses presented in this chapter, I include parental age in the estimation of birth order effects on maternal economic hardship, and in doing so provide a more appropriate test of the relative consequences of having older versus younger siblings.

Sex and economic hardship

Current knowledge of sex effects on economic hardship is similarly limited. Studies of financial investments in education have reported mixed effects of sex and sex of siblings, with some studies suggesting males are favoured (e.g. Powell and Steelman 1989) and others concluding daughters are favoured (e.g. Steelman and Powell 1989). Lundberg and Rose (2004) used data from a US family expenditure survey to consider if spending differs by family sex configuration. This analysis also reached mixed conclusions depending on the type of expenditure, and many effects failed to reach statistical significance. Nevertheless, Lundberg and Rose (2004) interpret the general pattern as suggestive of a higher expenditure on sons. In particular, expenditure on housing was higher in families with one son relative to one daughter, which they speculatively suggest reflects a greater parental investment in economic stability of the family unit (see also: Lundberg 2005). If sons require, or are perceived as requiring higher levels of financial investment in the ALSPAC population, then we can predict that mothers with relatively more sons than daughters will report higher levels of economic hardship.

Paternal relatedness and economic hardship

Single parenthood and step-family status are often associated with pronounced socio-economic deficits, with mothers both more likely to come from disadvantaged backgrounds and to have faced the financial costs associated with relationship disruption (e.g. setting up a new household) (McLanahan and Booth 1989; Case et al. 2001). ALSPAC data enable me to test whether, in the presence of strong controls for socio-economic status, the presence of unrelated father-figures retains any influence on maternal perceptions of economic hardship.

4.2. Data and Methods

4.2.1 Economic hardship score

Financial difficulty of the mother in affording the key expenditures of food, rent, heat, clothes, and items for the study child was self-rated at four points over the study period between eight months and seven years, one month (Table 4.1). At each point difficulty was scored as not difficult (0), slightly difficult (1), fairly difficult (2) or very difficult (3). Cases where the respondent indicated that heating or rent was paid by the Department of Social Security were coded as very difficult (3). Missing cases were coded as not difficult (0 - always the most frequent category) provided response had been provided for at least one other expenditure at the same questionnaire. A summed measure, which I refer to as the economic hardship score, was then derived ranging zero to 15. In total 36,662 measurements of economic hardship are available for 11,257 individual mothers. This outcome measure is treated as a continuous variable in the presented analyses.

4.2.2 Data analysis

The relationship of family structure to economic hardship over the study period was examined using multivariate multi-level models for change (Chapter 2).

4.3. Results

4.3.1 Child age and economic hardship

A negative linear relationship between time and economic hardship was not significantly improved upon by any higher order function; overall mothers perceived a steady decline in economic hardship over time. Initial status at eight months since study recruitment is estimated as 3.30 (*CI: 3.23 – 3.37, p<0.001*) decreasing at -0.17 (*CI: -0.18 – -0.16, p<0.001*) units per year.

Table 4.1 Economic hardship score and composite items

			Child Age			
			0y8m	*1y9m*	*2y9m*	*7y1m*
Economic Hardship Score	Mean		3.17	2.99	3.07	2.05
	Standard Deviation		3.58	3.49	3.64	2.05
	N		10,510	9,409	9,002	7,741
Items (%)						
	Food	*Not Difficult*	71	73	76	87
		Slightly	19	18	16	10
		Fairly	8	8	7	3
		Very	2	2	2	1
	Clothing	*Not Difficult*	34	35	40	58
		Slightly	33	35	33	29
		Fairly	18	17	17	9
		Very	14	13	11	4
	Heating	*Not Difficult*	65	65	69	85
		Slightly	21	21	19	11
		Fairly	10	11	9	3
		Very (or DSS paid)	4	4	3	1
	Rent	*Not Difficult*	68	65	63	74
		Slightly	19	17	17	11
		Fairly	8	7	8	3
		Very (or DSS paid)	5	12	15	12
	Items for child	*Not Difficult*	59	57	59	66
		Slightly	26	28	27	25
		Fairly	11	11	10	6
		Very	4	5	4	2

Note that these values refer to the sample available at each study wave. They should not be directly interpreted as evidence of change over time due to selective attrition.
Total N: 36,662 for 11,257 individuals

Univariate associations

Univariate associations between each independent variable and the economic hardship score can be consulted in the Appendix (Table A3). A large majority of independent variables are associated with economic hardship at high levels of significance.

Final multivariate model

Table 4.2 summarises the final multivariate model predicting the economic hardship score. Pseudo R^2 statistics estimate that 27% of within-person variance over time, 32% of between-person variance in initial status and 20% in rate of change is accounted for by the independent variables.

4.3.2 Family size

Family size was positively related to economic hardship, suggesting relatively lower access to material resources in large sibships. This effect did not interact with time since recruitment, indicating that the economic burden of rearing children was constant over the study period. Figure 4.1 illustrates the relationship between family size and economic hardship graphically. The positive effects of family size are incremental and confidence intervals do not overlap, except between four and five or more child family contrasts.

Table 4.2 Main model for economic hardship: predictors of financial difficulties in childhood

			Initial Status (0y 8m) Coefficient (B)	*95% CI*	**Rate of Change** (per year) Coefficient (B)	*95% CI*
	Intercept †		6.07 ***	5.74 – 6.40	-0.09 **	-0.15 – 0.03
Family Structure	Family Size *(Ref: 1)*	2	0.28 ***	0.18 – 0.38	-	-
		3	0.56 ***	0.43 – 0.69	-	-
		4	0.89 ***	0.69 – 1.09	-	-
		5 +	1.30 ***	0.98 – 1.62	-	-
	Mother's Age *(Ref:<25)*	25-29	0.03 ns	-0.12 – 0.18	-	-
		30-34	0.01 ns	-0.18 – 0.20	-	-
		35+	-0.09 ns	-0.59 – 0.41	-	-
	Partner's Age *(Ref: <25)*	25-29	0.04 ns	-0.26 – 0.34	-0.01 ns	-0.07 – 0.05
		30-34	-0.23 ns	-0.54 – 0.08	0.05 ns	-0.01 – 0.11
		35+	-0.12 ns	-0.65 – 0.41	0.01 ns	-0.05 – 0.07
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	1.54 ***	1.51 – 1.57	-0.11 **	-0.18 – -0.04
		Unrelated Male	-0.29 ns	-0.92 – 0.34	0.09 ns	-0.02 – 0.20
Socio-economic Measures	Mother's Education *(Ref: CSE/Voc)*	O-level	-	-	-	-
		A-level	-	-	-	-
		Degree	-	-	-	-
	Income *(Ref: <£200)*	£200-299	-1.48 ***	-1.70 – -1.27	-0.17 ***	-0.22 – -0.12
		£300-399	-2.41 ***	-2.64 – -2.18	-0.16 ***	-0.22 – -0.10
		£400+	-3.23 ***	-3.46 – -3.00	-0.12 ***	-0.17 – -0.07
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.25 ***	-0.32 – -0.18		
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	-0.34 **	-0.55 – -0.13	0.01 ns	-0.04 – 0.06
		Owned Outright	-2.00 ***	-2.46 – -1.54	0.40 ***	0.31 – 0.49
Social Support	Social Network Score *(Ref: Low)*	23-25 (Med)	-0.45 ***	-0.65 – -0.25	-	-
		26+ (High)	-0.44 ***	-0.63 – -0.25	-	-
	Social Support Score *(Ref: Low)*	19-22 (Med)	-0.58 ***	-0.76 – -0.40	0.04 *	0.01 – 0.07
		23+ (High)	-0.92 ***	-1.10 – -0.74	0.07 ***	0.04 – 0.10
Other	Ethnicity of Child *(Ref: White)*	Non-White	0.47 *	0.06 – -0.88	-0.10 **	-0.18 – -0.02
	Maternal Employment *(Ref: No)*	Yes	-0.21 ***	-0.33 – -0.09	0.04 **	0.01 – 0.07

† - 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

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model Fit (Pseudo R^2): Within-Person (over time) – 0.27 ; Initial Status – 0.32; Rate of Change – 0.20

Final N - 23,302

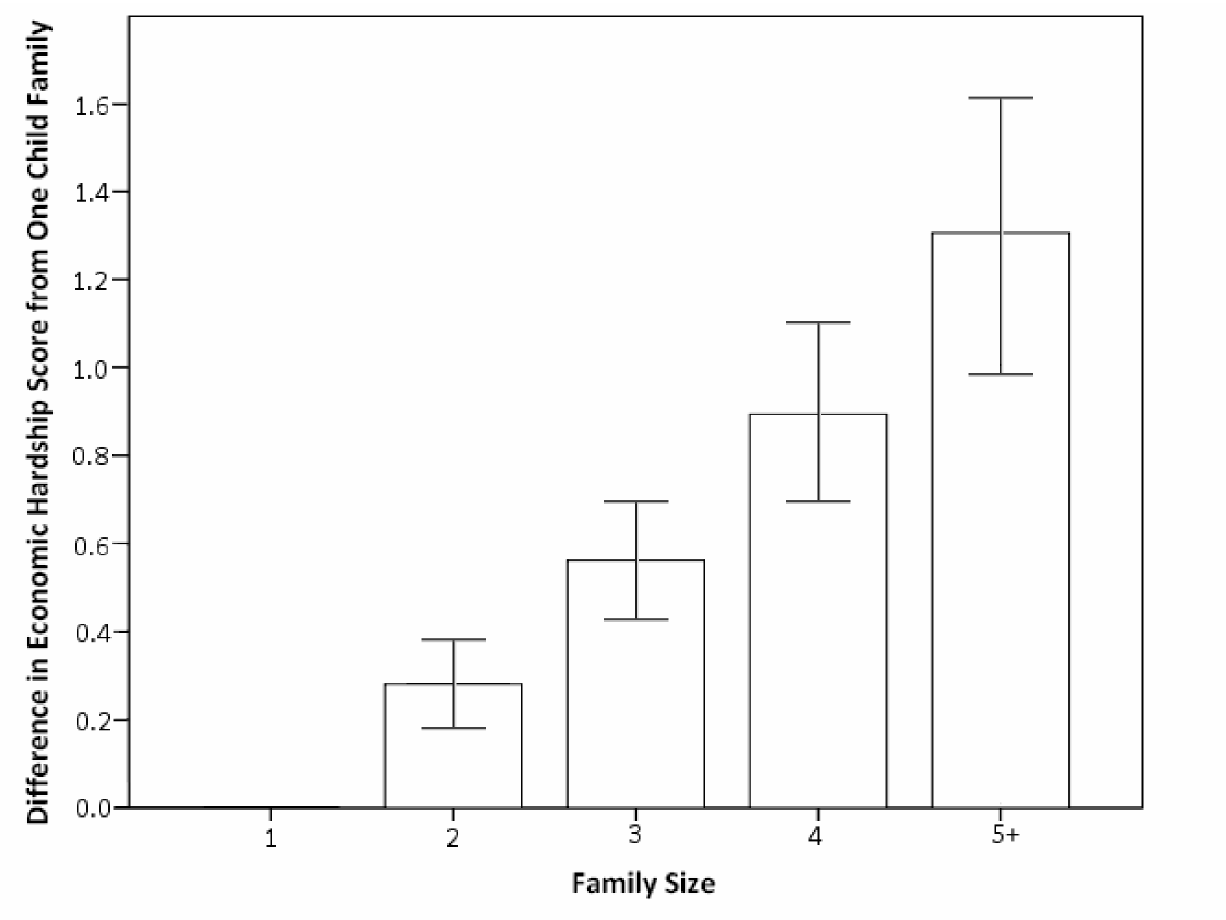

Figure 4.1: Family size and maternal perceptions of economic hardship *Increasing family size is associated with higher levels of economic hardship (all contrasts p<0.001). Final model controls for time of measurement, mother's age, partner's age, father figure status, household income, neighbourhood quality, home ownership, social support score, social network score, ethnicity and maternal employment (Table 4.2).*

4.3.3 Birth order

Table 4.3 Final economic hardship score model for sibling age configuration:

		Initial Status (0y 8m)		**Rate of Change** (per year)	
		Coefficient (B)	*95%CI*	Coefficient (B)	*95%CI*
Number of older siblings *(Ref: 0)*	1	0.31 ***	*0.19 – 0.43*	-	-
	2	0.47 ***	*0.30 – 0.64*	-	-
	3+	1.13 ***	*0.82 – 1.44*	-	-
Number of younger siblings *(Ref: 0)*	1	0.32 ***	*0.23 – 0.41*	-	-
	2	0.51 ***	*0.32 – 0.70*	-	-
	3+	0.68 ***	*0.30 – 1.06*	-	-

Model contains control variables for additional family aspects configuration and parental resources (Tables 4.2)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final N – 23,008

Re-running the main models, but replacing family size with number of older and number of younger siblings demonstrates only marginal evidence that economic conditions of the household vary with the birth order of the study child (Table 4.3). Only in very large sibships do effect estimates differentiate, with three or more older siblings associated with an increase in economic hardship substantially larger compared to three or more younger siblings. However, confidence intervals around these estimates are large and overlapping.

4.3.4 Sex

Table 4.4 Final economic hardship score model for sibling sex configuration:

		Initial Status (0y 8m)		**Rate of Change** (per year)	
		Coefficient (B)	*95%CI*	Coefficient (B)	*95%CI*
Number of brothers *(Ref: 0)*	1	0.32***	*0.22 – 0.42*	-	-
	2+	0.57***	*0.39 – 0.75*	-	-
Number of sisters *(Ref: 0)*	1	0.26***	*0.16 – 0.36*	-	-
	2+	0.61***	*0.42 – 0.80*	-	-

Model contains control variables for additional family aspects configuration, including sex of index child and parental resources (Tables 4.2)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final N – 20,764

Sex of the study child was not retained in final multivariate models, failing to even reach a significant univariate association with economic hardship (Table A3). Sibling sex configuration models also revealed no clear difference in the costs of brothers relative to sisters on economic hardship, with effect estimates being of comparable magnitude (Table 4.4).

4.3.5 Relatedness

Even in the presence of strong time-varying controls for socio-economic status, single motherhood was associated with higher levels of economic hardship, particularly at the beginning of the study period (Table 4.2). However, the mothers who had subsequently partnered with a new male did not differ from those who stayed with the biological father of study child.

4.3.6 Parental resources

Measures of socio-economic status showed strong negative relationships with economic hardship (Table 4.2). Mothers with higher household income, mothers living in better quality neighbourhoods or with higher home ownership status all reported lower levels of economic hardship. While maternal educational achievement also showed a negative univariate association with economic hardship, this association was not significant in the presence of other socio-economic measures (Table A3).

Working mothers reported lower levels of economic hardship. Non-white mothers reported higher economic hardship, even in the presence of other socio-economic and social support variables.

Improved social support and network scores were associated with lower economic hardship. The age of the mother and her current partner are not significantly associated with economic hardship in the presence of socio-economic measures. However, they did show negative associations with economic hardship in the first block containing only family structure variables and so are retained in the final model.

4.3.7 Interaction of socio-economic status and family size

Table 4.5 Final economic hardship score models for family size by socio-economic strata: **(a)** household income strata **(b)** maternal education strata

			Coefficient (B)	*95%CI*
(a) Household Income	Low Income (n = 4,420)	2 *(Ref: 1)*	0.46 *	0.17 – 0.75
		3 *(Ref: 2)*	0.02 ns	-0.33 – 0.37
		4+ *(Ref: 3)*	0.45 ns	-0.03 – 0.93
	Middle Income (n = 15,428)	2 *(Ref: 1)*	0.30 ***	0.18 – 0.42
		3 *(Ref: 2)*	0.40 ***	0.26 – 0.54
		4+ *(Ref: 3)*	0.40 ***	0.26 – 0.54
	High Income (n = 7,377)	2 *(Ref: 1)*	0.13 **	0.01 – 0.25
		3 *(Ref: 2)*	0.15 **	0.03 – 0.27
		4+ *(Ref: 3)*	0.40 ***	0.18 – 0.66
(b) Education	Low Education (n = 4,955)	2 *(Ref: 1)*	0.28 **	0.03 – 0.53
		3 *(Ref: 2)*	0.13 ns	-0.14 – 0.40
		4+ *(Ref: 3)*	0.35 ns	-0.02 – 0.72
	Middle Education (n = 14,597)	2 *(Ref: 1)*	0.32 ***	0.20 – 0.44
		3 *(Ref: 2)*	0.36 ***	0.22 – 0.50
		4+ *(Ref: 3)*	0.42 ***	0.18 – 0.66
	High Education (n = 3,750)	2 *(Ref: 1)*	0.14 ns	-0.03 – 0.31
		3 *(Ref: 2)*	0.20 **	0.00 – 0.40
		4+ *(Ref: 3)*	0.65 ***	0.28 – 1.02

Models contain control variables for additional aspects of family structure (see Table 4.2)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Finally, I refit the main models separately for low, middle and high SES families categorised first by household income and then maternal education levels (see Chapter 2). Each model contains the main effects of family size and all other main effects and rate of change effects included in the main model (Table 4.2). In total six separate models were fit to explore socio-economic variation (summarised in Table 4.5).

Figures 4.2 and 4.3 graphically contrast the incremental effects of increasing family size by household income and maternal education respectively. Increasing socio-economic status is associated with decreasing reproductive costs across both income and education strata in the transition from caring for one to two offspring. In the high education strata the change in economic hardship is statistically indistinguishable from the economic hardship associated with raising a single child.

The situation changes in considering the difference in economic hardship when caring for three relative to two children. Here, increased socio-economic status fails to alleviate the perceptible costs of further reproduction; with middle level strata in particular experiencing the highest increases in economic hardship. High income and education also fail to alleviate the costs associated with caring for four or more children relative to three children; in fact the largest increases in economic hardship are experienced by middle or high level strata. In low income and education strata differences in economic hardship are statistically indistinguishable from raising three children. Note that all non-significant contrasts reported are based on comparisons of group samples of at least 373 cases. Non-significance is therefore unlikely to reflect lack of statistical power.

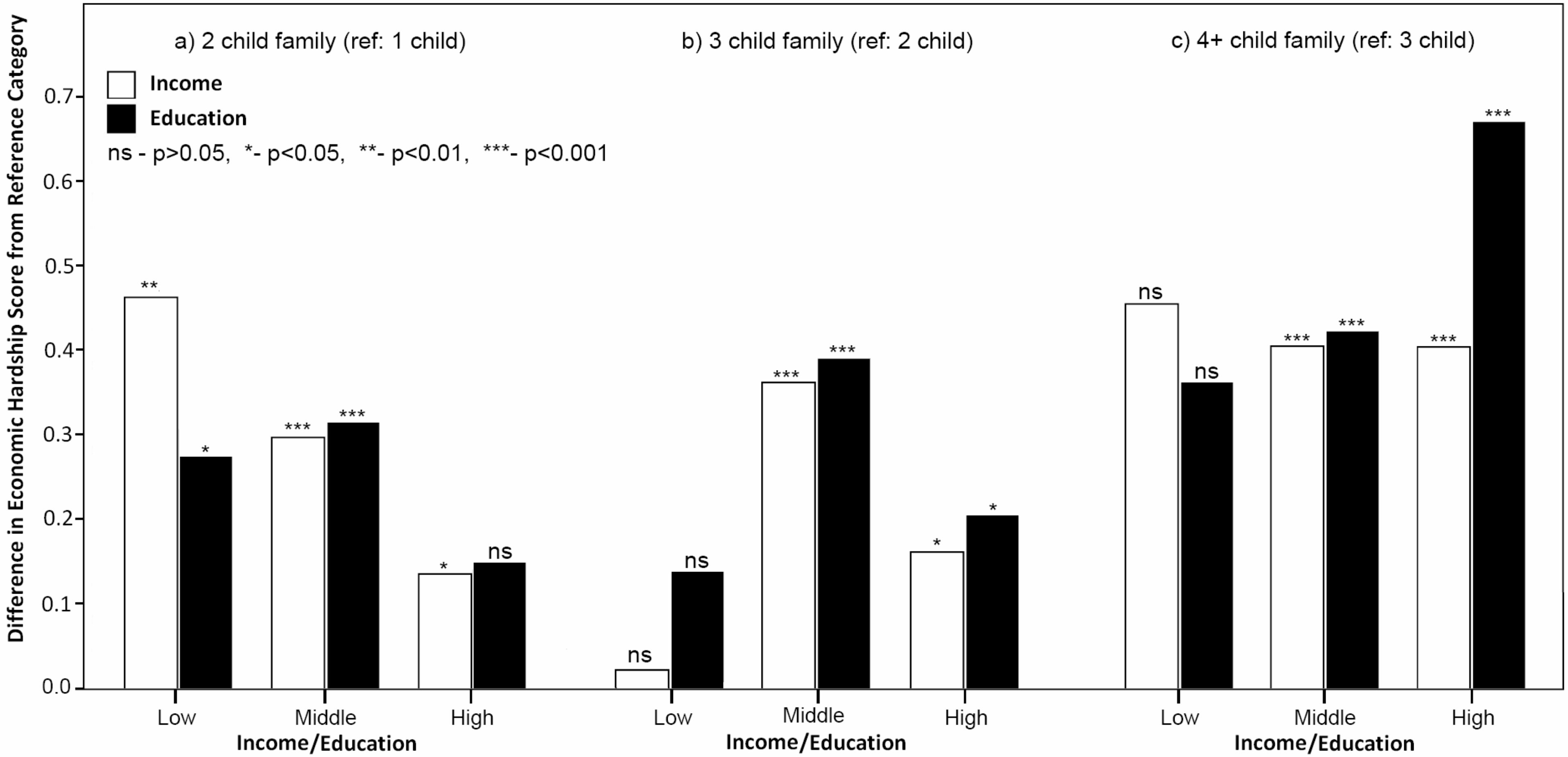

Figure 4.2 Incremental differences in economic hardship score as family size increases by socio-economic strata: a) caring for two relative to one child, b) caring for three relative to two children, c) caring for 4+ relative to three children. *Higher socio-economic status appears to reduce the trade-off between family size and economic hardship in the transition from one to two children. Above this threshold, middle and high socio-economic status families face the strongest trade-offs between family size and parental care. Final models control for time of measurement, mother's age, partner's age, father figure status, neighbourhood quality, home ownership, social support score, social network score, ethnicity and maternal employment (Table 4.2). See Table 4.5 for confidence intervals.*

4.4 Discussion

In this chapter, I used ALSPAC data to explore the effects of family structure on household financial difficulties during childhood. The outcome measure in this analysis was maternal perceptions of economic hardship over the first seven years of the study child's life. As might be expected for a wealthy modern population, overall levels of economic hardship were typically low across the study period.

Family size and economic hardship

High fertility clearly comes at a significant economic cost in modern populations. Following previous research (Bradshaw 2006; Iacovou and Berthoud 2006), I demonstrate that larger family size is associated with greater recorded difficulty in meeting key economic demands (Figure 4.1). This pattern remains even when socio-economic differences between families have been taken into account. This suggests that parents must trade-off their own quality of life with the decision to have children, and that children suffer economic deficits in financial investment with the addition of siblings.

Although I only consider an overall measure of economic hardship, greater difficulty affording each item included in this score has the potential to negatively impact child development. Difficulty affording rent and heating, for example, suggest poorly managed and overcrowded housing, while budget constraints on food, clothing and other items for the study child could have obvious negative effects on the quality of investment. Economic hardship may also act as a significant source of psycho-social stress within families.

Note that unlike parental time investments, which show a non-linear (1/x) relationship with family size (Chapter 3), trade-off effects on economic hardship appear quite linear (Figure 4.1). This finding is not at odds with a resource dilution perspective (Downey 1995) because in this case I estimate trade-off effects from the perspective of the mother, rather than for a child experiencing the addition of siblings.

Birth order and economic hardship

Few previous studies have examined the association between birth order and economic hardship in childhood, but it has been suggested on the basis of later support for educational expenses that later-borns are at a general advantage (Steelman and Powell 1989). While there is some suggestion of this effect in the univariate associations (Table A3), when the effects of birth order are estimated in multivariate models including time-varying socio-economic measures, there is no evidence of a later-born advantage. In fact, the relationship appears to be in the reverse direction, at least when comparing children with many younger siblings relative to many older siblings. This result is consistent with the hypothesis that older siblings represent a larger drain on parental resources than younger siblings. Relatively poor child development outcomes for later-born children are therefore anticipated.

Sex and economic hardship

Both sex of the study child and sex of siblings did not alter maternal perceptions of economic hardship which might have been expected if investment was biased in terms of sex. This result however does not provide a strong test for the existence of sex-biased investment. Lundberg and Rose (2002), for example, found that in a modern American sample, the working hours of fathers following the birth of a child demonstrated a higher increase over time if the child was male relative to female. This suggests that men are more inclined to invest time in income generation to later transfer to sons (see also: Choi et al. 2007). The analysis presented in this chapter controls for differences in household income and does not test for the possibility that sex may be associated with parental earnings. It is also possible that a Trivers-Willard effect on sex-ratio biasing could cancel out the predicted bias towards high economic hardship in relatively male-biased families, because if wealthy mothers are more likely to bear sons then male offspring might be associated with low economic hardship. The existence of Trivers-Willard effects on human sex-ratio biasing however are controversial (Lazarus 2002).

Paternal relatedness and economic hardship

Mothers partnered with a father figure unrelated to the study child reported equivalent levels of economic hardship as those partnered with the child's biological father. This suggests that once differences in socio-economic status are taken into account the presence of unrelated father figures does not place additional economic constraints on the household. This stands to further confirm that associations between unrelated father-figures and reduced parental time investments in childcare (Chapter 3) are unlikely to be confounded by unadjusted socio-economic disadvantage in these families.

Of course, the presented analysis can not rule out the possibility that within step-families father-figures are biasing the investment of material resources to genetic children over step-children. Anderson et al (1999) considered this issue in a sample of American families and found no significant difference in paternal financial expenditures on coresident step-children compared to genetic children. Although, consistent with the previous chapter, step-children received lower levels of time involvement (Chapter 3).

Socio-economic status and family size trade-offs

As expected, I find strong socio-economic gradients in economic hardship, with high socio-economic status, particularly high household income, associated with the lowest levels of financial difficulty. Interestingly, improved social support and network size also substantially reduced economic hardship. This suggests that social bonds may reap real economic advantages to parents. This could be the case if, for instance, social networks tend to pool resources and so reduce total expenses (e.g. through activities such as joint childcare arrangements, car-pooling or sharing of consumer goods). Direct transfer of money and material resources between close friends and family are also possible. Alternatively, low levels of social support may lead mothers to pessimistically perceive higher levels of economic hardship independently of absolute financial security due to its association with depression (Thorpe et al. 1992).

High socio-economic status is associated with the lowest effects of family size on economic hardship in the transition from one to two children. However, when considering further increases to family size, middle and high socio-economic status indicators are associated with the largest trade-off effects (Figure 4.2). Thus, it appears that, similar to the results on parental care (Chapter 3), high socio-economic status generally fails to alleviate the costs of resource competition between siblings and may actually lead to larger trade-off effects in economic hardship when family size is particularly large.

Chapter 5. Physical Development

5.1 Introduction

The aim of this chapter is to model associations between family structure and physical development, specifically childhood growth trajectories, in the ALSPAC sample (see also: Lawson and Mace 2008). ALSPAC has regularly collected height data, using a mix of self report and direct assessment, from birth length through to 10 years. Height is a well recognised biomarker for general health status, determined by genetic potential and the balance between nutrition and environmental demands such as disease, particularly in early life (Deaton 2007). Socio-economic gradients in health and mortality are routinely documented in modern populations, even in the wealthiest and most egalitarian of societies (Petrou et al. 2006; De Vogli et al. 2007). Research by Propper et al. (2007) confirms that positive relationships between socio-economic status and child health characterise the ALSPAC sample. As the previous chapters demonstrate, family structure is an important determinant of resource constraints on children and therefore is predicted to exert further influence on physical development. Family structure, however, often goes unconsidered in epidemiological studies, and when variables such as family size are included, this has more often been as a covariate of marginal interest, rather than the driving force behind research (Hart and Davey Smith 2003). Nevertheless, an emerging literature, much of which focuses on height data, suggests important family structure effects. ALSPAC data enable a further assessment of the robustness of these relationships under longitudinal analysis and a more effective exploration of neglected areas of research.

Family size and physical development

A number of epidemiological studies have reported negative relationships between family size and child or and adult height (Grant 1964; Goldstein 1971; Rona et al. 1978; Kuh and Wadsworth 1989; Li et al. 2004; Li and Power 2004). While the earliest of these studies may be criticised for poor inclusion of potential socio-economic confounds, the most recent research suggests these relationships are robust. Li and Power (2004) demonstrate a negative association between family size and childhood height for age in childhood (at seven years), independent of a wide range of socio-economic measures, in both the 1958 British birth cohort (i.e. the National Child Development Study) and the cohort's offspring (between four and 18 years) (see also: Li et al. 2004).

There is also some indication that family size effects are not uniform across socio-economic strata; although few studies have formally considered this issue. Li et al. (2004) report that reductions in height associated with large family size (3 or more children) were larger in manual relative to non-manual social class families in the 1958 British birth cohort. A study by Rona et al. (1978) reported that family size was negatively associated with childhood height in manual, but not non-manual, social classes in England. In Scotland, family size was associated with height in all social groups. On the basis of current evidence then, it appears that higher levels of parental resources serve to reduce quantity-quality trade-off effects on physical development.

Birth order and physical development

It is well established that later-born children tend to be larger at birth than their older siblings, independent of the effects of maternal age (for review see: Fessler et al. 2006). Studies to consider birth order effects in later childhood and adulthood have demonstrated the reverse pattern; implying reduced rates of growth in later-born children

(Goldstein 1971; Kuh and Wadsworth 1989; Li and Power 2004; but see Grant 1964). Indeed, a study by Blair et al (2004), using ALSPAC data, indicates that the later-born advantage in birth weight may be short lived, as high maternal parity is an important risk factor for 'failing to thrive' (i.e. substantially poor growth relative to infant peers).

Sex of siblings and physical development

If parental investment is biased towards sons, then we should expect shorter height for age in children with more brothers relative to sisters. A number of recent studies have shown that elder brothers reduce birthweight relative to elder sisters (Nielsen et al. 2008; Rickard 2008). As discussed, differences in birthweight are not necessarily indicative of later growth patterns and very little research has considered associations between sibling sex and later growth. Rickard (2008) presents the only data that I am aware of, finding that elder brothers are associated with shorter adult height than elder sisters in a small university sample (n=79). This study does not include any covariates relating to socio-economic status, parental age or relationship status, all of which may lead to spurious associations between sex of siblings and height. ALSPAC data provide opportunity to provide a stronger test of this hypothesis.

Paternal relatedness and physical development

Parental divorce has been associated with lower childhood height in the 1958 British birth cohort (Montgomery et al. 1997; Li and Power 2004), but not in the offspring of this cohort suggesting that the consequences of divorce has decreased for recent generations (Li and Power 2004). I not aware of any studies which has compared the height or health of children in the presence of biological versus non-biological father figures once differences in socio-economic status have been taken into account.

5.2 Data and Methods

5.2.1 Height data

Birth length was extracted from medical records and height further measured to the nearest millimetre by ALSPAC staff at several points over the study period, principally at focus clinics attended by children. The latest of these measured height at a mean age of 9.9 years on 7,238 children (Focus@9 Clinic). Additional height data are provided by self-reports in questionnaires distributed to the mother. Figure 5.1 plots height measurements for all children coded to the nearest month of measurement. In total 88,291 measurements of height are available for 12,999 individuals.

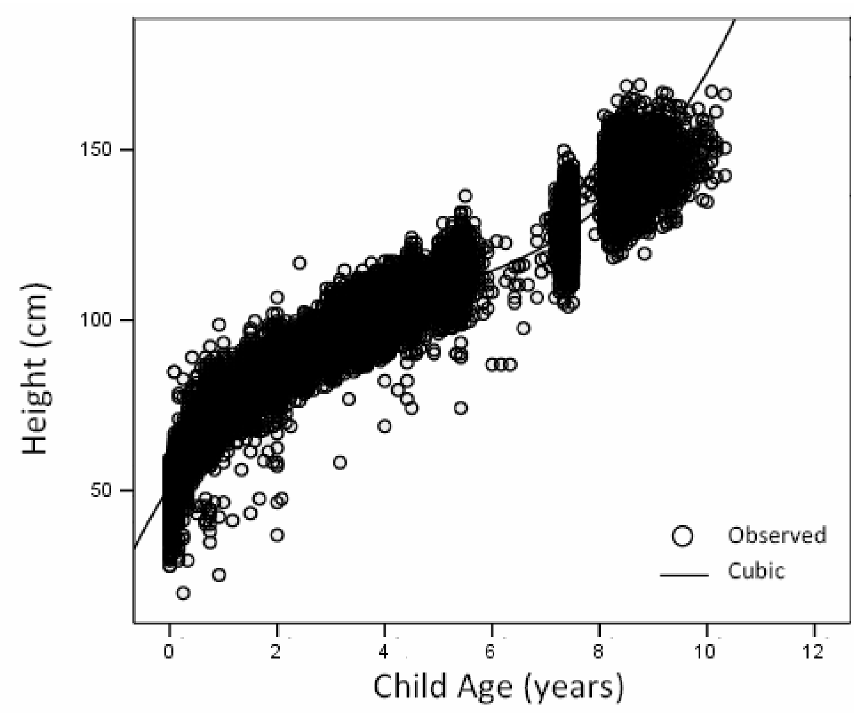

Figure 5.1 - Childhood height measurements over the study period (birth to 10 years)

Height follows a cubic growth curve over the study period (R^2 = 0.97)

5.2.2 Data analysis

The relationship of family structure to height assessments over the study period was examined using multi-level models for change (see Chapter 2). Maternal height is included as an additional covariate term in all multivariate models to provide partial control for heritable differences in height. Self-reported maternal height was recorded at pregnancy and is available for a large majority of families (Table 2.3).

In previous chapters, variation in family size effects was considered by comparison of the main effects of family size across separate models for low, medium and high socio-economic groups. By running models with main effects only, visual comparison of effects is straightforward. This method is inappropriate in analysis of childhood growth, because both main effects and interactions with child age are required to adequately capture the effects of family size. Therefore, I run a separate cross-sectional analysis on height at the Focus@9 Clinic to consider socio-economic variation in family size effects. A stepwise General Linear Modelling (GLM) procedure was conducted using SPSS v.13. Categorical independent variables were entered as factors and a continuous term for age at measurement (in weeks) entered as a covariate. For time-varying independent variables, the measurement at the closest time of assessment to the Focus@9 Clinic assessment. F statistics test the significance of the overall effect of each independent variable, while planned comparison tests are used to determine the direction and magnitude of effects. Variation in the effects of family size by socio-economic status is considered by testing the significance of interaction terms between family size and maternal education and household income (using the same three-way coding as earlier chapters).

5.3 Results

5.3.1 Childhood growth over the study period

Using the curve-fit procedure in SPSS v.13, a cubic relationship between child age and height provides the best fit, with an R-squared value of 0.97 (p<0.001) (Figure 5.1). Each individual is therefore assigned a cubic growth curve over the study period by the inclusion of both an age^2 and age^3 function in all models.

Univariate associations

Univariate associations between each independent variable and height over the study period and at the final clinic assessment (Focus@9) are summarised in the Appendix (Tables A4 – A5). In the multilevel models, at least one predictor term (relating to initial status or rate of change) for each independent variable demonstrated a significant univariate association with childhood growth (Table A.4). In the GLM model for Focus@9 height, father figure status, parental age, neighbourhood quality, ethnicity and measures of social support all failed to reach significance at the univariate level (Table A.5).

Final multivariate model

Table 5.1 summarises the final multi-level model for family size including 95% confidence intervals. In this model, 98% of within-person variance over time, 26% of between-person variance in initial status and 14% in rate of change is explained by the predictors.

Table 5.1 Main model for childhood growth: predictors of height in millimetres

			Initial Status (at 0y0m)		Rate of Change (per year)	
			Coefficient (B)	*95% CIs*	Coefficient (B)	*95% CIs*
Intercept †			408.82 ***	*395.15 – 422.49*	158.98 ***	*154.73 – 172.65*
Additional age terms		*Age²*	-	-	-26.18 ***	*-26.39 –- - 25.97*
		Age³	-	-	1.41 ***	*1.39 – 1.43*
Family Structure	Family Size *(Ref: 1)*	2	-4.28 ***	*-5.39 – -3.17*	-2.42 ***	*-2.88 – -1.96*
		3	-5.38 ***	*-7.05 – -3.71*	-2.55 ***	*-3.08 – -2.02*
		4	-6.38 ***	*-9.46 – -3.30*	-2.57 ***	*-3.31 – -1.83*
		5+	-5.87 *	*-10.83 – -0.91*	-3.09 ***	*-4.28 – -1.90*
	Sex of Child *(Ref: Male)*	Female	-14.77 ***	*-15.85 – - 13.69*	0.81 ***	*0.49 – 1.13*
	Father Figure Status *(Ref: Presence)*	Mother Alone	-0.33 ns	*-4.01 – 3.35*	-	-
		Unrelated Male	-8.91 ***	*-11.14 – -6.68*	-	-
	Mother's Age *(Ref:<25)*	25-29	1.33 ns	*-0.33 – 2.99*	-	-
		30-34	1.79 *	*0.00 – 3.58*	-	-
		35+	1.43 ns	*-0.81 –3.67*	-	-
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	0.04 ns	*-1.42 – 1.50*	-	-
		A-level	-1.13 ns	*-2.73 – 0.47*	-	-
		Degree	-1.05 ns	*-2.92 – 0.82*	-	-
	Household Income *(Ref: <£200)*	£200-299	-	-	0.38 ns	*-0.02 – 0.78*
		£300-399	-	-	0.79 ***	*0.35 – 1.23*
		£400+	-	-	1.67 ***	*1.23 – 2.11*
	Neighbourhood (*Ref:<V. Good*)	V. Good	0.90 **	*0.27 – 1.53*	-	-
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	2.03 **	*0.66 – 3.40*	-	-
		Owned	0.80 ns	*-1.97 –3.57*	-	-
Social Support	Social Network Score (Ref: Low)	Med	-	-	-	-
		High	-	-	-	-
	Social Support Score (Ref: Low)	Med	-	-	-	-
		High	-	-	-	-
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	1.84 ***	*0.94 – 2.74*
	Mother's Height in cm	(cont)	0.94 ***	*0.86 – 1.02*	0.29 ***	*0.26 – 0.30*

† - 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

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model Fit (Pseudo R^2): Within-Person (over time) – 0.98 ; Initial Status – 0.26; Rate of Change – 0.16
Final N: 53,998

5.3.2 Family size

With the exception of the strong effects of maternal height (which probably also accounts for some correlated socio-economic effects) contrasts by family size were the largest effects estimated on childhood growth (Table 5.1). Compared to only children, children in large sibships had lower initial status and relatively decreased growth per year. Estimates imply an incremental cost of siblings, with each additional sibling bringing further deficits to growth. The biggest difference by far is between one and two child families. By age 10, based on direct extrapolation of the effect estimates in Table 5.1, children in one child families are predicted to be 28.4mm (*CI: 22.8mm – 34.5mm*) taller than children in two child families, 30.9mm (*CI: 23.9mm – 37.9mm*) taller than children in three child families, 32.1mm (*CI: 21.6mm – 42.6mm*) taller than children in four child families, and 36.8mm (*CI: 19.9mm – 53.6mm*) taller than children in families with more than four children (Figure 5.2). These estimates should be treated with some caution as rate of change estimates can only be interpreted as the average effect over the study period (i.e. I don't estimate interactions between family size and age^2 or age^3) rather than specific estimates of height at a particular age.

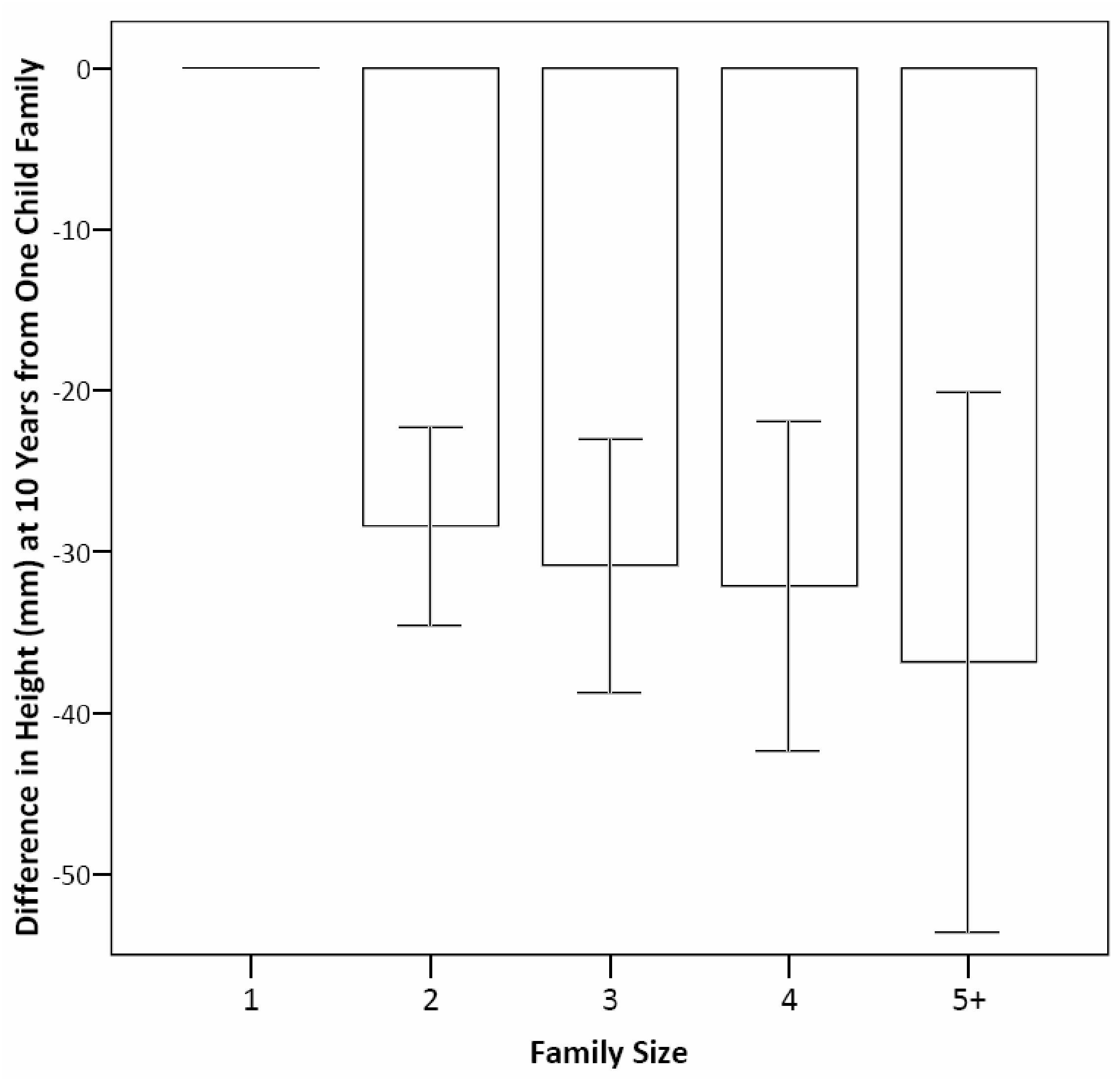

Figure 5.2 Family size and estimated child height at 10 years *Family size is negatively associated with physical growth over the study period. Displayed confidence intervals are based on the sum of the confidence intervals around initial status and rate of change effects. The final model controls for sex of child, father-figure status, mother's education, household income, neighbourhood quality, home ownership status, ethnicity, and mother's height (see Table 5.1 for full model)*

5.3.3 Birth order

Table 5.2 Final height model for sibling age configuration

		Initial Status (0y 0m)		Rate of Change (per year)	
		Coefficient (B)	*95%CI*	Coefficient (B)	*95%CI*
Number of older siblings	1	-2.51 ***	*-3.71 – -1.31*	-1.13 ***	*-1.52 – -0.74*
(Ref: 0)	2+	-2.52 **	*-5.74 – -0.88*	-1.49 ***	*-2.03 – -0.95*
Number of younger	1	-17.60 ***	*-19.99 – -15.21*	1.17 ***	*0.72 – 1.62*
siblings†	2+	-15.83 ***	*-21.35 – -10.31*	0.71 ns	*-0.07 – 1.49*
(Ref: 0)					

† = initial status for this variable estimated at 1y 9m
Model contains control variables for additional aspects of family configuration and parental resources (Table 5.1)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final N – 53,541

Table 5.2 summarises the final model for the effects of younger and older siblings. Note that initial status effects for number of younger siblings are estimated at one year, nine months. This is the first point at which ALSPAC data codes their existence (Table 2.1). Compared to being the last-born child, having younger siblings was associated with early childhood deficits in height, evidenced by a reduced initial status effect. However, these deficits were recovered over time, represented by positive effects on rates of change per year. In contrast, compared to being a first-born child, having older siblings was associated with reduced initial status and reduced rate of growth per year. At age 10 then, controlling for number of older siblings, we can estimate last-born children as 8.0 mm (*CI:1.9mm – 14.0mm*) taller than those with one younger sibling and 10.0mm (*CI: 2.0mm – 21.9mm*) taller than those with two or more (Figure 5.3a). While controlling for number of younger siblings, we can estimate first-born children as 13.8mm (*CI:8.7mm – 18.9mm*) taller than those with one older sibling and 17.4mm (*CI:8.6mm – 26.0mm*) taller than those with two or more (Figure 5.3b).

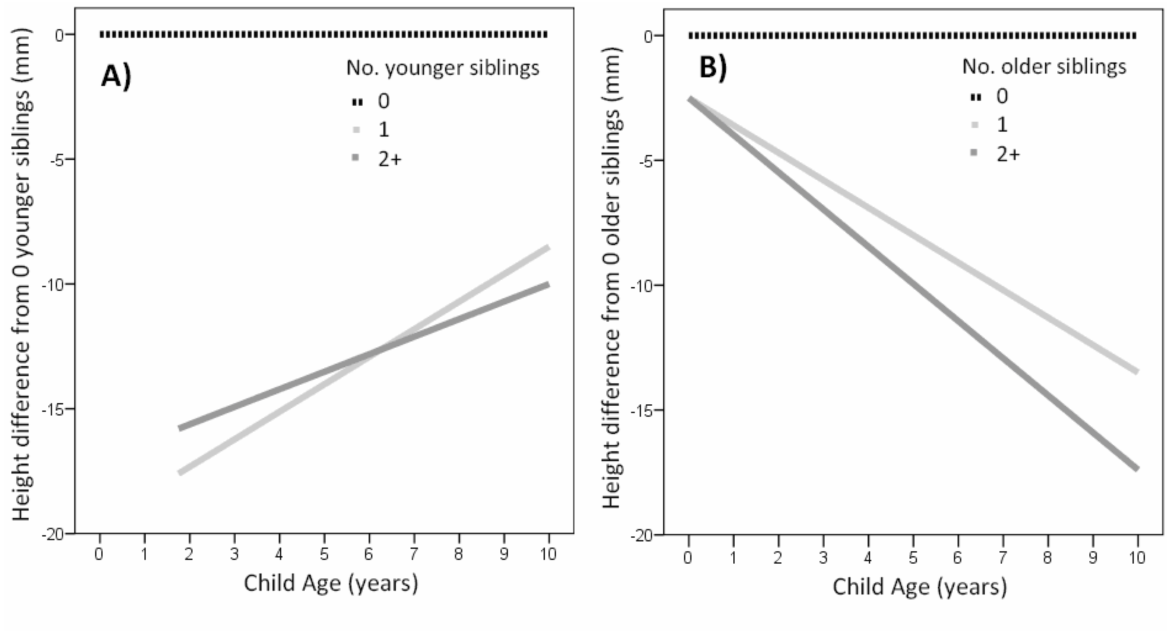

Figure 5.3 Sibling age configuration and estimated childhood height from birth to 10 years: (a) Height difference by number of younger siblings (b) Height difference by number of older siblings. *Older siblings are associated with larger lasting effects on physical growth. Younger siblings are associated with the largest height deficits if present in early childhood. The final model controls for sex of child, father-figure status, mother's age, mother's education, household income, neighbourhood quality, home ownership status, ethnicity and mother's height (See Table 5.1 for full model).*

5.3.4 Sex of siblings

Table 5.3 Final height model for sibling sex configuration

		Initial Status (0y 0m)		**Rate of Change (per year)**	
		Coefficient (B)	*95%CI*	Coefficient (B)	*95%CI*
Number of brothers *(Ref: 0)*	1	-5.39 ***	*-6.62 – -4.16*	-0.87 ***	*-1.24 – -0.50*
	2+	-4.06 ***	*-6.53 – -1.59*	-1.24 ***	*-1.84 – -0.64*
Number of sisters *(Ref: 0)*	1	-5.17 ***	*-6.39 – -3.95*	-0.74 ***	*-1.11 – -0.37*
	2+	-4.56 ***	*-7.14 – 1.98*	-1.22 ***	*-1.85 – -0.59*

Model contains control variables for additional family aspects configuration and parental resources (Table 5.1)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final N – 49,153

Girls were initially smaller than boys, but had an elevated rate of growth leading them to close this gap significantly over time (Table 5.1). Table 5.3 summarises the final model for the effects of brothers and sisters. The presence of both sibling sexes was associated with negative effects on initial status and rate of change of comparable magnitude. I also ran separate versions of this model for each sex and split by relative sibling age (results not shown). In all cases neither sibling sex was consistently more costly than the other.

5.3.5 Relatedness

Relative to presence of a biological father figure, the presence of an unrelated father figure was associated with a steady height deficit over the study period (Table 5.1). Children of single mothers did not differ from children of mothers remaining with their biological father.

5.3.6 Parental resources

Socio-economic profile was an important predictor of childhood height measurements (Table 5.1). Children in relatively high income families experienced an increased rate of growth, with those in the £300-399 and £400+ per week range growing more per year than those on less than £200 per week. Children living in mortgaged compared to rented housing and relatively poor quality neighbourhoods were consistently taller across the study period.

Children of taller mothers were both estimated as being born larger and growing faster. Non-white children grew faster than white children in the presence of other covariates.

Main effects of maternal age and education were retained in the final model because of their demonstrated importance in earlier blocks (not shown). In the absence of covariates related to paternal resources, maternal age was positively associated with childhood height. While in the absence of maternal height, maternal education was positively associated with childhood height. In the final model the magnitude and significance level of these effects are substantially reduced.

5.3.7 Interactions between socio-economic status and family size

Table 5.4 summarises the GLM model on Focus@9 height conducted to test for interaction effects between family size and measures of socio-economic position. The non-significance of interaction terms by both maternal education and household income indicate that the costs of additional siblings is not influenced by the socio-economic position of the parents. However, graphical presentation of these interaction effects (Figures 5.4) suggests that in low socio-economic strata only children are relatively uninfluenced by increases to family size. Given that family size effects in middle and high socio-economic status families also appear extremely similar, I reran the model with interaction terms coding household income and education as ‘low’ versus ‘medium-high’. Under this specification, interaction terms further approached, but did not reach, statistical significance (Family Size x Maternal Education: F(3, 4472) = 1.93, p =0.12; Family Size x Family Income: F(3, 4472) = 1.32, p = 0.26). The conclusions of this analysis do not change if I use the same set of independent variables as the final multi-level model (Table 5.1).

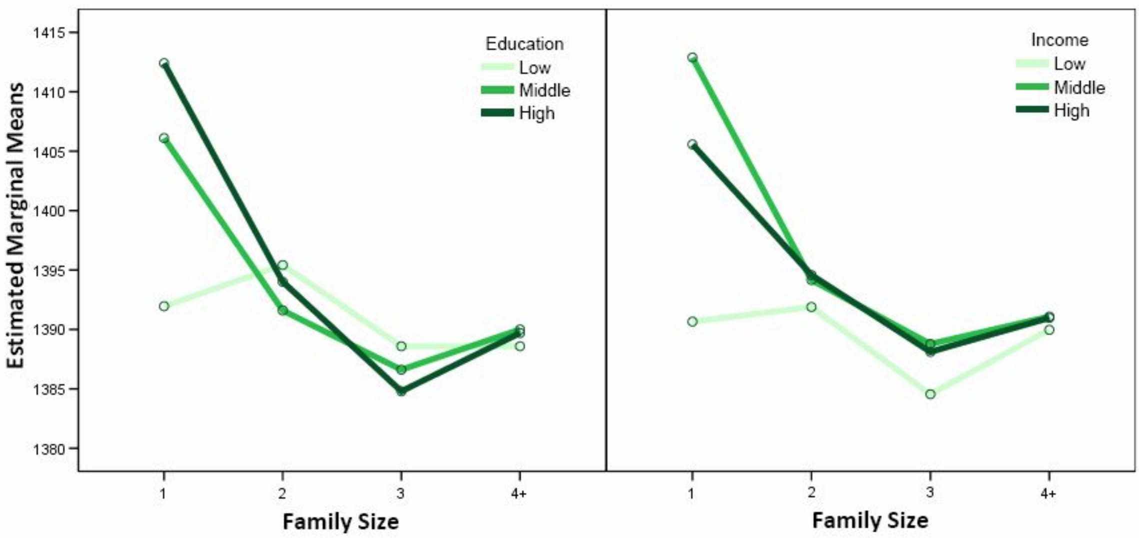

Figure 5.4 Interactions between family size and socio-economic status effects on Focus@9 height in millimetres. *There is some indication that negative relationships between family size and child height are limited to high socio-economic strata. However, interaction effects failed to reach statistical significance (see Table 5.4 for F statistics and covariates included in the final model)*

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Table 5.4 Main GLM model: child height at Focus@9 in millimetres

			F Statistic	Simple Contrast (B)	95% Confidence Intervals
Family Structure	Family Size *(Ref: 1)*	2	F(4, 4470) = 7.81 ***	-11.51 ***	*-17.58 – -5.44*
		3		-17.81 ***	*-24.30 – -11.32*
		4		-15.20 **	*-23.37 – -7.02*
		5 +		-13.54 *	*-26.10 – -0.97*
	Sex of Child *(Ref: Male)*	Female	F(1, 4470) = 9.30 **	-5.02 **	-8.23 – -1.79
	Mother's Age *(Ref:<25)*	25-29	-	-	-
		30-34		-	-
		35+		-	-
	Father's Age *(Ref: <25)*	25-29	-	-	-
		30-34		-	-
		35+		-	-
	Father Figure Status *(Ref: Presence)*	Mother Alone	F(2, 4470) = 1.32 ns	-4.00 ns	*-9.96 – 2.00*
		Unrelated Male		-4.10 ns	*-10.86 – 2.66*
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	F(3, 4470) = 0.23 ns	-1.40 ns	*-6.16 – 3.35*
		A-level		-0.35 ns	*-5.40 – 4.70*
		Degree		0.38 ns	*-5.39 – 6.15*
	Household Income *(Ref: <£200 per week)*	£200-299	F(3, 4470) = 1.96 ns	7.48 ns	*0.89 – 14.07*
		£300-399		2.73 ns	*-3.72 – 9.29*
		£400+		4.05 ns	*-2.17 – 10.27*
	Neighbourhood *(Ref: <V. Good)*	V. Good	-	-	-
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	-	-	-
		Owned Outright		-	-
Social Support	Social Network Score *(Ref: Low)*	Med	-	-	-
		High		-	-
	Social Support Score *(Ref: Low)*	Med	-	-	-
		High		-	-
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-
	Age of Child in weeks	(Continuous)	F(1, 4470) = 325.23 ***	1.01 ***	0.90 – 1.12
	Mother's Height in cm	(Continuous)	F(1, 4470) = 779.91 ***	3.56 ***	3.31 – 3.81
	Family Size x Maternal Education		F(6, 4467) = 1.16 ns	-	-
	Family Size x Household Income		F(6, 4467) = 0.89 ns	-	-

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model R^2: 0.21
Final N = 4486 cases

5.4 Discussion

In this chapter, I used ALSPAC data to explore the effects of family structure on childhood growth trajectories between birth and 10 years as a general marker for physical development.

Family size and physical development

The presence of siblings was associated with significant deficits in height over the first decade of life (Figure 5.2). The analyses presented in this chapter are not the first to reach this conclusion, but offer important methodological advancement over prior studies which have typically been cross-sectional in design (Grant 1964; Goldstein 1971; Kuh and Wadsworth 1989; Li and Power 2004) or used repeated measurements of height without consideration of temporal variation in family structure and parental resources (Rona et al. 1978; Li et al. 2004). Hence, we can conclude that negative effects of large family size on childhood growth represents a robust phenomenon. By extension this suggests, all else being equal, important negative health consequences of growing up in a large family. In fact, the effects of family size represented the largest contrasts estimated in the final model (with the exception of the strong effects of maternal height). Running a cross-sectional analysis on the height data available at the end of the study period reaches the same conclusion. Both analyses also indicate that the largest difference is between children in single child families and those in multiple child families. However, incremental deficits in growth as family size increases are suggested. This is consistent with the predictions of a resource dilution perspective (Downey 1995).

While longitudinal and cross-sectional analyses, reach broadly the same conclusions on family size, the estimated difference in height at age 10 is notably smaller in the cross-sectional models. While longitudinal models are more able to control for confounding relationship in the data, estimated family size effects on rate of change (i.e. growth) represent the average effect over the study period. Thus, if family size effects are larger in early childhood, where most data are available, this could lead to an overestimation of the cumulative effects of slow growth. Supporting this interpretation, Li et al (2004) found that negative effects of family size were associated with the largest height deficits at younger ages in the 1958 British Birth Cohort. In Li et al's own study, the effect of large family size (three or more siblings versus less than three siblings) is estimated as a deficit of 22mm – 23mm at 11 years. However, it should also be noted that Li et al (2004) probably underestimate the real impacts of large family size, because they adjust for household crowding and breast feeding practice, both of which are likely negatively influenced by siblings.

A number of studies have demonstrated associations between parenting and child health (Hoghughi 1998; Stewart-Brown 2008; Waylen et al. 2008), suggesting that slow growth in large families may be mediated by reductions in parental investment. Waylen et al. (2008) recently explored this association in the ALSPAC cohort, albeit using distinct measures to those considered in this thesis. They found that self-reported maternal hostility and resentment in early life predicted relatively poor reported child health and elevated incidence of common malaise at six and seven years, independent of the estimated effects of socio-economic status (including the economic hardship score) (see also: Propper et al. 2007). Further studies of the ALSPAC cohort have specifically linked large family size with health related behaviours which are consistent with resource dilution of either parental time or finances. Northstone and Emmett (2005) found that childhood dietary quality at ages four and seven follows a socio-economic gradient, with poor families more like to eat 'junk food'. Controlling for this effect, children in large sibships remained significantly more likely to eat food of lower nutritional value. High parity mothers also suffered poor quality diets in pregnancy (Northstone et al. 2007). A study of health care consultation for common childhood illnesses in ALSPAC also found that mothers are less likely to seek consultations for later-borns, suggesting reduced parental attendance to healthcare (Hay et al. 2005). Similarly, high parity has been associated with lower uptake of recommended immunisations of toddlers in the 1958 British Birth Cohort (Kaplan et al. 1992). However, the methodology of these studies do not clearly distinguish between consequences of overall family size and a later-born disadvantage.

A negative effect of siblings on physical development may not be completely generalised across all health measures. For example, there is a fast growing body of literature documenting a so-called 'sibling effect' on allergy in both children and adults, such that large family size is associated with reduced incidence of asthma, hay fever, eczema and related symptoms, has generated considerable research and public interest (reviewed in: Karmaus and Botezan 2002). The prevailing 'hygiene hypothesis' identifies the negative effects of small family size as stemming from reduced contact with infections in early life, which can continuatively lead to protective effects on immune maturation (Strachan 1989). As such positive effects of siblings remain consistent with a reduction in parental investment. However, the hygiene hypothesis remains controversial (Karmaus and Botezan 2002).

Birth order and physical development

The analyses presented here also confirm that later-born advantages in birthweight are not representative of later growth patterns (Goldstein 1971; Kuh and Wadsworth 1989; Blair et al. 2004; Li and Power 2004). In fact, by age 10 the presence of older siblings was associated with height deficits of almost twice the magnitude of those estimated for the presence of younger siblings (Figure 5.3).

That height deficits associated with the presence of younger siblings appear largest in early life suggests that their negative effects are immediate to the high energetic demands associated with pregnancy and young infant care for parents of newborn children. It may even be possible that younger siblings have negative effects on parental allocation of resources before their conception (for example if this period is associated with 'preparation costs' such as moving home or changes in parental relationships). To fully answer these questions requires comparison of individual growth trajectories in the preceding and subsequent periods to the arrival of a younger sibling. Unfortunately, lacking consistent data on the date of birth of younger siblings in the study sample I am unable to further investigate this issue.

Sex of siblings and physical development

Rickard (2008) found suggestive evidence that individuals with an elder brother reached a shorted adult height than those with elder sisters. Providing a more robust test of this hypothesis, I find no evidence that sex configuration influences childhood growth.

Paternal relatedness and physical development

This chapter also indicates that the presence of unrelated father figures compared to biological fathers is associated with lower height for age across the study period, even after controlling for socio-economic factors which might covary with this aspect of family structure. Children of single mothers, who have also experienced parental separation, however, did not suffer deficits in growth.

Socio-economic status and family size trade-offs

I find a clear socio-economic gradient in childhood growth trajectories. This finding is in strong agreement with other studies of height, and related health outcomes, such as childhood malaise, in the ALSPAC sample (Propper et al. 2007). Maternal height also showed strong positive associations with childhood height, representing the further importance of somatic resources and genetic factors in growth. Social support was not an important as a determinant of growth when other factors are taken into account.

Contrary to previous studies (Rona et al. 1978; Li et al. 2004), I find no evidence that low socio-economic status increases the risks of poor childhood growth associated with large family size. In fact, a non-significant interaction term suggests the opposite pattern. At least two factors may be responsible for this discrepancy. In Li et al. (2004) social class was coded as manual versus non-manual and family size as less than three children versus three or more children. A significant interaction between these variables suggested that large family size was more detrimental to growth in the manual class. Reducing family size to a binary variable assumes that 'large families' are equally large in both groups. This hardly provides as a strong test of socio-economic variation in family size effects. For example, if large families are particularly large in the manual class this could misleadingly create a statistical interaction.

Alternatively, it is possible that children in low socio-economic status families faced the strongest sibship size effects in the past and this pattern has since has disappeared or reversed. There is a gap of several decades between the cohorts studied in the previous studies (Rona et al. 1978; Li et al. 2004) and the ALSPAC cohort. Downey's base-surplus model of parental investment (Downey 2001) may be a relatively better fit to socio-economic variation in health-related behaviour in the Britain we see today, rather than 50 years ago. It seems likely, for example, that more families are now meeting the conditions of guaranteed ‘base investments’ in terms of nutrition and healthcare, while the range of ‘surplus’ investments available for only the wealthiest families has been further extended (e.g. private medical care, dietary supplements).

Chapter 6. Cognitive Development

6.1 Introduction

The aim of this chapter is to model associations between family structure and cognitive development in the ALSPAC sample. Cognitive development is measured as performance in two formal school examinations and an IQ test administered by ALSPAC researchers. These measures are modelled as separate outcomes, rather than collectively in longitudinal models. This is because each assessment is measured by different means on a distinct metric (Singer and Willett 2003). Of each aspect of child development considered in this thesis, cognitive development has received the most scholarly attention in relation to family structure and parental investment. Sociologists and psychologists have had a long standing interest in the consequences of family size and birth order in intelligence and educational attainment (Steelman et al. 2002). Less research has considered sex of siblings as a potential influence and whether or not performance on cognitive tests differs in the presence of unrelated father figures.

Family size and cognitive development

A large body of empirical literature attests to a negative relationship between family size and measures of cognitive development in modern societies. Over the last four decades, effects have been reliably demonstrated in a wide range of datasets in Europe, the USA and Asia (Blake 1981; Blake 1989; Downey 1995; Kuo and Hauser 1997; Downey 2001; Steelman et al. 2002). In review of this research, Steelman et al. (2002:248) describe the evidence as "*virtually unequivocal*"', while Downey (2001: 497) notes that "*[F]ew patterns in the social and behavioural sciences reach this level of consistency*". This pattern is not only consistent; the effects of family size relative to other covariates, including socio-economic measures, is generally substantial (Blake 1989; Steelman et al. 2002). Studies which have assessed measures of educational attainment (i.e. years in education or qualifications obtained) tend to find the largest effects. Studies which directly assess cognitive development though IQ tests or examination grades have been more variable. It has been suggested that this is because educational attainment is more strongly determined by parental resource allocations, whereas intelligence may be relatively more influenced by genetic factors which are not divisible by the presence of siblings (Steelman et al. 2002).

The general assumption within this literature is that negative effects of family size will be the strongest in the poorest families. Phillips (1999:190) sums up this position well – "*If resource dilution occurs in large families and if it affects academic skills, the sibship-size effect on children's cognitive skills should be particularly noticeable in families in which resources are scarce. In a country where most families have more resources than they need, sibship size may dilute the resources essential to cognitive development (a good diet for instance) only among the very poor*". However, as I have outlined (Chapter 1), the logic of this assumption is questionable when we consider the distinction between base and surplus investments (Downey 2001). Unfortunately, content with establishing population trends, researchers have left the possibility of socio-economic variation in family size effects largely unexplored in empirical terms (Steelman et al. 2002).

Birth order and cognitive development

The consequences of ordinal position within the family for cognitive development is a source of much controversy and academic dispute. Research interest in the issue can be dated back to Galton (1874) who reported a disproportionate number of first-borns among British scientists, suggesting an intellectual prominence of early-born offspring. A number of studies since then have documented apparent negative relationships between birth order and cognitive development (Belmont and Marolla 1973; Zajonc and Markus 1975; Bjerkedal et al. 2007; Kristensen and Bjerkedal 2007). A contrasting set of studies have found birth order effects to be very weak or absent altogether (Rodgers et al. 2000; Wichman et al. 2006). Studies finding no or little effect of birth order have generally used longitudinal or within-family models, suggesting that relationships reported in opposing studies reflect a failure to adequately control for between-family differences (Steelman et al. 2002).

Sex and siblings and cognitive development

There is a small literature considering the relative influence of brothers and sisters in cognitive development (reviewed in: Steelman et al. 2002; Hopcroft 2004). Research has focused almost exclusively on educational attainment. Findings are not consistent between studies, with some reporting that sisters are associated with lower educational attainment than brothers (e.g. Butcher and Case 1994), others suggesting the opposite pattern (e.g. Powell and Steelman 1989), while others still have found no effect of sibling sex (e.g. Jacobs 1996; Kaestner 1997). ALSPAC data enable a further assessment of the role of family sex composition on performance on cognitive tests.

Paternal relatedness and cognitive development

I know of few studies that have considered differences in cognitive development between children with unrelated father figures compared to biological fathers. Beller and Jung (1992) found that remarriage of single mothers was associated with improved levels of educational attainment, but at levels below children remaining with their biological father. Studying children of *step-mothers*, Case et al. (Case et al. 2001) found that children coresident with step-mothers attained lower levels of education than children coresident with their biological mother.

6.2 Data and Methods

6.2.1 Measures of cognitive development

Table 6.1 Cognitive development measures over the study period

	Measure		
	Entry Assessment	*Key Stage 1 Assessment*	*IQ Assessment*
Child Age at Assessment (years)			
Mean	4.56	7.36	8.63
Standard Deviation	0.31	0.32	0.33
Value			
Mean	12.74	9.15	104.34
Standard Deviation	3.26	3.75	16.42
Correlation Between Measures			
Entry Assessment	-	0.64 ***	0.49 ***
Key Stage 1 Assessment	0.64 ***	-	0.61 ***
IQ test	0.49 ***	0.61 ***	-
Number of cases (n)	*8,876*	*10,495*	*6,581*

Note that these values refer to the sample available at each study wave. They should not be directly interpreted as evidence of change over time due to selective attrition.
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

I used three measures of cognitive development, two based on academic performance and one independent measure of IQ (Table 6.1). The two school-based measures of cognitive development available in ALSPAC are the Entry Assessment test taken shortly after starting school at four or five years and the Key Stage 1 Assessment which is administered at six or seven years. Each test is composed of four subscores that capture ability in reading, writing, mathematics and language skills (Entry Assessment only) or spelling (Key Stage 1 Assessment only). Parents were required to give written permission for the release of the school based test results. At eight years, ALSPAC participants were also invited to attend a half-day clinic during which cognitive ability was assessed using the Wechsler Intelligence Scale for Children (WISC-III^{UK}) (Wechsler et al. 1992). This scale is the most widely used individual cognitive ability test worldwide. It consists of ten subscores, comprising five verbal test subsets and five performance subtests, which can be used to calculate intelligence quotient (IQ) scores. For each measure of cognitive development, I analyse the determinants of the summary scores only.

6.2.2 Data analysis

A General Linear Modelling (GLM) procedure was conducted using SPSS v.13 to analyse relationships between family structure and cognitive development over the study period. Each measure of cognitive development is treated as a continuous score and modelled independently. Categorical independent variables are entered as factors and continuous independent variables entered as covariates. For time-varying independent variables, the measurement at the closest point to the mean time of assessment for the outcome measure was used. In addition to the independent variables listed in Chapter 2, I include additional covariates specific to this chapter. For the Entry Assessment and Key Stage 1 Assessment I include a covariate for the exact age in months at assessment and a factor for the school year at assessment. IQ scores are age-adjusted across the observed range by ALSPAC (based on the Look-up tables provided in the WISC manual – Wechsler et al. 1992) and so do not require additional covariates for timing. F statistics test the significance of the overall effect of each independent variable, while planned comparison tests are used to determine the direction and magnitude of effects.

Following, the analysis strategy set out in previous chapters, final models are constructed in a stepwise fashion. The first block includes all independent variables relating to family structure. Models were then reduced by removing the least significant predictor at each iteration, until only significant variables remain. All remaining independent variables were entered in the second step, which was then reduced in a similar fashion removing non-significant variables unless their inclusion modified the effects of any of the family structure variables. Separate models were used to assess first the overall effects of family size, and then birth order and sibling sex. Socio-economic variation in family size effects was considered by testing the significance of interaction terms between family size and maternal education and household income. All analyses were carried out in SPSS vs.13.

6.3 Results

Univariate associations

Univariate associations between each independent variable and the cognitive development assessments can be consulted in the Appendix (Table A6 – A8). Every independent variable showed a significant univariate association with the Entry Assessment (Table A6) and Key Stage 1 Assessment scores (Table A7). However, sex of child, number of sisters, maternal employment and ethnicity all failed to reach significant associations with the IQ score (Table A8).

Final multivariate models

Tables 6.2 – 6.4 summarise the final multivariate models for each measure of cognitive development. R^2 statistics estimate that model fit is highest at 25% in the model predicting the Entry Assessment scores, falling to a low of 16% for the model predicting IQ scores.

6.3.1 Family size

Children in larger families have lower cognitive development scores for all three measures (Tables 6.2 - 6.4). In the Entry Assessment model these effects are apparent from the comparison of one to two child families, and show signs of tailing-off in the largest sibships. However, in the Key Stage 1 Assessment model there is no difference between one and two child families, and in the IQ Assessment model there is no difference between one and two child or one and three child families, with effects only becoming significant for families with at least three children (Figure 6.1). In the Entry Assessment model family size effects are comparable in magnitude the effects of socio-economic indicators. In, the Entry Assessment and IQ Assessment models, socioeconomic effects are notably larger than family size effects.

Table 6.2 Main model: entry assessment

			F Statistic	Simple Contrast (B)	Confidence Intervals
Family Structure	Family Size *(Ref: 1)*	2	F(4, 3733) = 15.95 ***	-0.31 *	*-0.57 – -0.04*
		3		-0.77 ***	*-1.08 – -0.46*
		4		-1.49 ***	*-1.95 – -1.03*
		5 +		-1.45 ***	*-2.14 – -0.76*
	Sex of Child *(Ref: Male)*	Female	F(1, 3733) = 144.24 ***	1.06 ***	*0.88 – 1.23*
	Mother's Age *(Ref:<25)*	25-29	F(3, 3733)= 2.86 *	0.15 ns	*-0.15 – 0.44*
		30-34		0.41 *	*0.08 – 0.74*
		35+		0.48 *	*0.06 – 0.91*
	Father's Age *(Ref: <25)*	25-29	F(3, 3733)= 1.69 ns	0.33 ns	*-0.06 – 0.71*
		30-34		0.15 ns	*-0.25 – 0.55*
		35+		0.30 ns	*-0.13 – 0.74*
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	F(2, 3733)= 2.53 ns	-0.64 *	*-1.21 – -0.06*
		Unrelated Male		0.26	*-0.16 – 0.67*
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	F(3, 3733)= 34.63 ***	0.51 ***	*0.28 – 0.75*
		A-level		0.77 ***	*0.51 – 1.03*
		Degree		1.72 ***	*1.39 – 2.05*
	Household Income *(Ref: <£200 per week)*	£200-299	F(3, 3733)= 16.44 ***	0.47 **	*0.17 – 0.76*
		£300-399		0.74 ***	*0.42 – 1.05*
		£400+		1.12 ***	*0.79 – 1.46*
	Neighbourhood *(Ref: <V. Good)*	V. Good	F(1, 3733)= 12.11 **	0.31 **	*0.14 – 0.49*
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	F(2, 3733)= 7.98 ***	0.65 ***	*0.33 – 0.96*
		Owned Outright		0.55 *	*0.06 – 1.04*
Social Support	Social Network Score *(Ref: Low)*	Med	F(2, 3733)= 6.39 **	0.21 ns	*-0.01 – 0.42*
		High		0.39 ***	*0.18 – 0.61*
	Social Support Score *(Ref: Low)*	Med	-	-	-
		High		-	-
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	
	Maternal Employment *(Ref: No)*	Yes	-	-	-
	Age in years	Continuous	F(1, 3733)= 312.08 ***	3.37 ***	*3.00 – 3.74*
	School Year *(Ref: 1995/1996)*	1996/1997	F(2,3733)= 4.65 **	-0.34 **	*-0.60 – -0.09*
		1997/1998		-0.55 **	*-0.92 – -0.18*

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model R^2: 0.25
Final N - 3762

Table 6.3 Main model: key stage 1 assessment

			F Statistic	Simple Contrast (B)	Confidence Intervals
Family Structure	Family Size *(Ref: 1)*	2	F(4, 4609) = 8.15 ***	-0.22 ns	*-0.56 – 0.12*
		3		-0.62 **	*-0.99 – -0.26*
		4		-0.83 **	*-1.30 – -0.36*
		5 +		-1.21 **	*-1.92 – -0.50*
	Sex of Child *(Ref: Male)*	Female	F(1, 4609) = 111.95 ***	0.95 ***	*0.78 – 1.13*
	Mother's Age *(Ref:<25)*	25-29	F(3, 4609) = 0.58 ns	0.10 ns	*-0.21 – 0.41*
		30-34		-0.04 ns	*-0.39 – 0.31*
		35+		0.04 ns	*-0.40 – 0.48*
	Father's Age *(Ref: <25)*	25-29	F(3, 4609) = 1.18 ns	0.18 ns	*-0.21 – 0.57*
		30-34		0.35 ns	*-0.07 – 0.77*
		35+		0.35 ns	*-0.14 – 0.76*
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	F(2, 4609) = 0.36 ns	-0.14 ns	*-0.57 – 0.30*
		Unrelated Male		0.06 ns	*-0.32 – 0.43*
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	F(3, 4609) = 88.68 ***	1.17 ***	*0.92 – 1.41*
		A-level		1.55 ***	*1.28 – 1.82*
		Degree		2.69 ***	*2.36 – 3.02*
	Household Income *(Ref: <£200 per week)*	£200-299	F(3, 4609) = 11.22 ***	0.42 *	*0.05 – 0.78*
		£300-399		0.62 **	*0.24 – 1.00*
		£400+		1.00 ***	*0.62 – 1.38*
	Neighbourhood *(Ref: <V. Good)*	V. Good	F(1, 4609) = 6.71 *	0.24 *	*0.06 – 0.42*
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	F(2, 4609) = 13.47 ***	0.89 ***	*0.55 – 1.23*
		Owned Outright		0.77 **	*0.27 – 1.26*
Social Support	Social Network Score *(Ref: Low)*	Med	-	-	-
		High		-	-
	Social Support Score *(Ref: Low)*	Med	F(2, 4609) = 5.52 **	0.33 **	*0.11 – 0.55*
		High		0.31 **	*0.09 – 0.53*
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-
	Maternal Employment *(Ref: No)*	Yes	-	-	-
	Age in years	Continuous	F(1, 4609) = 133.99 ***	2.23 ***	*1.85 – 2.61*
	School Year (Ref: 1997/1998)	1998/1999	F(2, 4609) = 6.15 **	0.31 *	*0.10 – 0.61*
		1999/2000		0.67 **	*0.29 – 1.05*

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model R^2: 0.21

Final N - 4638

Table 6.4 Main model: IQ assessment

			F Statistic	Simple Contrast (B)	Confidence Intervals
Family Structure	Family Size *(Ref: 1)*	2	F(4, 4132) = 3.58 *	0.15 ns	*-1.61 – 1.91*
		3		-0.93 ns	*-2.81 – 0.95*
		4		-2.67 *	*-5.04 – 0.30*
		5 +		-3.13 ns	*-6.69 – 0.38*
	Sex of Child *(Ref: Male)*	Female	-	-	-
	Mother's Age *(Ref:<25)*	25-29	F(3, 4132) = 2.07 ns	1.21 ns	*-0.55 – 2.97*
		30-34		2.09 *	*0.16 – 4.02*
		35+		2.73 *	*0.37 – 5.08*
	Father's Age *(Ref: <25)*	25-29	F(3, 4132) = 0.25 ns	0.84 ns	*-1.45 – 3.12*
		30-34		0.50 ns	*-1.87 – 2.88*
		35+		0.75 ns	*-1.79 – 3.28*
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	F(2, 4132) = 0.00 ns	0.05 ns	*-1.94 – 2.05*
		Unrelated Male		0.07 ns	*-1.71 – 1.85*
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	F(3, 4132) = 123.73 ***	5.00 ***	*3.63 – 6.36*
		A-level		8.51 ***	*7.06 – 9.97*
		Degree		15.72 ***	*14.06 – 17.38*
	Household Income *(Ref: <£200 per week)*	£200-299	F(3, 4132) = 11.14 ***	-0.35 ns	*-2.31 – 1.62*
		£300-399		1.22 ns	*-0.72 – 3.17*
		£400+		3.35 **	*1.45 – 5.25*
	Neighbourhood *(Ref: <V. Good)*	V. Good	-	-	-
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	F(2, 4132) = 3.32 *	2.36 *	*0.42 – 4.29*
		Owned Outright		3.37 *	*0.69 – 5.86*
Social Support	Social Network Score *(Ref: Low)*	Med	F(2, 4132) = 4.19 *	1.63 **	*0.48 – 2.79*
		High		1.29 *	*0.13 – 2.45*
	Social Support Score *(Ref: Low)*	Med	-	-	-
		High		-	-
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-
	Maternal Employment *(Ref: No)*	Yes	-	-	-

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model R^2: 0.16
Final N - 4155

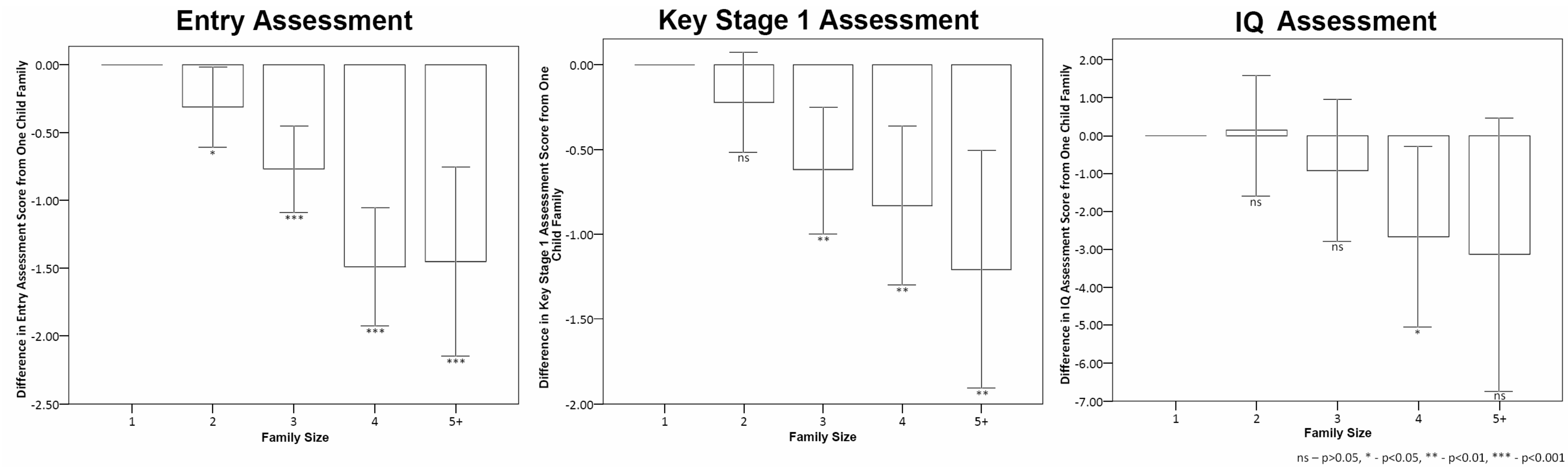

Figure 6.1 Family size and cognitive development over the study period. *Family size is negatively associated with cognitive development. This relationship stands for Entry Assessments at a mean age of 4.6 years (Table 6.4 for full model), Key Stage 1 Assessment scores at a mean age of 7.4 years (Table 6.5 for full model), and IQ Assessment scores at a mean age of 8.6 years (Table 6.6 for full model). Final models control for age at measurement and a range of relevant socio-economic and demographic measures (Tables 6.4 – 6.6).*

6.3.2 Birth order

Table 6.5 Final cognitive development models for sibling age configuration: **(a)** entry assessment **(b)** key stage 1 assessment **(c)** IQ assessment

			F Statistic	**Simple Contrast (B)**	**Confidence Intervals**
(a) Entry Assessment	Number of older siblings *(Ref: 0)*	1	F(3, 3674) = 20.06 ***	-0.48 ***	*-0.69 – -0.26*
		2		-1.06 ***	*-1.37 – -0.75*
		3+		-1.44 ***	*-2.00 – -0.88*
	Number of younger siblings *(Ref: 0)*	1	F(2, 3674) = 4.83 **	-0.20 ns	*-0.40 – 0.02*
		2+		-0.62 **	*-1.04 – -0.21*
(b) Key Stage 1 Assessment	Number of older siblings *(Ref: 0)*	1	F(3, 4501) = 17.89 ***	-0.50 ***	*-0.73 – -0.27*
		2		-1.11 ***	*-1.44 – -0.78*
		3+		-1.25 ***	*-1.83 – -0.66*
	Number of younger siblings *(Ref: 0)*	1	F(2, 4501) = 0.77 ns	-0.07 ns	*-0.30 – 0.16*
		2+		-0.21 ns	*-0.54 – 0.12*
(c) IQ Assessment	Number of older siblings *(Ref: 0)*	1	F(3, 4007) = 10.34 ***	-1.41 *	*-2.50 – -0.23*
		2		-4.11 ***	*-5.84 – -2.37*
		3+		-6.78 ***	*-10.28 – -3.28*
	Number of younger siblings *(Ref: 0)*	1	F(2, 4007) = 0.54 ***	0.54 ns	*-0.68 – 1.75*
		2+		0.00 ns	*-1.60 – 1.60*

Models contain control variables for additional aspects of family structure and parental resources (see Tables 6.2-6.4)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final N – Entry Assessment – 3706; Key Stage 1 Assessment – 4530; IQ Assessment - 4031

For all three measures, older siblings are associated with larger costs on cognitive development than younger siblings (Table 6.5). In the IQ Assessment model this pattern is particularly evident. Relative to first-born children, those with older siblings perform significantly worse. However, there is no statistically distinguishable difference between lastborn children and those with one and two or more younger siblings.

6.3.3 Sex of siblings

Table 6.6 Final cognitive development models for sibling sex configuration: **(a)** entry assessment **(b)** key stage 1 assessment **(c)** IQ assessment

			F Statistic	**Simple Contrast (B)**	**Confidence Intervals**
(a) Entry Assessment	Number of brothers *(Ref: 0)*	1	F(2, 3265) =	-0.32 **	*-0.54 – -0.10*
		2+	12.04 ***	-0.89 ***	*-1.27 – -0.52*
	Number of sisters *(Ref: 0)*	1	F(2, 3265) =	-0.26 *	*-0.48 – -0.05*
		2+	9.39 ***	-0.82 **	*-1.20 – -0.44*
(b) Key Stage 1 Assessment	Number of brothers *(Ref: 0)*	1	F(2, 4028) =	-0.31 **	*-0.54 – -0.08*
		2+	8.70 ***	-0.73 ***	*-1.08 – -0.38*
	Number of sisters *(Ref: 0)*	1	F(2, 4028) =	-0.22 ns	*-0.45 – 0.00*
		2+	2.71 ns	-0.36 *	*-0.72 – -0.07*
(c) IQ Assessment	Number of brothers *(Ref: 0)*	1	F(2, 3534) =	-1.07 ns	*-2.26 – 0.12*
		2+	4.43 *	-2.68 **	*-4.48 – -0.88*
	Number of sisters *(Ref: 0)*	1	F(2, 3534) =	-0.50 ns	*-1.67 – 0.68*
		2+	0.54 ns	-0.86 ns	*-2.71 – 0.98*

Models contain control variables for additional aspects of family structure and parental resources (see Tables 6.2-6.4)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final N – Entry Assessment – 3293; Key Stage 1 Assessment – 4057; IQ Assessment - 3552

Girls performed better on the Entry Assessment (Table 6.2) and Key Stage 1 Assessment (Table 6.3). There was no sex difference in performance on the IQ Assessment (Table 6.4). For all three measures, the presence of brothers is associated with lower performance than the presence of sisters (Table 6.6). In IQ Assessment model, only number of brothers influences IQ performance, while children with one and two or more sisters are not significantly different from children with no sisters.

6.3.4 Relatedness

Father figure status failed to reach significance in any of the final models assessing cognitive development (Tables 6.2 – 6.4). However, this variable is retained in final models because of its demonstrated importance in the absence of socio-economic controls (Tables A6 – A8).

6.3.5 Parental resources

Relatively high socio-economic status was strongly associated with improved performance on cognitive tests (Table 6.2 – 6.4). Maternal education was the most important predictor in relation to other socio-economic covariates, demonstrating a clear positive gradient across its full range. Children living in above average income households and in mortgaged/owned housing where also at an advantage. Neighbourhood quality was positively associated with performance on the Entry Assessment and Key Stage 1 Assessment, but the IQ Assessment.

Measures of social support were also positively associated with cognitive scores, although the measure which reaches significance changes (Table 6.2 – 6.4). Parental age was retained in all final models, due to its demonstrated importance in the absence of socio-economic measures, but did generally not reach significance in final models.

Ethnicity and maternal employment are not important when socio-economic measures and social support models are included (Table 6.2 – 6.4). Mother's age was positively associated with performance on the Entry Assessment (Table 6.2).

6.3.6 Interaction between socio-economic status and family size

Table 6.7 Interaction effects of family size x socio-economic status:
(a) entry assessment **(b)** key stage 1 assessment **(c)** IQ assessment

		F Statistic
(a) Entry Assessment	Family Size x Maternal Education	F(6, 3729) = 0.54 ns
	Family Size x Household Income	F(6, 3729) = 0.87 ns
(b) Key Stage 1 Assessment	Family Size x Maternal Education	F(6, 4605) = 0.78 ns
	Family Size x Household Income	F(6, 4605) = 0.41 ns
(c) IQ Assessment	Family Size x Maternal Education	F(6, 4128) = 0.40 ns
	Family Size x Household Income	F(6, 4128) = 0.17 ns

Models contain control variables for additional aspects of family structure and parental resources (see Tables 6.2-6.4)
ns = non-significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final N – Entry Assessment – 3762; Key Stage 1 Assessment – 4638; IQ Assessment - 4155

Re-running the main models (Tables 6.2 – 6.4) and including interaction terms between family size and measures of socio-economic position provides no indication that trade-offs between family size and cognitive development vary across socio-economic strata. Figure 6.2 graphically illustrates these interaction terms, confirming no indication of socio-economic variation.

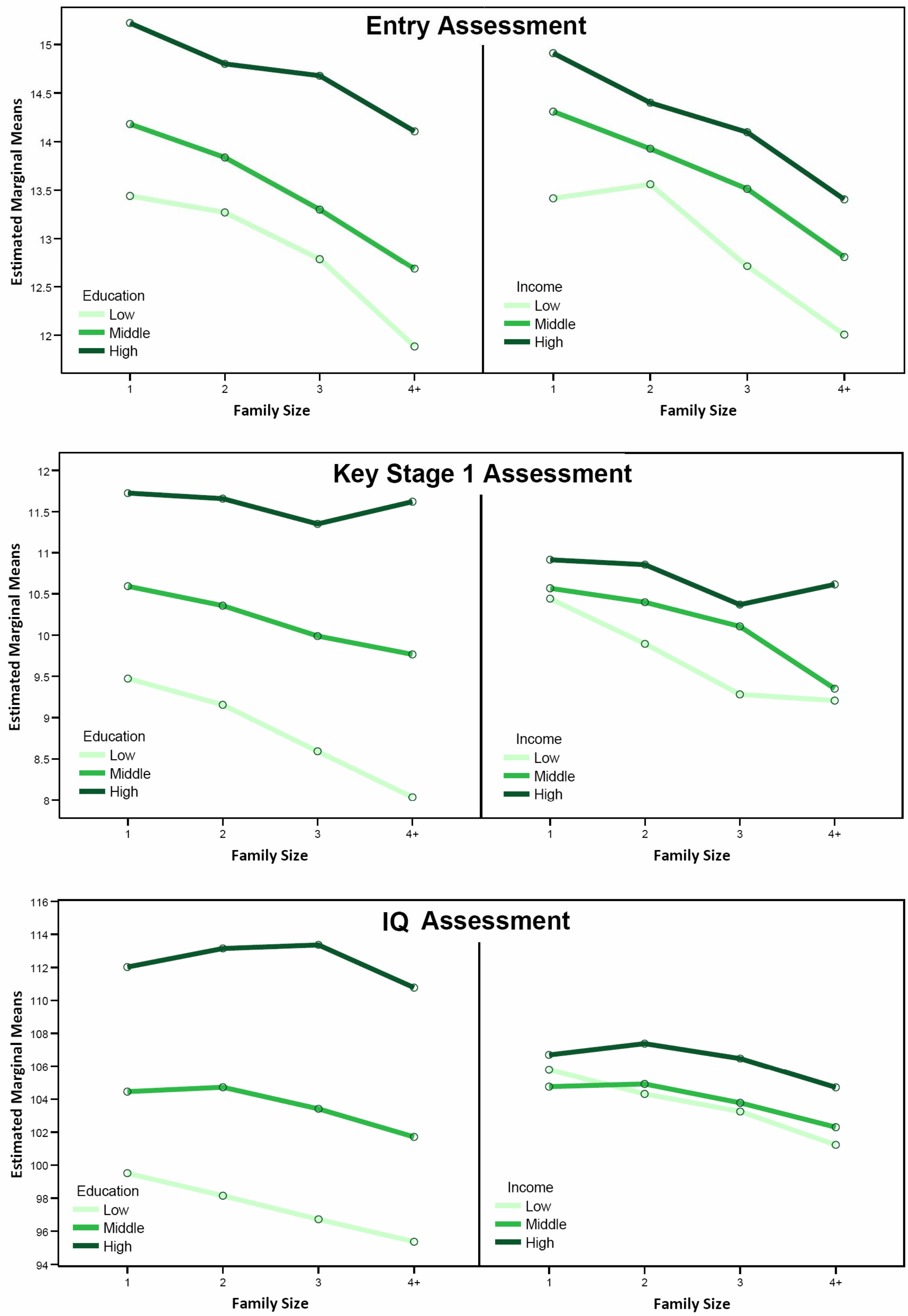

Figure 6.2 Interactions between family size and socio-economic status effects on cognitive development. *There is no indication that family size effects vary across socio-economic strata (see Table 6.5 for F statistics and Tables 6.2 – 6.4 for covariates included in final models).*

6.4 Discussion

In this chapter, I used ALSPAC data to explore the effects of family structure on performance in school examinations and an IQ test as markers for child cognitive development between the ages of four and eight years.

Family size and cognitive development

As expected from previous research (Downey 2001; Steelman et al. 2002) number of siblings was negatively related to measures of cognitive development at all ages considered (Figure 6.1). In comparison to other covariates, this effect was relatively large, particularly at the earliest assessment, with only maternal education consistently exerting more influence on cognitive development (Tables 6.2 – 6.4, and also Figure 6.2). Model fit declined as children grew older, despite consideration of the same independent variables in each model. This pattern may be accounted for by the increasing importance of school-level rather than family-level factors in cognitive development.

I find no evidence that, as predicted from quantity-quality trade-off models (Downey 1995), that the addition of siblings is most costly in one-child families. This result is also in agreement with prior research (Blake 1989; Downey 2001). Blake (1989) suggests that this can be explained if children in one-child families are often disadvantaged in others ways which go unmeasured. Modern populations tend toward a strong two child norm (Carey and Lopreato 1995). Thus, parents which stop at the production of one child may be less likely to be doing so by 'choice' and more likely because of intervening factors such as problems with first child or relationship dissatisfaction. While the argument for this hypothesis is quite logical, it does not fit well with the findings on parental time investments (Chapter 3) and child height (Chapter 5). In both cases, trade-off effects followed the predicted 1/x pattern. An alternate explanation for this result is that levels of parental investment have threshold effects on cognitive development, with increasing family size from one to two children generally not as influential as increases beyond this point (Downey 1995; Downey 2001).

A division of both time and financial investments in offspring could be responsible for the negative effects of large family size. Research is accumulating on the importance of parenting practice in cognitive development (Downey 1995; Williams et al. 2002; Flouri and Buchanan 2004; Nettle 2008). Studies of the ALSPAC cohort have suggested that maternal and early childhood dietary quality may be important determinants of childhood cognitive development (Daniels et al. 2004). Downey (1995) is the only study, that I am aware of, to directly consider parental allocations of time and material resources to offspring as a mediator of family size effects. In this study of American families, invested resources explained one half of the effect of the sibship size effect on reading test scores and the entire effect on mathematics test scores and overall grades.

An alternative theory of family size effects, specific to cognitive development, has been presented by Zajonc and Markus (1975; Zajonc 2001). According to this model, cognitive development is determined by the overall intellectual environment of the family unit – calculated by averaging the intellectual levels of all family members. Thus, the addition of each child to the family automatically lowers the intellectual atmosphere of the household and leads to comparatively poor levels of cognitive development. Early-born children are also seen to be advantaged on average, because they experience at least some uninterrupted time with parents and a correspondingly sophisticated intellectual environment.

Birth order and cognitive development

Birth order effects are apparent in this study, with clear signs of a later-born disadvantage particularly as children get older. I was not able to estimate these effects with a longitudinal or within-family model. However, the results of a recent Norwegian study suggests the later-born disadvantage demonstrated here is unlikely to be spurious. Using both within-family and between-family data for Norwegian conscripts, Bjerkedal et al (2007) demonstrated that later-borns scored lower on IQ tests. Furthermore, the researchers found that the later-born disadvantage disappeared when older siblings were deceased, strongly indicating post-natal resource dilution as the principal mechanism behind birth order effects (Kristensen and Bjerkedal 2007). The authors suggest that previous within-family size studies may have failed to find birth order effects due to a reliance on relatively small samples, leading to low statistical power.

Sex of siblings and cognitive development

In all three measures of cognitive development considered here, brothers had larger negative impacts on performance in cognitive tests than sisters. This pattern is consistent with a parental bias in investment towards sons, making them more costly as siblings. It is unclear why the conclusions of previous studies on family sex composition effects have not always found this pattern (Steelman et al. 2002; Hopcroft 2004). Hopcroft (2004) has suggested that mixed findings are the result of failure to test for interaction effects between parental resources and the sex of offspring in line with the Trivers-Willard hypothesis (Trivers and Willard 1973). However, this proposal is not very helpful – as I outlined in the introduction (Chapter 1) post-natal biases in parental investment are not expected to follow a Trivers-Willard model (Keller et al. 2001). More plausibly, sibling sex effects may differ by the sex of the child, leading to disagreement between studies focused solely only males or females. Conley, (2000) for instance, has suggested relatively negative effects of opposite-sex siblings because they lead to gender-specific needs being unsatisfied within the household. Differences in the outcome measure under investigation may also be important because previous studies have focused almost exclusively on educational attainment rather than direct tests of cognitive development.

Paternal relatedness and cognitive development

I find no evidence that the presence of unrelated father-figures influenced cognitive development, even in the face of demonstrated negative effects on both paternal and maternal time allocation to childcare (Chapter 3). In contrast, Beller and Chung (1992) did find that step-fathers were associated with poor levels of educational attainment at later ages. Thus, it remains possible that negative effects may become apparent as children grow older.

Socio-economic status and family size trade-offs

Children in high socio-economic status families performed better on all cognitive tests, particularly when maternal education was high (see also: Gregg et al. 2008). Maternal employment did not influence cognitive development once adjusted for socio-economic measures. This result is supported by Gregg et al. (2005) who, in a more detailed treatment of this issue, found that maternal employment was generally associated with no negative effects on cognitive development in the ALSPAC sample.

Contrary to the common assumption of the family size literature on cognitive development (Phillips 1999), I find no evidence that high socio-economic status alleviates the negative impacts of large family size. Similar to the results on physical development (Chapter 5), I find no evidence that family size effects interact with either household income or maternal education (Figure 6.2)

Chapter 7. Mental Health

7.1 Introduction

The aim of this chapter is to model associations between family structure and childhood mental health in the ALSPAC sample. Assessments of mental health are based on the Strengths and Difficulties Questionnaire (SDQ), a recently developed instrument for assessing psychological morbidity in children (Goodman 1997; Goodman 2001). The SDQ is made up of a series of subscales representing the recognised key domains of mental health: conduct problems, emotional problems, hyperactivity and peer problems. The existing mental health literature has rarely been directed by economic or evolutionary models of family structure (Downey and Condron 2004). Where associations between family structure and mental health have been reported, effects have generally been estimated in cross-sectional models and with little or no consideration of potential socio-economic or demographic confounds. ALSPAC data offer an excellent opportunity to provide a more robust set of tests for family structure influences on childhood mental health.

Family size and mental health

Existing studies of the relationship between family size and mental health in childhood have revealed mixed results. The best data to date comes from two large national samples of UK families (Meltzer et al. 2000; Green et al. 2005). Meltzer et al. (2000) found that, controlling for a range of socio-economic indicators, large family size was associated with increased prevalence of mental health disorders. This effect was largely driven by an increase in conduct disorders, with no significant relationship detected with emotional or hyperactivity problems in multivariate models. However, in reanalysis of this data, adjusting for a wider range of covariates, Ford et al. (2004) found no independent effects of family size. Green et al. (2005) reported that large family size was not associated with the overall prevalence of mental disorders, but was associated with increased conduct and emotional problems. In this report, effect estimates were not adjusted for related socio-economic and demographic factors. Autistic spectrum disorders were also considered in this study, with no effect of family size detected. Using a distinct measure of peer-related mental health, Downey and Condron (2004) found that children in multiple child families were scored as having better social skills than only children in an American sample. This study, based on teacher ratings of child behaviour, adjusted the effects of family size for a range of socio-economic factors. A number of studies specifically considering the development of theory of mind have also reported that children in multiple child families tend to perform better for their age on theory of mind tasks (see Peterson 2000).

Birth order and mental health

None of the main childhood mental health studies have tested for the existence of birth order effects (Meltzer et al. 2000; Ford et al. 2004; Green et al. 2005). Downey and Condron (2004) reported no difference in the effects of older and younger siblings on social skills. Elliot (1992) summarizes a small number of studies of adult psychopathology which have suggested birth order effects on specific conditions such as alcoholism and anorexia nervosa. This research has generally been based solely on univariate associations and has reported mixed results. Elliot (1992) concludes these findings are impossible to interpret clearly in the face of a wide range of potential confounding factors.

Sex of siblings and mental health

Downey & Condron (2004) reported no differences in childhood social skills by sex of siblings. As far as I am aware, no other studies have considered whether or not family sex composition is related to mental health problems.

Paternal relatedness and mental health

The consequences of parental relationship status for childhood mental health have received more research attention (for review: McMunn et al. 2001). McMunn and colleagues present data on the SDQ adjusted for a wife range of socio-economic factors, providing some of the most relevant comparisons to this thesis. In a sample of UK families, they report relatively poor mental health in children of single mothers and children in step-families in comparison to 'intact families'. The effect of single motherhood was largely accounted for by socio-economic disadvantage. Children in step-families had significantly more mental health problems than children coresident with both biological parents, even after adjusting for socio-economic factors (see also: Dunn et al. 1998; Ford et al. 2004)

7.2 Data and Methods

7.2.1 Strengths and difficulties questionnaire

The SDQ measures four domains of poor mental health status, on separate scales with five items each: emotional problems, hyperactivity, conduct problems and peer problems (Goodman 1997; Goodman 2001). Responses to questions from the emotional problems, behavioural problems, hyperactivity and peer problems subscales are added to give a total difficulties score (TDS), with a range of 0-40. This can be used as a dimensional outcome measure of mental health problems (Goodman and Goodman in press). The SDQ was parentally assessed at three points over the study period available at four years, six years nine months and nine years. Table 7.1 provides descriptive data on the SDQ scores along each subscale. For the TDS there are 23,991 cases available for analysis on 9,826 individuals.

Table 7.1 Strengths and difficulties score

		Child Age		
		3y11m *n = 8,900*	*6y9m* *n = 7,891*	*9y0m* *n = 7295*
		Mean (Standard Deviation)		
Total Difficulties Score (TDS)		8.85 (4.54)	7.45 (4.74)	6.79 (4.90)
Components	Hyperactivity Score	3.95 (2.30)	3.38 (2.36)	2.94 (2.25)
	Emotional Score	1.44 (1.50)	1.50 (1.67)	1.50 (1.76)
	Conduct Score	1.95 (1.40)	1.60 (1.46)	1.27 (1.42)
	Peer Score	1.51 (1.48)	1.05 (1.41)	1.11 (1.49)

Note that these values refer to the sample available at each study wave. They should not be directly interpreted as evidence of change over time due to selective attrition.

Total N: TDS – 23,991 for 9,826 individuals; Hyperactivity Score – 24,019 for 9,826 individuals; Emotional Score – 24,020 for 9,828 individuals; Conduct Score– 24,046 for 9,829 individuals; Peer Score– 24,028 for 9,829 individuals.

7.2.2 Data analysis

The relationship between the independent variables and SDQ over the study period was examined using multivariate multi-level models (Chapter 2). I analyse each individual subscale of the SDQ separately to allow for the possibility that different aspects of mental health are influenced independently by family structure. In all analyses, I include a measure of maternal depressive symptomology (assessed by the Edinburgh Post-Natal Depression Score - Table 2.3). Dunn et al (1998) have previously shown this measure is associated with childhood mental health in the ALSPAC sample.

7.3 Results

7.3.1 Mental health over the study period

Unconditional growth models estimate overall relationships of each behavioural score with child age (linear functions are estimated only to keep models easy to compute and compare directly). For the TDS, initial status (i.e. at three years, 11 months) was estimated at 8.83 (*CI: 8.74 – 8.92, p<0.001*) decreasing at -0.40 units per year (*CI: -0.42 – -0.38, p<0.001*) indicating the prevalence of behavioural problems decreases as children age. This pattern was confirmed for all component measures of the TDS (Figure 7.1): Hyperactivity Score - initial status: 3.96 (*CI: 3.91 – 4.01, p<0.001*), rate of change: -0.19 (*CI: -0.20 – -0.18, p<0.001*); Emotional Score - initial status: 1.45 (*CI: 1.42 – 1.48, p<0.001*), rate of change: -0.01 (*CI: -0.02 – 0.00, p<0.005*); Conduct Score - initial status: 1.97 (*CI: 1.94 – 2.00, p<0.001*), rate of change: -0.13 (*CI: -0.14 – -0.12, p<0.001*); Peer Score - initial status: 1.46 (*CI: 1.43 – 1.49, p<0.001*), rate of change: -0.09 (*CI: -0.10 – -0.08, p<0.001*).

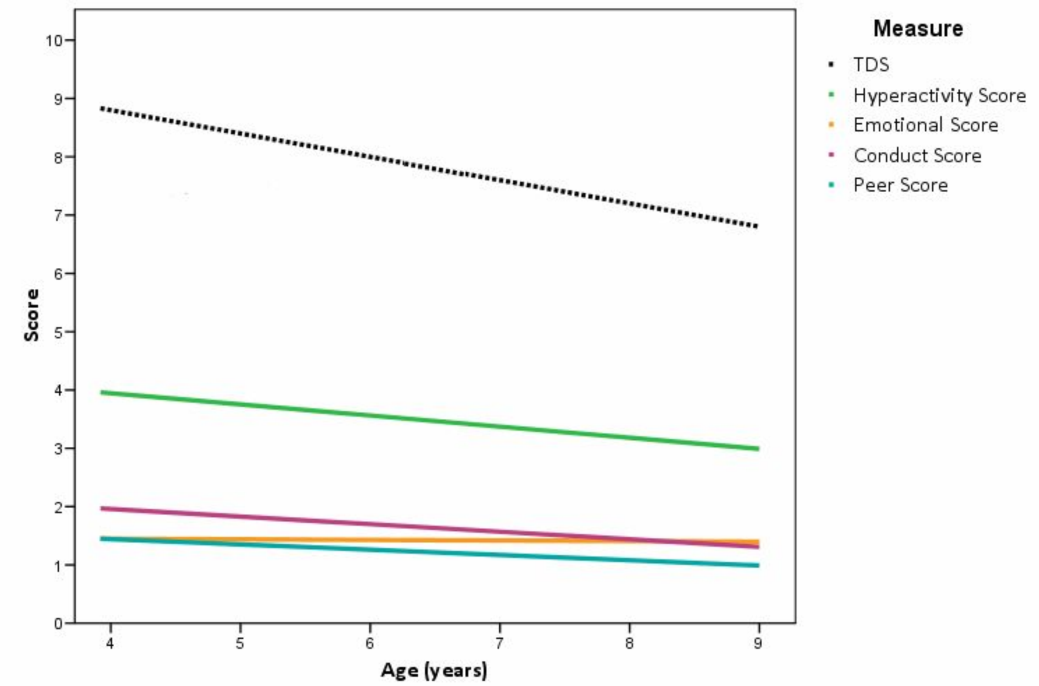

Figure 7.1 Change in behaviour scores over the study period (3.92 years – 9 years).

Univariate associations

Univariate associations between each independent variable and mental health score can be consulted in the Appendix (Tables A9 – A13). Independent variables were significantly associated with initial status more often than rate of change effects. Socio-economic measures, measures of social support and maternal emotional problems were significant in every model at high levels of significance. Family structure variables demonstrated a mixed pattern of association across measures.

Final multivariate models

Tables 7.2 and 7.6 summarise the final multivariate models for the TDS and each component measure of mental health. Pseudo R^2 statistics estimate the percentage of total variance explained by these models. In the TDS model 29% of within-person variance, 19% of between-person variance in initial status and 2% of between-person variance in rate of change is accounted for by the independent variables. Variance explained in the component measures of the TDS are similar in magnitude.

7.3.2 Family size

The effects of family size failed to show a consistent pattern across measures of mental health. For the TDS, significant main effects and rate of change effects were retained in the final model for some comparisons but these effects run in the opposite direction (Table 7.2). Similar mixed effects are found on the hyperactivity score (Table 7.3). Family sizes of two, and to a lesser extent three, were associated with more emotional problems compared to single child families. However, family sizes of four or five plus were not significantly different from only child families (Table 7.4). Conduct problems followed a clearer trade-off pattern with incremental increases in family size associated with more problems (Table 7.5). Peer problems followed the reverse pattern with increased family size associated with reduced problems, particularly in later childhood (Table 7.6). Figure 7.2 displays the mixed effects of family size graphically when only main effects are fit for the TDS and all component measures.

As there is little evidence of a trade-off between family size and childhood mental health (with the exception of conduct disorders), I do not consider how socio-economic measures interact with family size effects in this chapter.

Table 7.2 Main model: total difficulties score

			Initial Status (at 3y11m) Coefficient (B)	*95%CI*	Rate of Change (per year) Coefficient (B)	*95%CI*
Intercept†			10.64 ***	*10.12 -11.16*	-0.33 ***	*-0.42 – -0.29*
Family Structure	Family Size *(Ref: 1)*	2	0.38 **	*0.11 – 0. 65*	-0.14 **	*-0.23 – -0.05*
		3	0.15 ns	*-0.17 – 0.47*	-0.11 *	*-0.21 – -0.01*
		4	0.07 ns	*-0.39 – 0.53*	-0.12 ns	*-0.25 – 0.01*
		5 +	0.15 ns	*-0.55 – 0.85*	-0.18 ns	*-0.38 – 0.02*
	Sex of Child *(Ref: Male)*	Female	-0.84 ***	*-1.02 – -0.66*	-	-
	Mother's Age *(Ref:<25)*	25-29	-0.40 **	*-0.68 – -0.12*	-	-
		30-34	-0.55 ***	*-0.84 – -0.26*	-	-
		35+	-0.79 ***	*-1.15 – -0.43*	-	-
	Father's Age *(Ref: <25)*	25-29	-	-	-	-
		30-34	-	-	-	-
		35+	-	-	-	-
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.29 *	*0.02 – 0.56*	-	-
		Unrelated Male	0.50 **	*0.15 – 0.85*	-	-
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.40 **	*-0.68 – -0.12*	0.02 ns	*-0.05 – 0.09*
		A-level	-0.84 ***	*-1.14 – -0.54*	0.05 ns	*-0.03 – 0.13*
		Degree	-1.19 ***	*-1.54 – -0.84*	0.15 ***	*0.07 – 0.23*
	Family Income *(Ref: <£200 per week)*	£200-299	-0.07 ns	*-0.31 – 0.17*	-	-
		£300-399	-0.38 **	*-0.64 – -0.12*	-	-
		£400+	-0.46 ***	*-0.73 – -0.19*	-	-
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.37 ***	*-0.50 – -0.24*	-	-
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	-0.60 ***	*-0.89 – -0.31*	-	-
		Owned	-0.46 *	*-0.87 – -0.05*	-	-
Social Support	Social Network Score *(Ref: Low)*	Med	-0.34 ns	*-0.69 – 0.01*	-	-
		High	-0.79 ***	*-1.12 – -0.46*	-	-
	Social Support Score *(Ref: Low)*	Med	-0.59 ***	*-0.82 – -0.36*	-	-
		High	-1.17 ***	*-1.46 – -0.88*	-	-
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-	-
	Maternal Employment (*Ref: No*)	Yes	-	-	-	-
	Mat Emotional Problems (*Ref: Low*)	Med	1.05 ***	*0.84 – 1.26*	-	-
		High	2.35 ***	*2.12 – 2.58*	-	-

† -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.

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model Fit (Pseudo R^2): Within-Person (over time) – 0.29 ; Initial Status – 0.19; Rate of Change – 0.02
Final N – 16,526

Table 7.3 Main model: hyperactivity score

			Initial Status (at 3y11m) Coefficient (B)	95%CI	Rate of Change (per year) Coefficient (B)	95%CI
Intercept†			4.76 ***	*4.51 – 5.01*	-0.16 ***	*-0.21 – -0.11*
Family Structure	Family Size *(Ref: 1)*	2	0.27 ***	*0.14 – 0.40*	-0.09 ***	*-0.13 – -0.05*
		3	0.15 ns	*-0.01 – 0.31*	-0.08 ***	*-0.12 – -0.04*
		4	0.06 ns	*-0.16 – 0.28*	-0.08 **	*-0.14 – -0.02*
		5 +	-0.05 ns	*-0.39 – 0.29*	-0.05 ns	*-0.15 – -0.05*
	Sex of Child *(Ref: Male)*	Female	-0.55 ***	*-0.65 – -0.45*	-0.05 ***	*-0.07 – -0.03*
	Mother's Age *(Ref:<25)*	25-29	-0.17 *	*-0.33 – -0.01*	-0.04 ns	*-0.08 – 0.00*
		30-34	-0.29 ***	*-0.46 – -0.12*	-0.05 *	*-0.09 – -0.01*
		35+	-0.43 ***	*-0.63 – -0.23*	-0.04 ns	*-0.09 – 0.01*
	Father's Age *(Ref: <25)*	25-29	-	-	-	-
		30-34	-	-	-	-
		35+	-	-	-	-
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.04 ns	*-0.08 – 0.16*	-	-
		Unrelated Male	0.49 ***	*0.33 – 0.65*	-	-
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.22 **	*-0.36 – -0.08*	0.01 ns	*-0.02 – 0.04*
		A-level	-0.53 ***	*-0.68 – -0.38*	0.03 ns	*0.00 – 0.06*
		Degree	-0.99 ***	*-1.16 – -0.82*	0.11 ***	*0.07 – 0.15*
	Household Income *(Ref: <£200 per week)*	£200-299	-	-	-	-
		£300-399	-	-	-	-
		£400+	-	-	-	-
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.10 **	*-0.16 – -0.04*	-	-
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	-0.19 **	*-0.33 – -0.05*	-	-
		Owned	-0.19 ns	*-0.38 – -0.19*	-	-
Social Support	Social Network Score *(Ref: Low)*	Med	-0.18 *	*-0.35 – -0.01*	-	-
		High	-0.32 ***	*-0.48 – -0.16*	-	-
	Social Support Score *(Ref: Low)*	Med	-0.18 **	*-0.29 – -0.07*	-	-
		High	-0.46 ***	*-0.60 – 0.32*	-	-
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-	-
	Maternal Employment (*Ref: No*)	Yes	-	-	-	-
	Mat Emotional Problems (*Ref: Low*)	Med	0.40 ***	*0.30 – 0.50*	-	-
		High	0.81 ***	*0.70 – 0.92*	-	-

† -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.

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model Fit (Pseudo R^2): Within-Person (over time) – 0.27; Initial Status – 0.13; Rate of Change – 0.06

Final N – 18,512

Table 7.4 Main model: emotional problems score

			Initial Status (at 3y11m) Coefficient (B)	95%CI	Rate of Change (per year) Coefficient (B)	95%CI
Intercept†			1.27 ***	*1.12 – 1.42*	-0.01 *	*-0.02 – 0.00*
Family Structure	Family Size *(Ref: 1)*	2	0.17 ***	*0.09 – 0.25*	-	-
		3	0.10 *	*0.01 – 0.19*	-	-
		4	0.07 ns	*-0.05 – 0.19*	-	-
		5 +	0.13 ns	*-0.06 – 0.32*	-	-
	Sex of Child *(Ref: Male)*	Female	-	-	0.05 ***	*0.03 – 0.07*
	Mother's Age *(Ref:<25)*	25-29	-0.04 ns	-0.13 – 0.05	-	-
		30-34	-0.11 *	-0.20 – -0.02	-	-
		35+	-0.18 **	-0.29 – -0.07	-	-
	Father's Age *(Ref: <25)*	25-29	-	-	-	-
		30-34	-	-	-	-
		35+	-	-	-	-
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.18 ***	*-0.27 – -0.05*	-	-
		Unrelated Male	-0.05 ns	*-0.17 – 0.07*	-	-
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.05 ns	*-0.13 – 0.03*	-	-
		A-level	-0.10 *	*-0.18 – -0.02*	-	-
		Degree	0.06 ns	*-0.04 – 0.16*	-	-
	Household Income *(Ref: <£200 per week)*	£200-299	-	-	-	-
		£300-399	-	-	-	-
		£400+	-	-	-	-
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.08 ***	*-0.13 – -0.03*	-	-
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	-	-	-	-
		Owned	-	-	-	-
Social Support	Social Network Score *(Ref: Low)*	Med	-0.05 ns	*-0.16 – 0.06*	-	-
		High	-0.11 *	*-0.22 – 0.00*	-	-
	Social Support Score *(Ref: Low)*	Med	-0.10 **	*-0.17 – -0.03*	-	-
		High	-0.19 ***	*-0.28 – -0.10*	-	-
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-	-
	Maternal Employment (*Ref: No*)	Yes	-	-	-	-
	Mat Emotional Problems (*Ref: Low*)	Med	0.30 ***	*0.23 – 0.37*	-	-
		High	0.68 ***	*0.61 – 0.75*	-	-

† -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.

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model Fit (Pseudo R^2): Within-Person (over time) – 0.15 ; Initial Status – 0.09; Rate of Change – 0.03

Final N – 19.307

Table 7.5 Main model: conducts problems score

			Initial Status (at 3y11m) Coefficient (B)	*95%CI*	**Rate of Change (per year)** Coefficient (B)	*95%CI*
Intercept†			2.33 ***	*2.18 – 2.48*	-0.13 ***	*-0.14 – -0.12*
Family Structure	Family Size *(Ref: 1)*	2	0.15 ***	*0.08 – 0.22*	-	-
		3	0.19 ***	*0.11 – 0.27*	-	-
		4	0.19 ***	*0.08 – 0.30*	-	-
		5 +	0.24 ***	*0.08 – 0.40*	-	-
	Sex of Child *(Ref: Male)*	Female	-0.14 **	*-0.19 – -0.09*	-	-
	Mother's Age *(Ref:<25)*	25-29	-0.18 ***	*-0.27 – -0.09*	-	-
		30-34	-0.18 ***	*-0.29 – -0.07*	-	-
		35+	-0.26 ***	*-0.33 – -0.19*	-	-
	Father's Age *(Ref: <25)*	25-29	-	-	-	-
		30-34	-	-	-	-
		35+	-	-	-	-
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.09 *	*0.01 – 0.17*	-	-
		Unrelated Male	0.10 ns	*-0.01 – 0.21*	-	-
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.09 *	*-0.16 – -0.02*	-	-
		A-level	-0.13 *	*-0.21 – -0.05*	-	-
		Degree	-0.19 ***	*-0.28 – -0.01*	-	-
	Household Income *(Ref: <£200 per week)*	£200-299	-	-	-	-
		£300-399	-	-	-	-
		£400+	-	-	-	-
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.13 ***	*-0.17 – -0.09*	-	-
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	-0.19 ***	*-0.27 – -0.11*	-	-
		Owned	-0.14 *	*-0.24 – 0.04*	-	-
Social Support	Social Network Score *(Ref: Low)*	Med	-0.09 ns	*-0.19 – 0.01*	-	-
		High	-0.20 ***	*-0.30 – -0.10*	-	-
	Social Support Score *(Ref: Low)*	Med	-0.13 ***	*-0.20 – -0.06*	-	-
		High	-0.20 ***	*-0.28 – -0.12*	-	-
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-	-
	Maternal Employment (*Ref: No*)	Yes	-	-	-	-
	Mat Emotional Problems (*Ref: Low*)	Med	0.23 ***	*0.17 – 0.29*	-	-
		High	0.51 ***	*0.44 – 0.58*	-	-

† -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.

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Model Fit (Pseudo R^2): Within-Person (over time) – 0.19; Initial Status – 0.11; Rate of Change – 0.00
Final N – 17,757

Table 7.6 Main model: peer problems score

			Initial Status (at 3y11m) Coefficient (B)	*95%CI*	**Rate of Change (per year)** Coefficient (B)	*95%CI*
Intercept†			2.33 ***	*2.15 – 2.51*	-0.04 *	*-0.08 – 0.00*
Family Structure	Family Size *(Ref: 1)*	2	-0.21 ***	*-0.31 – -0.11*	-0.04 **	*-0.07 – -0.01*
		3	-0.23 ***	*-0.35 – -0.11*	-0.04 **	*-0.08 – 0.00*
		4	-0.19 ns	*-0.36 – -0.02*	-0.04 ns	*-0.09 – 0.01*
		5 +	0.07 ns	*-0.19 – 0.33*	-0.16 ***	*-0.24 – -0.08*
	Sex of Child *(Ref: Male)*	Female	-0.18 ***	*-0.24 – -0.12*	-	-
	Mother's Age *(Ref:<25)*	25-29	-0.10 *	*-0.19 – -0.01*	-	-
		30-34	-0.11 *	*-0.20 – -0.02*	-	-
		35+	-0.06 ns	*-0.18 – 0.06*	-	-
	Father's Age *(Ref: <25)*	25-29	-	-	-	-
		30-34	-	-	-	-
		35+	-	-	-	-
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.04 ns	*-0.08 – 0.16*	-	-
		Unrelated Male	0.08 ns	*-0.01 – 0.17*	-	-
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.14 **	*-0.24 – -0.04*	0.01 ns	*-0.02 – 0.04*
		A-level	-0.19 ***	*-0.03 – -0.08*	0.02 ns	*-0.03 – 0.05*
		Degree	-0.22 ***	*-0.34 – -0.10*	0.04 *	*0.01 – 0.07*
	Household Income *(Ref: <£200 per week)*	£200-299	-	-	-0.01 ns	*-0.04 – 0.02*
		£300-399	-	-	-0.02 ns	*-0.05 – 0.01*
		£400+	-	-	-0.03 *	*-0.06 – 0.00*
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.19 ***	*-0.29 – -0.09*	-	-
	Home Ownership *(Ref: Rented)*	Mortgaged/ Buying	-0.28 **	*-0.45 – -0.11*	-	-
		Owned	-0.21 ***	*-0.28 – -0.14*	0.03 **	*0.01 – 0.05*
Social Support	Social Network Score *(Ref: Low)*	Med	-0.11 *	*-0.22 – 0.00*	-	-
		High	-0.28 **	*-0.38 – -0.18*	-	-
	Social Support Score *(Ref: Low)*	Med	-0.17 ***	*-0.24 – -0.10*	-	-
		High	-0.28 ***	*-0.37 – -0.09*	-	-
Other	Ethnicity of Child *(Ref: White)*	Non-White	-	-	-	-
	Maternal Employment (*Ref: No*)	Yes	-0.08 **	*-0.13 – -0.03*	-	-
	Mat Emotional Problems (*Ref: Low*)	Med	0.16 ***	*0.09 – 0.23*	-	-
		High	0.37 ***	*0.30 – 0.44*	-	-

† -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.
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Model Fit (Pseudo R^2): Within-Person (over time) – 0.21; Initial Status – 0.13; Rate of Change – 0.02
Final N –15,066

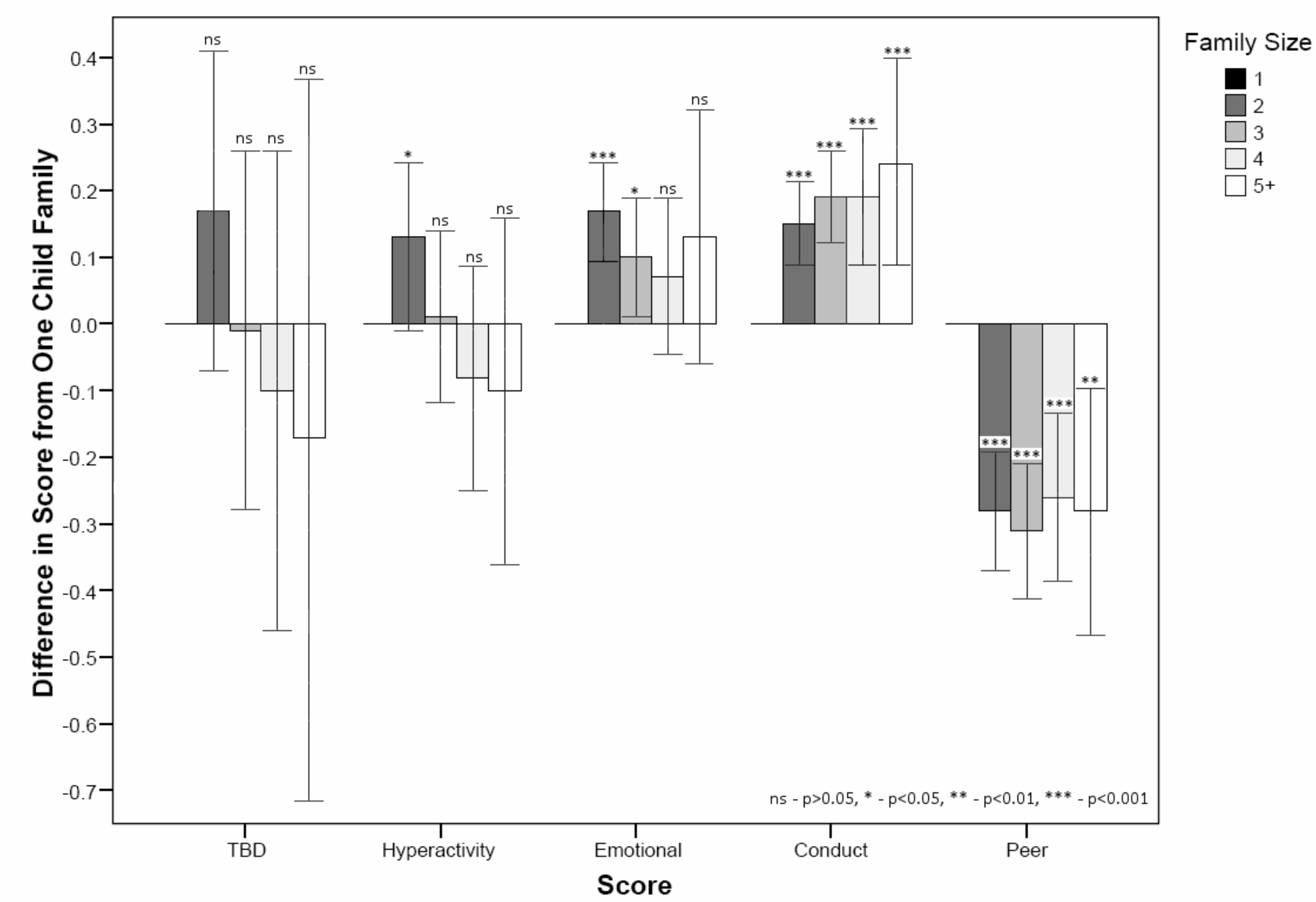

Figure 7.2 Family size and childhood mental health over the study period (main effects only). *Overall there is very little evidence for a trade-off between family size and childhood mental health. Only conduct problems were increased incrementally with family size, and peer problems are reduced in the presence of siblings. Estimated relationships are adjusted for a range of demographic and socio-economic measures (see Tables 7.2-7.6 for full models).*

7.3.3 Birth order

Analysing the effects of siblings on mental health in childhood by sibling age rather than total number provides a much clearer pattern of results across measures. For every measure the effects of older siblings are relatively negative compared to the effects of younger siblings, indicating a later-born *advantage* in childhood mental health (Table 7.7). In fact, in most cases older siblings are actually associated with reduced mental health problems, while younger siblings are associated with increased mental health problems. These effects are compared graphically in Figure 7.3 which shows main effects only. This implies that being born into a large family carries benefits, provided younger siblings are not later added to the family.

Table 7.7 Final mental health score models for sibling age configuration
(a) total difficulties score **(b)** hyperactivity score **(c)** emotional problems score **(d)** conduct problems score **(e)** peer problems score

			Initial Status (at 3y11m)		**Rate of Change (per year)**	
			Coefficient (B)	*95%CI*	Coefficient (B)	*95%CI*
(a) Total Difficulties Score	Number of older siblings *(Ref: 0)*	1	-0.12 ns	*-0.34 – 0.10*	-	-
		2	-0.67 ***	*-0.99 – -0.35*	-	-
		3+	-1.00 ***	*-1.57 – -0.43*	-	-
	Number of younger siblings *(Ref: 0)*	1	0.32 ***	*0.13 – 0.51*	-	-
		2	0.27 ns	*-0.01 – 0.55*	-	-
(b) Hyperactivity Score	Number of older siblings *(Ref: 0)*	1	0.25 ***	*0.14 – 0.36*	-0.09 ***	*-0.12 – -0.06*
		2	-0.19 *	*-0.36 – -0.02*	-0.02 ns	*-0.06 – 0.02*
		3+	-0.22 ns	*-0.51 – 0.07*	-0.03 ns	*-0.10 – 0.04*
	Number of younger siblings *(Ref: 0)*	1	-	-	-	-
		2+	-	-	-	-
(c) Emotional Problems Score	Number of older siblings *(Ref: 0)*	1	-0.10 **	*-0.17 – -0.03*	-	-
		2	-0.21 ***	*-0.31 – -0.11*	-	-
		3+	-0.25 **	*-0.43 – -0.07*	-	-
	Number of younger siblings *(Ref: 0)*	1	0.27 ***	*0.20 – 0.34*	-0.03 **	*-0.05 – -0.01*
		2+	0.32 ***	*0.19 – 0.45*	-0.05 **	*-0.09 – -0.01*
(d) Conduct Problems Score	Number of older siblings *(Ref: 0)*	1	0.11 ***	*0.04 – 0.18*	-	-
		2	0.10 ns	*0.00 – 0.20*	-	-
		3+	-0.11 ns	*-0.29 – 0.07*	-	-
	Number of younger siblings *(Ref: 0)*	1	0.10 **	*0.03 – 0.17*	0.03 ***	*0.01 – 0.05*
		2+	0.16 *	*0.03 – 0.29*	0.03 ns	*0.00 – 0.06*
(e) Peer Problems Score	Number of older siblings *(Ref: 0)*	1	-0.22 ***	*-0.29 – -0.15*	-	-
		2+	-0.20 ***	*-0.30 – -0.10*	-	-
		3+	-0.13 ns	*-0.32 – -0.06*	-	-
	Number of younger siblings *(Ref: 0)*	1	-0.12 ***	*-0.19 – -0.05*	-	-
		2+	-0.12 *	*-0.22 – -0.02*	-	-

Models contain control variables for additional aspects of family structure and parental resources (see Tables 7.2 – 7.7)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final Ns: TDS – 16,158; Hyperactivity – 18,702; Emotional – 15,536; Conduct – 15,536; Peer – 14,741;

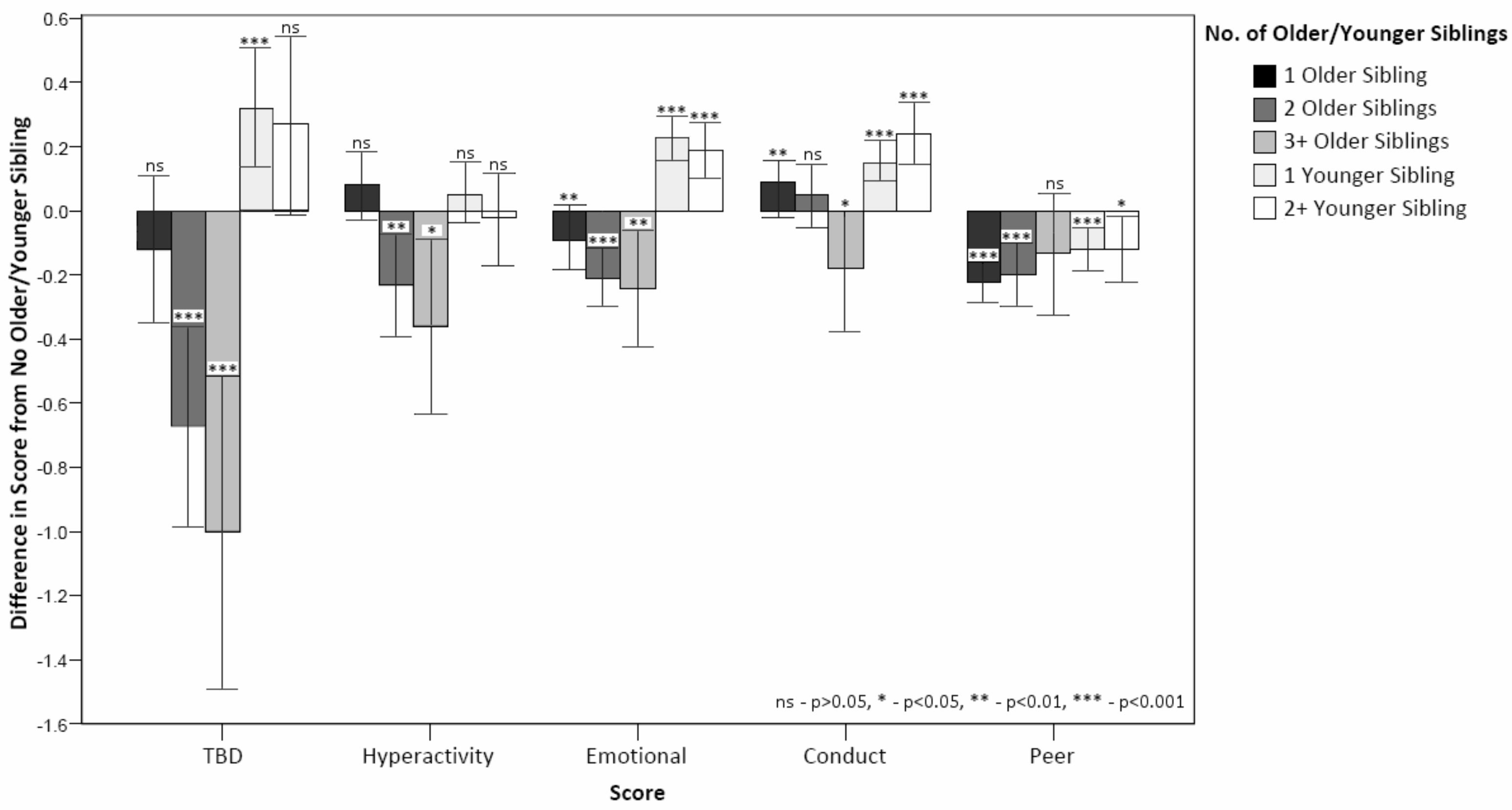

Figure 7.3 Number of older and younger siblings and mental health over the study period (main effects only). *Overall and for a majority of component measures, the presence of older siblings is associated with improved mental health. In contrast, the presence of younger siblings is usually associated with relatively poor mental health. Estimated relationships are adjusted for a range of demographic and socio-economic measures (see Tables 7.2-7.6 for full models).*

7.3.4 Sex of siblings

Boys tended to have more mental health problems than girls across the study period, represented both in the TDS (Table 7.2) and component scores for hyperactivity, conduct problems and peer problems (Tables 7.3, 7.5 and 7.6). However, girls were scored as having higher levels of emotional problems than boys (Table 7.4).

I analysed the effects of family sex composition by splitting sibling groups into brothers and sisters by older and younger siblings to take into account the strong effects of birth order over family size. There is no consistent pattern in the costs of brothers relative to sisters (Table 7.8).

7.3.5 Relatedness

In general, the absence of father figures and particularly the presence of unrelated father figures were associated with increased mental health problems relative to children with biological fathers recorded as present (See the TDS model, Table 7.2). However, for several of the individual component score of the TDS these effects failed to reach significance (Tables 7.3 – 7.6).

Table 7.8 Final mental health score models for sibling sex x age configuration (main effects only)
(a) total difficulties score **(b)** hyperactivity score **(c)** emotional problems score **(d)** conduct problems score **(e)** peer problems score

	Older Sibling Effects				**Younger Sibling Effects**			
			Coefficient (B)	*95%CI*			Coefficient (B)	*95%CI*
(a) Total Difficulties Score	No. older brothers	1	-0.32 **	*-0.55 – -0.09*	No. younger brothers	1	0.33 **	*0.11 – 0.55*
	(Ref: 0)	2+	-0.97 ***	*-1.42 – -0.52*	*(Ref: 0)*	2+	0.12 ns	*-0.42 – 0.66*
	No. of older sisters	1	-0.02 ns	*-0.25 – 0.21*	No. of younger sisters	1	0.25 *	*0.04 – 0.46*
	(Ref: 0)	2+	-0.80 **	*-1.28 – -0.48*	*(Ref: 0)*	2+	-0.04 ns	*-0.58 – 0.50*
(b) Hyperactivity Score	No. older brothers	1	-0.20 ***	*-0.31 – -0.09*	No. younger brothers	1	0.03 ns	*-0.07 – 0.13*
	(Ref: 0)	2+	-0.49 ***	*-0.71 – -0.27*	*(Ref: 0)*	2+	-0.16 ns	*-0.30 – -0.02*
	No. of older sisters	1	0.17 **	*0.06 – 0.28*	No. of younger sisters	1	-0.02 ns	*-0.12 – 0.08*
	(Ref: 0)	2+	-0.23 ns	*-0.46 – 0.00*	*(Ref: 0)*	2+	-0.11 ns	*-0.36 – 0.14*
(c) Emotional Problems Score	No. older brothers	1	-0.07 ns	*-0.15 – 0.00*	No. younger brothers	1	0.19 ***	*0.12 -0.26*
	(Ref: 0)	2+	-0.19 **	*-0.33 – -0.05*	*(Ref: 0)*	2+	0.11 ns	*-0.07 – 0.29*
	No. of older sisters	1	-0.08 *	*-0.15 – -0.01*	No. of younger sisters	1	0.24 ***	*0.17 – 0.31*
	(Ref: 0)	2+	-0.29 ***	*-0.44 – -0.14*	*(Ref: 0)*	2+	0.24 *	*0.06 – 0.42*
(d) Conduct Problems Score	No. older brothers	1	0.12 ***	*0.05 – 0.19*	No. younger brothers	1	0.18 ***	*0.11 – 0.25*
	(Ref: 0)	2+	-0.05 ns	*-0.18 – 0.08*	*(Ref: 0)*	2+	0.25 **	*0.09 – 0.41*
	No. of older sisters	1	0.06 ns	*-0.01 – 0.13*	No. of younger sisters	1	0.11 **	*0.05 – 0.17*
	(Ref: 0)	2+	-0.03 ns	*-0.17 – 0.11*	*(Ref: 0)*	2+	0.15 ns	*-0.01 – 0.31*
(e) Peer Problems Score	No. older brothers	1	-0.17 ***	*-0.25 – -0.09*	No. younger brothers	1	-0.07 ns	*-0.14 – 0.00*
	(Ref: 0)	2+	-0.17 *	*-0.32 – 0.02*	*(Ref: 0)*	2+	-0.22 *	*-0.40 – -0.04*
	No. of older sisters	1	-0.15 ***	*-0.23 – -0.07*	No. of younger sisters	1	-0.06 ns	*-0.13 – 0.01*
	(Ref: 0)	2+	-0.14 ns	*-0.30 – 0.02*	*(Ref: 0)*	2+	-0.12 ns	*-0.31 – 0.07*

Models contain control variables for additional aspects of family structure and parental resources (see Tables 7.2 – 7.7)
ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
Final Ns: TDS – 14,480; Hyperactivity – 16,150; Emotional – 16,827; Conduct – 15,519; Peer – 13,229

7.5.6 Parental resources

The TDS shows a clear socio-economic gradient across the study period. Improved maternal education, family income, home ownership status and neighbourhood quality all demonstrate independent negative effects on the prevalence of behavioural difficulties in childhood (Table 7.2). This pattern is shared by all component measures of the TDS, albeit to varying degrees with, for example, emotional problems showing relatively weak socio-economic effects (Tables 7.3 -7.6).

Higher levels of maternal social support and better social networks were also strongly associated with reduced mental health problems on all measures (Tables 7.2 – 7.6). Maternal employment failed to be retained in most final models. However, employed mothers reported that their children had slightly lower peer problems (Tables 7.2 – 7.6)

Children of older mothers had improved mental health on the TDS and all component scores (Tables 7.2 – 7.6). Children of mothers recording high levels of emotional problems in pregnancy had higher levels of behavioural difficulties on all measures. These effects were the most important predictor of childhood mental health considered (Tables 7.2 – 7.6).

7.4 Discussion

In this chapter I assessed the role of family structure in the incidence of child mental health problems between the ages of three and nine years in the ALSPAC sample.

Family size and childhood mental health

I find no consistent pattern between family size and childhood mental health (Figure 7.2). The only evidence for quantity-quality trade-off effects is on conduct problems (see also Meltzer et al. 2000). Peer problems were actually reduced in the presence of siblings. Other measures display mixed and largely non-significant associations with family size. This mix of patterns occurs despite of the existence of strong socio-economic gradients in mental health for all measures, even though large families face higher levels of economic hardship (Chapter 4). It is also generally considered that good parenting practice leads to positive child mental health outcomes (Dunn et al. 1998). So it is surprising that the presence of siblings do not reduce mental health through decreasing parental time investment (Chapter 3). These findings suggest that siblings offset their negative effects on parental resource dilution by other means.

Downey and Condron (2004) found that children in multiple child families had better social skills than only children, but found little difference between children within multiple child families by number of siblings. This pattern of results is very similar to the presented findings for peer problems in this study (Figure 7.2). Thus, there is some evidence that exposure to siblings have a positive influence on social maturation. Perhaps, by becoming accustom to sharing resources with at least other child, children with siblings learn how to navigate social relationships more easily (Downey and Condron 2004; see also Peterson et al. 2000).

Birth order and childhood mental health

Considering mental health problems by the relative age of siblings presents a much clearer pattern. Across all measures, with the exception of the conduct score, older siblings are associated with reduced mental health problems (Figure 7.3). These results reverse the pattern of later-born disadvantage found consistently across previous chapters of parental investment (Chapters 3 and 4) and other aspects of child development (Chapters 5 and 6). As far as I am aware this study is the first to show a broad trend of *later-born advantage* in childhood mental health. Previous research has either not tested for birth order effects, or has done so only with very poor consideration of potential confounding factors.

In the lack of previous research on this topic, and in direct contraction to the expectations of the theoretical framework of this thesis, it is difficult to provide a definitive explanation for this result. Nevertheless, the current findings suggest that social interaction with older siblings may hold important mental health benefits over and above their negative effects on parental resource dilution. In a recent study using a small subset of ALSPAC cohort, Grass et al. (2007) found that self-reported affectionate relationships between siblings had a protective effect on adjustment to stressful life events. Thus, older siblings may be more effective in providing a buffering role to social stress. Alternatively, the existence of older children may ensure that children are born into a household environment that is already socially prepared for family life and so more conducive to positive mental health outcomes, even though time and money are in shorter supply.

In contrast, the effects of younger siblings are largely negative, particularly for emotional and conduct problems (Figure 7.3). This result is consistent with a number of studies noting the difficulty of adjusting to a new sibling (e.g. Dunn and Munn 1985). It also gives some support for the psychologist Alfred Alder's theoretical model of birth order in which early born children are seen to suffer feelings of 'dethronement' with the arrival of younger siblings (see: Gates et al. 1986).

One limitation of the analyses presented in this chapter is that mental health scores are based on the parent ratings. Parent-rated measures of mental health may be open to perception biases in the presence of other children in the household which could potentially explain the pattern of results by birth order. For example, because children's mental health problems tend to decline with age (Figure 7.1), having older children in the house may bias the mother towards feeling her children in general have fewer problems. Future research should consider whether this birth order pattern holds up for independent ratings of mental health, such as teacher-rated scores.

Sex of siblings and childhood mental health

I find no evidence that family sex configuration influences childhood mental health. This finding matches the results on physical development (Chapter 5) and suggests any bias in parental investment towards male offspring is insufficient to cause a higher cost of brothers in terms of behavioural development.

Paternal relatedness and childhood mental health

I find that childhood mental health is negatively influenced by the presence of unrelated father-figures compared to biological fathers, even in the presence of strong controls for socio-economic status. This finding is consistent with prior literature on step-families (McMunn et al. 2001).

Paternal resources

Matching the results of previous studies (Dunn et al. 1998; McMunn et al. 2001; Ford et al. 2004; Green et al. 2005), and similar to measures of physical and cognitive development (Chapters 6 and 7), I find clear signs of a positive socio-economic gradient in child mental health. Strong social support and social networks of the parent were also protective of child mental health, as was low depressive symptomology of the mother (see also Dunn et al. 1998). These effects remained significant even after socio-economic and demographic variables had been taken into account and are consistently the strongest predictors of childhood mental health across all measures considered.

Chapter 8. Conclusions

8.1 Quantity-Quality Trade-offs in Modern Families

This thesis provides strong evidence that the modern human family is characterised by significant trade-offs between number of offspring and levels of parental investment. This conclusion stands for both time-based investments, as evidenced by maternal and paternal allocation to childcare activities (Chapter 3), and financial investments, as evidenced by maternal perceptions of economic hardship (Chapter 4). In both cases, trade-off functions represent powerful predictors of parental investment in relation to other covariates. For parental time allocation to childcare, family size was the most important independent variable considered. I also demonstrate that modern families face substantial trade-offs between quantity and 'quality' of offspring, measured in terms of child well-being. Children in larger families, all else being equal, exhibit relatively poor physical (Chapter 5) and cognitive development outcomes (Chapter 6). Mental health, however, was not consistently influenced by family size (Chapter 7).

Available evidence from related studies indicates that the costs of large family size persist well into adulthood. Cooney and Uhlenberg (1992) for example, have reported that, independent of socio-economic status, number of siblings is negatively related to a range of later investments including the direct receipt of money or gifts, giving advice in difficult decisions and direct assistance with childcare. Keister (2003) has also demonstrated that number of siblings is a strong determinant of the likelihood of receiving a trust fund or an inheritance. In developed countries, childhood height is strongly associated with adult height (Li et al. 2004). On average taller adults have improved health status and live longer (Waaler 1984; Davey Smith et al. 2000). Poor performance on cognitive tests in childhood is also predictive of adult educational qualifications and social mobility (Feinstein 2003;

Nettle 2003). Finally, and of particular relevance to evolutionary theories of modern low fertility, Keister shows that the combined effects of large family size on inheritance sums and potential for income generation are responsible for strong negative relationships between family size and adult wealth ownership (Keister 2003; Keister 2004). This implies that high fertility strategies in modern populations will have important negative consequences on the wealth of future generations. Analyses presented in this thesis and elsewhere confirm the existence of strong socioeconomic gradients in practically all measures of child development studied. As such the long term cost of high fertility in modern populations is likely to be substantial.

It is well known that physical development is closely associated with performance on cognitive measures and educational attainment throughout life, probably due to shared nutritional and stress-related pathways (Gunnel et al. 2005; Case and Paxson 2006). These aspects of parental investment may therefore be particularly open to dilution effects. However, one important limitation of this thesis is that I have not directly estimated the role of parental investments in mediating family size effects on child outcomes (in fact I know of only one study which has done this: Downey 1995). Further research into this area could answer many interesting questions, such as the relative importance of time versus financial allocations or of maternal versus paternal investments in the establishment of quantity-quality trade-offs. This line of research could also help to explain why, while trade-offs in investment follow the predicted 1/x resource dilution relationship as family size increases (Chapter 3, Downey 1995), the situation with regard to the costs on child development is less clear (Chapters 5 and 6). Defining associations between dimensions of parental investment and offspring outcomes can also inform questions about other aspects of human life history. Nettle (2008), for example, has shown that high levels of paternal involvement in childcare are associated with relatively high rewards on offspring cognitive development in high social class families. This effect could explain why paternal relative to maternal involvement in childcare tends to increase with socioeconomic status, a pattern also recognised in this study (Chapter 6).

8.2 Biased Parental Investment in Modern Families

8.2.1 Birth order

In review of the existing literature, no other aspect of family structure has been the source of more contradictory findings and academic controversy than birth order. Recurrent methodological issues continue to impede clear conclusions on its importance in parental investment and child development. Many studies reporting the most striking patterns have failed to adjust for well recognised confounding factors such as overall family size, socio-economic status, parental age or even the age of the individuals under study. Moreover, a number of subtle within-family or longitudinal studies have concluded that birth order fails to have any effect of real magnitude once between-family heterogeneity has been taken into account (for a recent discussion: Wichman et al. 2006). Consequently, research into birth order has now accumulated many critics and a general cynical regard in the social sciences (e.g. Townsend 1997; Rodgers 2000; Rodgers 2001; Steelman et al. 2002; Wichman et al. 2006). Somit et al. (1996) even go as far as to compare birth order research to a cyclically reappearing 'vampire', which neither contravening evidence nor rational argument have been able to exorcise from the literature.

The analyses presented in this thesis, which are methodologically sophisticated in contrast to much prior research, do not support the null hypothesis that meaningful birth order effects are absent in modern populations. Consistent with the life history theory predictions I laid out in the introduction (Chapter 1), I find clear indication of a later-born disadvantage in parental care (Chapter 3), and suggestive evidence for higher levels of household economic hardship for later-born children when families are very large (Chapter 4). Lower allocation of parental investment in high birth order children is also supported by Price (2008), who through detailed analysis of an American time-use survey further shows that such effects can be 'covert' as this bias is only revealed when investment by age of child is considered. Later-born children also exhibited lower levels of physical growth (Chapter 5) and reduced performance on school examinations and IQ tests (Chapter 6). ALSPAC measures did not enable a longitudinal analysis of cognitive development, but a recent large sample within-family study by Bjerkedal et al (2007) confirm that such effects are unlikely to be spurious. In contrast, childhood mental health bucked this trend, with relatively improved outcomes for children born into a large family, and relatively poor mental health for those who experienced the arrival of a younger sibling (Chapter 7).

The findings on mental health are particularly interesting for a number of reasons. Firstly, they provide one of the few empirical demonstrations that siblings can have a positive effect on child development in the context of modern society (see also: Downey and Condron 2004). That this effect occurs solely in the domain of mental health, rather than physical or cognitive development, suggests that the mechanism underlying this benefit is inherently social (as opposed to factors such as healthcare quality, diet and access to material resources). This result highlights the importance of considering multiple measures of child development and supports the largely folk hypothesis that siblings can play an important role in social maturation. Secondly, that this positive effect is reversed for children experiencing the arrival of one or more younger siblings is intriguing. One interpretation of this pattern would be to consider the behavioural problems of these children as a stress response to sudden arrival of a competitor for parental investment. More speculatively, it can also be suggested that these mental health problems are functionally similar to begging behaviour observed in animal families (Rodríguez-Gironés et al. 1996). Perhaps by displaying 'bad behaviour' older siblings are attempting to divert parental attention in their favour. Finally, that birth order effects on mental health run in the reverse direction to findings on physical and cognitive development adds further confidence that these relationships are not the by-product of unobserved socio-economic heterogeneity between families – all three measures of child well-being are positively associated with socioeconomic measures.

This thesis did not consider whether or not middle-born status has additional effects on parental investment, independent of ordinal position. Hertwig et al (2002) argue that middle-borns may be at a unique disadvantage because they are the less likely to obtain exclusivity in parental care, which is always granted to first-borns and potentially last-born offspring. Behavioural ecologists have largely ignored this hypothesis, I suspect because parental investment theory makes stronger predictions about relative age and ordinal position (Clutton-Brock 1991; Jeon 2008). Nevertheless, this idea merits empirical consideration. Existing research into this issue in modern populations has suffered particularly badly from methodological limitations (e.g. Salmon and Daly 1998; Rohde et al. 2003) because very large sample size is required to study middle-borns in the context of low fertility. ALSPAC data provide a good opportunity to evaluate this hypothesis in future research.

8.2.2 Sex-biased investment

This thesis documents mixed evidence for sex-biased parental investment in modern populations. Where a bias is detected, the pattern is consistent with the predicted parental favouritism of male offspring (Chapter 1). Overall parental allocations of care time are biased towards sons, particularly as children grow older (Chapter 3), and the presence of brothers relative to sisters was associated with relatively poor performance on cognitive tests at all time points considered (Chapters 6). I found no evidence that male children or children with relatively more male siblings influence the living standards experienced in childhood (Chapter 4). However, this does not rule out the possibility of differential allocation of material resources within the family. Recent studies have shown that elder brothers relative to elder sisters reduce birth weight (Nielsen et al. 2008; Rickard 2008). Despite this early disadvantage, I found no evidence that brothers relative to sisters have a detectable influence on post-natal growth (Chapter 5). Childhood mental health was also not consistently influenced by the sex of siblings (Chapter 7).

In summary, it appears that while some degree of male-biased investment occurs in the modern family, the extent of this bias is modest in comparison to the situation in many traditional populations (Chapter 1). Post-natal favouritism of sons is predicted when the fitness returns to investment in male offspring outweigh the returns to female offspring (Keller et al. 2001). In traditional human and animal populations, where individuals generally strive for high fertility, these conditions are often met as males are uniquely able to reach high fertility rates. However, in modern populations individuals no longer strive for high fertility, but seemingly high levels of parental investment. Since both sexes are relatively equal in their ability to transfer wealth across generations in comparison to their ability to translate resources into high reproductive success, an attenuation of male-biased investment in modern societies is consistent with parental investment theory.

Of course, more subtle forms of sex-biased parental investment than those measured in this thesis are also possible. The demonstration of higher marital stability in couples with relatively more sons than daughters is a particularly interesting example (Lundberg and Rose 2003; Dahl and Moretti 2004; Lundberg 2005). This effect is less detectable in more recent cohorts (Lundberg 2005: 347), consistent with the hypothesis that strategies of male-biased investment decline with the advance of modernisation. There is also evidence that voting behaviour is influenced by the sex of children, with the birth of daughters relative to sons associated with more left-wing and feminist attitudes, which bias future political and cultural conditions in their favour (Oswald and Powdthavee 2006; Washington 2008).

Sociological studies of the modern family are currently undergoing an increasing recognition of the importance of gender (Lundberg 2005). However, lacking a unifying theoretical framework, a large number of opposing hypotheses threatens to leave definitive conclusions in abeyance (Steelman et al. 2002: 259). Epidemiological frameworks have also struggled with the interpretation of sex differences in early physical development and mortality (Wells 2000). Human behavioural ecology offers a rich theoretical perspective to integrate and direct research.

8.2.3 Relatedness and paternal care

The thesis adds further confirmation to prior literature demonstrating lower levels of care when father figures are unrelated to children (Daly and Wilson 1985; Flinn 1988; Daly and Wilson 1998; Anderson et al. 1999; Marlowe 1999; Anderson et al. 2007). A negative effect of the presence of unrelated live-in father figures is observed on both father figure and maternal allocations of care time (Chapter 3). One important caveat, which applies to practically all prior literature on this topic, is that biological fathers may remain important investors in children and thus compensate for their absence. Two findings detract from this hypothesis. Firstly, in the absence of a new partner single mothers invest more time in offspring and record higher levels of economic hardship despite controls for household socio-economic profile (Chapter 4). This suggests that the continued contribution of absent fathers is not fully compensating. Secondly, the presence of unrelated father-figures was associated with relatively poor physical development (Chapter 5) and mental health (Chapter 7), although not cognitive outcomes (Chapter 6). As levels of economic hardship did not differ by relatedness of father-figures once socioeconomic measures had been taken into account (Chapter 4), this suggests negative effects of living in a step-family household originate primarily from time-based investment, rather than from a lack of material resources.

Downey (2001) has suggested that if siblings must divide the benefits of parental investment, as a flip-side to this we might also expect negative consequences of parental behaviour to be diluted. Thus, one potentially fruitful area for further research would be to test for interaction effects between family size and negative family factors such as the presence of unrelated males in the household. A larger number of children, for example, may place further demands on unrelated males to provide investments, or they may buffer each other from the stress associated with family disruption. I am aware of only one study that supports this hypothesis. Kempton et al. (1991) found that teacher's ratings of children who had experienced a divorce were more positive for those with a sibling than those without. A second research question that requires further empirical investigation is why do unrelated father figures invest in offspring at all? The most obvious answer from an evolutionary perspective is that such behaviour may secure future mating opportunities with the child's mother. Longitudinal data could be used to evaluate this hypothesis and test whether or not high-investing unrelated males are more likely to subsequently reproduce with the mother.

8.3 Disentangling Phenotypic Correlations

Studies of human family structure, unable to harness the power of the experimental method, face important methodological challenges in identifying and quantifying life history trade-offs and biases in parental investment. The analyses presented in this thesis, by using longitudinal methods, large samples sizes and considering an unusually wide range of relevant covariates, provide an unusual level of confidence that estimated relationships are independent of associated demographic and socio-economic heterogeneity between families. They also highlight some of the difficulties faced in disentangling the complex web of relationships between resources, family structure and development.

All measures of investment and child development considered showed substantial socio-economic gradients, confirming the central importance of resource constraints in the production of successful offspring. However, the precise indicators of socio-economic status retained in the final models varied across chapters. Measures of social support, independent of socio-economic indicators, were also important determinants of parental investment and child development schedules. Larger social networks and higher levels of social support enable parents to invest relatively more time in childcare (Chapter 3), relieve economic constraints on the family (Chapter 4) and are associated with improved cognitive (Chapter 6) and mental health outcomes in offspring (Chapter 7). These findings underline the fact that parental resources are multidimensional and that researchers of human life history face a significant challenge in controlling for all relevant factors.

In recent years, the applied human sciences have witnessed an increasing recognition of the multidimensional nature of 'wealth' (Braveman et al. 2005). The importance of this observation is taking more time to filter into the literature of human behavioural ecologists. This surely results from the fact that the heart of this literature remains focused on animal studies, where physical condition and social rank are easily observed and experiments used in place of correlational studies. Researchers overcoming this 'adaptive lag', however, are reaping the benefits of a fuller understanding of human behaviour. Von Rueden et al. (2008) for example, have challenged the common anthropological assumption that forager communities lacking significant material wealth or intergenerational inheritance can necessarily be considered egalitarian. Using data from the Bolivian Tsimane they document considerable variation in social status along separate dimensions of physical condition, skill in resource accumulation, social support and level of acculturation. Each of these measures will have their own relationship with fitness, which will further vary by socioecological context. Researchers of the modern human family have also demonstrated that relationships between socio-economic status and fertility may also depend on the measure used. Most recently, Nettle and Pollet (2008) have shown that while educational attainment is negatively related to fertility in the 1958 British Birth Cohort, the independent relationship with income is weakly positive, at least for men.

Life history theory has provided behavioural ecologists with a rich framework to study the effects of resource allocation on fertility and parental investment strategies. In the neighbouring social sciences this perspective is often reversed, with reproductive behaviour modelled as a determinant of parental resource budgets (Lundberg and Rose 2002; Iacovou and Berthoud 2006; Choi et al. 2007). Most obviously the birth of children restricts a mother's ability to generate income through employment. Conversely, a number of studies have shown that male work hours increase after the birth of children, at least within marriage. Human behavioural ecologists need to pay more attention to this research and consider its implications. Interestingly for example, recent studies have reported that paternal wages increase more following the birth of a son relative to a daughter (Lundberg and Rose 2002; Choi et al. 2007). Standard cross-sectional research methods leave such patterns unmeasured. Behavioural ecology emphasises the importance of phenotypic plasticity. Embracing new statistical methods is an essential step forward in modelling a dynamic world.

8.4 The Evolution of Modern Low Fertility

8.4.1 Does wealth reduce or increase quantity-quality trade-offs?

In the introduction, I outlined alternative evolutionary theories of modern fertility decline. Human behavioural ecologists argue that modern fertility behaviour is a direct response to the perceived or observed costs of raising socially and economically competitive offspring (Kaplan et al. 2002; Mace 2007; Mace 2008). As a logical extension to this argument, the socio-economic levelling in fertility associated with modernisation must reflect a selective increase in the magnitude of quantity-quality trade-offs in high socio-economic status families. Thus, as I have argued (Chapter 1), the unusual conditions of modernity reverse the standard life history prediction that increases in wealth will alleviate resource competition between offspring.

The thesis provides some empirical backing to this argument. Measured in terms of both time-based (Chapter 3) and financial investment (Chapter 4) offspring are subject to increased resource competition effects when mothers have above average education and when household income is relatively high, particularly when family size is large. This finding is also matched in research by the resource dilution theorist Douglas Downey, who finds larger family size effects on parental savings for educational expenses in high socio-economic status families (Downey 2001:499). Despite these differences, I find no evidence of socio-economic variation in quantity-quality trade-offs on physical (Chapter 5) and cognitive development (Chapter 6). However, two recent studies of adult wealth ownership suggest the consequences may become apparent in later life (Keister 2004; Grawe in press). In both of these studies, large sibships had a negative impact on adult wealth when individuals were raised in wealthy families, but had little consequence for those born into relatively impoverished families. Grawe (in press) notes this pattern runs in direct contradiction to standard economic models of the family which have assumed increases in wealth reduce quantity-quality trade-offs, by relaxing the assumption of finite parental resources (Becker and Lewis 1973).

8.4.2 The coevolution of modern low fertility and extended childhood

Childhood is a decisive period in human life history. In traditional societies, levels of parental and alloparental investment received during this period can literally mean the difference between life and death (Sear and 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 et al. 2000). Anthropologists and historical demographers agree that cultural modernisation is associated with an '*extension in childhood'* (Stearns 2006: 139). Offspring remain dependent on parents longer, and parents invest more time and more resources in offspring, than ever before. Models of modern fertility decline based on changing social networks or novel contraceptive technologies can only regard the concurrence of this development with low fertility norms as coincidental. In contrast, this thesis demonstrates that a fall in fertility rates may also be interpreted as strategic shift from high fertility to high investment in offspring. Children growing up in small families reap clear advantages in parental care and early development outcomes which are further predictive of social and economic success in adulthood. Increases in socio-economic status within modern populations, and possibly between populations at varying levels of development (Desai 1995), only serve to exacerbate the benefits of fertility reduction on offspring success. While the adaptive significance of this new behavioural pattern remains difficult to evaluate in the absence of sufficient multigenerational data, parental investment models of modern fertility are fully supported by the current literature.

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Appendix. Univariate Associations

Table A.1 Univariate associations of each independent variable and the mother score

			Initial Status (at 1y6m) Coefficient (B)	**Rate of Change (per year)** Coefficient (B)
Family Structure	Family Size *(Ref: 1)*	2	-0.11 ***	0.01 ns
		3	-0.25 ***	0.01 ns
		4	-0.35 ***	0.02 *
		5 +	-0.34 ***	0.01 ns
	Number of Older Siblings *(Ref: 0)*	1	-0.27 ***	0.01 ns
		2	-0.34 ***	0.02 **
		3+	-0.49 ***	0.02 *
	Number of Younger Siblings *(Ref: 0)*	1	0.00 ns	0.01 ns
		2+	0.07 ns	-0.02 **
	Number of Brothers *(Ref: 0)*	1	-0.10 ***	0.01 *
		2	-0.29 ***	0.03 ***
		3 +	-0.38 ***	0.03 ns
	Number of Sisters *(Ref: 0)*	1	-0.06 ***	0.00 ns
		2	-0.20 ***	0.00 ns
		3 +	-0.38 ***	0.01 ns
	Sex of Child *(Ref: Male)*	Female	0.06 **	0.00 ns
	Mother's Age *(Ref:<25)*	25-29	0.09 ***	-0.02 ***
		30-34	0.10 ***	-0.03 ***
		35+	0.07 *	-0.03 ***
	Father's Age *(Ref: <25)*	25-29	0.07 *	-0.01
		30-34	0.11 **	-0.02 **
		35+	0.10 **	-0.02 **
	Father Figure Status *(Ref: Presence)*	Mother Alone	-0.01 ns	0.01 ns
		Unrelated Male	-0.20 **	0.03 *
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	0.16 ***	-0.02 ***
		A-level	0.36 ***	-0.04 ***
		Degree	0.31 ***	-0.06 ***
	Household Income *(Ref: <£200 per week)*	£200-299	0.08 **	-0.02 **
		£300-399	0.13 ***	-0.03 **
		£400+	0.20 ***	-0.03 ***
	Neighbourhood *(Ref: <V. Good)*	V. Good	0.04 *	0.00 ns
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	0.20 ***	-0.04 ***
		Owned Outright	0.33 ***	-0.06 ***
Social Support	Social Network Score *(Ref: Low)*	Med	0.25 ***	-0.02 **
		High	0.48 ***	-0.03 ***
	Social Support Score *(Ref: Low)*	Med	0.19 ***	-0.01 *
		High	0.34 ***	-0.01 ns
Other	Ethnicity of Child *(Ref: White)*	Non-White	-0.06 ns	0.00 ns
	Maternal Employment (Ref: No)	Yes	-0.01 ns	-0.00 ns

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
All models include a constant term, age terms, and question style and reference variables.

Table A.2 Univariate associations of each independent variable and the partner score

			Initial Status (at 1y6m) Coefficient (B)	**Rate of Change (per year)** Coefficient (B)
Family Structure	Family Size *(Ref: 1)*	2	-0.25 ***	0.06 ***
		3	-0.51 ***	0.08 ***
		4	-0.80 ***	0.12 ***
		5+	-0.88 ***	0.12 ***
	Number of Older Siblings *(Ref: 0)*	1	-0.59 ***	0.08 ***
		2	-0.92 ***	0.11 ***
		3+	-1.30 ***	0.14 ***
	Number of Younger Siblings *(Ref: 0)*	1	0.08 **	-0.02 ***
		2+	-0.09 ns	-0.01 ns
	Number of Brothers *(Ref: 0)*	1	-0.27 ***	0.04 ***
		2	-0.52 ***	0.09 ***
		3 +	-0.66 ***	0.07 *
	Number of Sisters *(Ref: 0)*	1	-0.17 ***	0.02 **
		2	-0.45 ***	0.04 ***
		3 +	-1.44 ***	0.19 ***
	Sex of Child *(Ref: Male)*	Female	0.00 ns	-0.04 ***
	Mother's Age *(Ref:<25)*	25-29	0.30 ***	-0.02 **
		30-34	0.26 ***	-0.03 **
		35+	0.12 ns	-0.02 ns
	Father's Age *(Ref: <25)*	25-29	0.32 ***	-0.02 ns
		30-34	0.32 ***	-0.02 ns
		35+	0.13 ns	-0.01 ns
	Father figure Status *(Ref: Biological Father)*	Mother Alone	N.A.	N.A.
		Unrelated Male	-0.41 ***	0.00 ns
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	0.33 ***	-0.03 ***
		A-level	0.69 ***	-0.07 ***
		Degree	0.89 ***	-0.11 ***
	Household Income *(Ref: <£200 per week)*	£200-299	0.29 ***	0.02 *
		£300-399	0.43 ***	0.01 ns
		£400+	0.49 ***	0.01 ns
	Neighbourhood *(Ref: <V. Good)*	V. Good	0.02 ns	0.02 ***
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	0.44 ***	0.00 ns
		Owned Outright	0.33 ***	-0.02 ns
Social Support	Social Network Score *(Ref: Low)*	Med	0.64 ***	-0.03 **
		High	1.09 ***	-0.06 ***
	Social Support Score *(Ref: Low)*	Med	0.66 ***	-0.04 ***
		High	0.99 ***	-0.05 ***
Other	Ethnicity of Child *(Ref: White)*	Non-White	-0.49 ***	0.03 ns
	Maternal Employment (Ref: No)	Yes	0.25 ***	-0.02 ***
	Mother Score	Continuous (0-10)	0.37 ***	-0.02 ns

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
All models include a constant term, age terms, and question style and reference variables.

Table A.3 Univariate associations of each independent variable and the economic hardship score

			Initial Status (at 0y 8m) Coefficient (B)	**Rate of Change (per year)** Coefficient (B)
Family Structure	Family Size *(Ref: 1)*	2	0.35 ***	-0.10 ***
		3	0.59 ***	-0.09 ***
		4	1.16 ***	-0.10 **
		5 +	1.63 ***	-0.14 **
	Number of Older Siblings *(Ref: 0)*	1	0.26 ***	-0.04 ***
		2	0.42 ***	-0.01 ns
		3+	1.56 ***	-0.03 ns
	Number of Younger Siblings *(Ref: 0)*	1	0.37 ***	-0.06 ***
		2	0.99 ***	-0.13 ***
		3+	0.89 **	-0.06
	Number of Brothers *(Ref:0)*	1	0.39 ***	-0.08 ***
		2+	0.62 ***	-0.05 *
	Number of Sisters *(Ref:0)*	1	0.24 ***	-0.03 **
		2+	0.69 ***	-0.03 *
	Sex of Child *(Ref: Male)*	Female	0.00	0.00 ns
	Mother's Age *(Ref:<25)*	25-29	-0.78 ***	-0.04 *
		30-34	-1.36 ***	0.01 ns
		35+	-1.31 ***	0.00 ns
	Father's Age *(Ref: <25)*	25-29	-0.80 ***	-0.05 *
		30-34	-1.52 ***	0.03 ns
		35+	-1.48 ***	0.03 ns
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	1.97 ***	0.15 ***
		Unrelated Male	0.54 *	0.03 ns
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.55 ***	-0.04 *
		A-level	-1.18 ***	-0.01ns
		Degree	-2.07 ***	0.05 **
	Household Income *(Ref: <£200 per week)*	£200-299	-1.73 ***	-0.21 ***
		£300-399	-2.74 ***	-0.22 ***
		£400+	-3.69 ***	-0.18 ***
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.52 ***	0.00 ns
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	-1.64 ***	-0.11 ***
		Owned Outright	-2.73 ***	0.27 ***
Social Support	Social Network Score *(Ref: Low)*	23-25 (Med)	-1.35 ***	0.03 ns
		26+ (High)	-1.98 ***	0.03 ns
	Social Support Score *(Ref: Low)*	19-22 (Med)	-1.21 ***	0.05 ***
		23+ (High)	-1.68 ***	0.07 ***
Other	Ethnicity of Child *(Ref: White)*	Non-White	0.89 ***	0.02 ns
	Maternal Employment *(Ref: No)*	Yes	-0.45 ***	-0.03 *

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
All models include a constant term and time term.

Table A.4 Univariate associations of each independent variable and childhood height in millimetres (Multi-level model)

			Initial Status (0y 0m) Coefficient (B)	**Rate of Change (per year)** Coefficient (B)
Family Structure	Family Size *(Ref: 1)*	2	-4.08 ***	-2.45 ***
		3	-4.91 ***	-2.63 ***
		4	-6.80 ***	-2.92 ***
		5 +	-6.06 ***	-4.06 ***
	Number of Older Siblings *(Ref: 0)*	1	-1.95 ***	-0.26 ns
		2	-2.32 **	-0.92 ***
		3+	-3.48 **	-1.23 **
	Number of Younger Siblings † *(Ref: 0)*	1	-19.22 ***	1.79 ***
		2+	-17.71 ***	1.06 **
	Number of Brothers *(Ref: 0)*	1	-4.90 ***	-0.67 ***
		2+	-3.64 ***	-0.97 ***
	Number of Sisters *(Ref: 0)*	1	-4.90 ***	-0.44 **
		2+	-3.92 ***	-0.77 **
	Sex of Child *(Ref: Male)*	Female	-14.90 ***	0.74 ***
	Mother's Age *(Ref:<25)*	25-29	2.97 ***	0.94 ***
		30-34	2.90 ***	1.59 ***
		35+	1.49 ns	1.80 ***
	Father's Age *(Ref: <25)*	25-29	0.99 ns	0.94 ***
		30-34	0.68 ns	1.49 ***
		35+	0.55 ns	1.49 ***
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	-4.35 ***	0.01 ns
		Unrelated Male	-13.20 ***	0.66 ns
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	3.07 ***	0.66 ***
		A-level	2.40 ***	1.21 ***
		Degree	5.01 ***	1.69 ***
	Household Income *(Ref: <£200 per week)*	£200-299	2.48 ***	0.25 ns
		£300-399	2.40 **	0.85 ns
		£400+	2.85 ***	1.94 ns
	Neighbourhood *(Ref: <V. Good)*	V. Good	1.01 **	-0.24 ns
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	4.86 ***	0.09 ns
		Owned Outright	4.27 **	0.36 ns
Social Support	Social Network Score *(Ref: Low)*	23-25 (Med)	-0.79 ns	0.30 ns
		26+ (High)	1.38 *	0.32 ns
	Social Support Score *(Ref: Low)*	19-22 (Med)	1.34 *	-0.04 ns
		23+ (High)	2.16 ***	-0.17 ns
Other	Ethnicity of Child *(Ref: White)*	Non-White	-4.41 ***	1.48 ***
	Mother's Height in cm	*Continuous*	0.98 ***	0.29 ***

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

† = initial status for this variable estimated at 1y 9m

All models include a constant term and time term.

N for each comparison is based on the maximum number of cases available for each variable (see

Table A.5 Univariate associations of each independent variable and Focus@9 height in millimetres (GLM)

			F Statistic	Simple Contrast (B)
Family Structure	Family Size *(Ref: 1)*	2	F (4,5666) = 5.74 ***	-10.36 **
		3		-14.89 ***
		4		-13.70 **
		5 +		-16.16 **
	Number of Older Siblings *(Ref: 0)*	1	F (3,6645) = 2.77 *	-3.82 *
		2		-5.37 *
		3+		1.85 ns
	Number of Younger Siblings *(Ref: 0)*	1	F (2,5451) = 3.79 *	-1.67 ns
		2+		-6.79 **
	Number of Brothers *(Ref: 0)*	1	F (2,4618) = 2.70 ns	-3.61 ns
		2+		-5.70 ns
	Number of Sisters *(Ref: 0)*	1	F (2,4618) = 3.89 *	-3.49 ns
		2+		-8.02 *
	Sex of Child *(Ref: Male)*	Female	F (1, 6745) = 11.04 **	-5.09 **
	Mother's Age *(Ref:<25)*	25-29	F (3, 6762) = 1.08 ns	0.41 ns
		30-34		2.97 ns
		35+		3.27 ns
	Father's Age *(Ref: <25)*	25-29	F (3, 6185) = 1.11 ns	4.47 ns
		30-34		5.54 ns
		35+		5.45 ns
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	F (2, 6311) = 1.56 ns	-4.51 ns
		Unrelated Male		-0.76 ns
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	F (3, 6492) = 3.64 *	-0.27 ns
		A-level		3.50 *
		Degree		6.58 *
	Household Income *(Ref: <£200 per week)*	£200-299	F (3, 5187) = 4.05 **	9.62 **
		£300-399		5.42 ns
		£400+		8.45 **
	Neighbourhood *(Ref: <V. Good)*	V. Good	F (1, 5822) = 1.73 ns	2.17 ns
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	F (2, 5738) = 4.72 **	8.37 **
		Owned Outright		6.75 ns
Social Support	Social Network Score *(Ref: Low)*	Med	F (2, 6493) = 0.98 ns	-0.05 ns
		High		-0.36 ns
	Social Support Score *(Ref: Low)*	Med	F (2, 6453) = 0.95 ns	-0.58 ns
		High		-0.58 ns
Other	Ethnicity of Child *(Ref: White)*	Non-White	F (1, 6383) = 2.97 ns	6.97 ns
	Age (weeks)	(continuous)	F (1, 6764) = 448.15 ***	0.93 ***

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Table A.6 Univariate associations of each independent variable and the entry assessment scores

			F Statistic	Simple Contrast (B)
Family Structure	Family Size *(Ref: 1)*	2 3 4 5 +	F(4, 6282) = 29.49 ***	-0.04 ns -0.63 *** -1.40 *** -1.68 ***
	Number of Older Siblings *(Ref: 0)*	1 2 3+	F(3, 8338) = 36.52 ***	-0.11 ns -0.68 *** -1.62 ***
	Number of Younger Siblings *(Ref: 0)*	1 2+	F(2, 6107) = 36.52 ***	0.13 ns -0.77 ***
	Number of Brothers *(Ref: 0)*	1 2 3 +	F(3, 5145) = 9.33 ***	-0.02 ns -0.57 ** -1.79 ***
	Number of Sisters *(Ref: 0)*	1 2 3 +	F(3, 5145) = 10.64 ***	-0.07 ns -0.60 ** -2.22 ***
	Sex of Child *(Ref: Male)*	Female	F(1, 8841) = 219.45 ***	1.02 ***
	Mother's Age *(Ref:<25)*	25-29 30-34 35+	F(3, 8872) = 89.16 ***	0.96 *** 1.44 *** 1.47 ***
	Father's Age *(Ref: <25)*	25-29 30-34 35+	F(3, 7318) = 45.68 ***	1.01 *** 1.32 *** 1.43 ***
	Father Figure Status *(Ref: Biological Father)*	Mother Alone Unrelated Male	F(2, 6708) = 25.90 ***	-0.98 *** -0.75 ***
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level A-level Degree	F(3, 7799) = 263.86 ***	1.28 *** 1.96 *** 3.24 ***
	Household Income *(Ref: <£200 per week)*	£200-299 £300-399 £400+	F(3, 5499) = 133.78 ***	0.91 *** 1.53 *** 2.27 ***
	Neighbourhood *(Ref: <V. Good)*	V. Good	F(1, 5749) = 51.30 ***	0.60 ***
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying Owned Outright	F(2, 5216) = 110.87 ***	1.76 *** 1.51 ***
Social Support	Social Network Score *(Ref: Low)*	Med High	F(2, 7809) = 79.61 ***	0.67 *** 1.09 ***
	Social Support Score *(Ref: Low)*	Med High	F(2, 7727) = 37.32 ***	0.49 *** 0.73 ***
Other	Ethnicity of Child *(Ref: White)*	Non-White	F(1, 7574) = 16.35 ***	-0.74 ***
	Maternal Employment *(Ref: No)*	Yes	F(1, 5440) = 42.36 ***	0.56 ***
	Age	(continuous)	F(1, 8874) = 849.61 ***	3.08 ***
	School Year *(Ref: 1995/1996)*	1996/1997 1997/1998	F(2, 8873) = 178.09 ***	0.71 *** 1.96 ***

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Table A.7 Univariate associations of each independent variable and the Key Stage 1 Assessment Scores

			F Statistic	Simple Contrast (B)
Family Structure	Family Size *(Ref: 1)*	2	F(4, 6568) = 16.12 ***	0.17 ns
		3		-0.29 ns
		4		-0.78 ***
		5 +		-1.46 ***
	Number of Older Siblings *(Ref: 0)*	1	F(3, 9850) = 44.58 ***	-0.19 *
		2		-0.88 ***
		3+		-1.80 ***
	Number of Younger Siblings *(Ref: 0)*	1	F(2, 6362) = 8.38 ***	0.35 ***
		2+		-0.42 ns
	Number of Brothers *(Ref: 0)*	1	F(3, 5461) = 2.78 *	-0.02 ns
		2		-0.29 ns
		3 +		-1.02 *
	Number of Sisters *(Ref: 0)*	1	F(3, 5461) = 4.92 **	-0.02 ns
		2		-0.21 ns
		3 +		-1.58 ***
	Sex of Child *(Ref: Male)*	Female	F(1, 10453) =185.21***	0.99***
	Mother's Age *(Ref:<25)*	25-29	F(3, 10491) = 133.03 ***	1.29 ***
		30-34		1.83 ***
		35+		1.93 ***
	Father's Age *(Ref: <25)*	25-29	F(3, 8666) = 63.71 ***	1.16 ***
		30-34		1.64 ***
		35+		1.73 ***
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	F(2, 7233) = 86.53 ***	-1.08 ***
		Unrelated Male		-1.00 ***
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	F(3, 9231) = 408.35 ***	1.86 ***
		A-level		2.51 ***
		Degree		4.00 ***
	Household Income *(Ref: <£200 per week)*	£200-299	F(3, 5690) = 134.01 ***	0.81 ***
		£300-399		1.54 ***
		£400+		2.44 ***
	Neighbourhood *(Ref: <V. Good)*	V. Good	F(1, 6819) = 71.76 ***	0.73 ***
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	F(2, 6250) = 170.52 ***	2.27 ***
		Owned Outright		1.77 ***
Social Support	Social Network Score *(Ref: Low)*	Med	F(2, 9225) = 102.66 ***	0.86 ***
		High		1.28 ***
	Social Support Score *(Ref: Low)*	Med	F(2, 9133) = 56.94 ***	0.73 ***
		High		0.91 ***
Other	Ethnicity of Child *(Ref: White)*	Non-White	F(1,8972) = 5.02 *	-0.42 *
	Maternal Employment *(Ref: No)*	Yes	F(1, 6406) = 47.66 ***	0.62 ***
	Age	(continuous)	F(1, 10493) = 562.06 ***	2.72 ***
	School Year (Ref: 1997/1998)	1998/1999	F(2, 10492) = 194.88 ***	1.02 ***
		1999/2000		2.29 ***

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Table A.8 Univariate associations of each independent variable and the IQ Assessment scores

			F Statistic	Simple Contrast (B)
Family Structure	Family Size *(Ref: 1)*	2 3 4 5 +	F(4, 5387) = 7.39 ***	0.52 ns -0.98 ns -2.37 * -5.60 **
	Number of Older Siblings *(Ref: 0)*	1 2 3+	F(3, 6477) = 22.86 ***	-1.43 ** -4.16 *** -6.88 ***
	Number of Younger Siblings *(Ref: 0)*	1 2+	F(2, 5197) = 2.91 ***	0.97 * -0.32 ns
	Number of Brothers *(Ref: 0)*	1 2 3 +	F(3, 4443) = 3.20 *	-0.83 ns -2.38 ** -2.99 ns
	Number of Sisters *(Ref: 0)*	1 2 3 +	F(3, 4443) = 0.36 ns	0.15 ns 0.02 ns -2.12 ns
	Sex of Child *(Ref: Male)*	Female	F(1, 6560) =0.63 ns	-0.32 ns
	Mother's Age *(Ref:<25)*	25-29 30-34 35+	F(3, 6577) = 80.93 ***	4.43 *** 8.13 *** 9.92 ***
	Father's Age *(Ref: <25)*	25-29 30-34 35+	F(3, 6051) = 44.99 ***	5.37 *** 7.62 *** 9.38 ***
	Father Figure Status *(Ref: Biological Father)*	Mother Alone Unrelated Male	F(2, 6121) = 19.49 ***	-3.81 *** -3.05 ***
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level A-level Degree	F(3, 6329) = 339.49 ***	5.97 *** 10.99 *** 18.90 ***
	Household Income *(Ref: <£200 per week)*	£200-299 £300-399 £400+	F(3, 5125) = 106.11 ***	1.85 * 4.51 *** 10.06 ***
	Neighbourhood *(Ref: <V. Good)*	V. Good	F(1, 5526) = 70.79 ***	3.72 ***
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying Owned Outright	F(2, 5449) = 71.01 ***	8.48 *** 10.73 ***
Social Support	Social Network Score *(Ref: Low)*	Med High	F(2, 6333) = 41.89 ***	3.22 *** 4.45 ***
	Social Support Score *(Ref: Low)*	Med High	F(2, 6293) = 17.56 ***	1.79 *** 2.92 ***
Other	Ethnicity of Child *(Ref: White)*	Non-White	F(1, 6228) = 2.95 ns	-1.86 ns
	Maternal Employment (Ref: No)	Yes	F(1, 5187) = 0.58 ns	0.35 ns

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001

Table A.9 Univariate associations of each independent variable and the total difficulties score

			Initial Status (at 3y11m) Coefficient (B)	**Rate of Change (per year)** Coefficient (B)
Family Structure	Family Size *(Ref: 1)*	2	-0.25 ***	-0.05 ***
		3	-0.22 ***	-0.05 ***
		4	-0.13 ns	-0.06 **
		5 +	0.16 ns	-0.13 ***
	Number of Older Siblings *(Ref: 0)*	1	-0.11 ns	-0.02 *
		2	-0.03 ns	-0.01 ns
		3+	0.20 *	-0.02 ns
	Number of Younger Siblings *(Ref: 0)*	1	-0.05 ns	0.00 ns
		2+	-0.03 ns	0.01 ns
	Number of Brothers *(Ref: 0)*	1	-0.06 ns	-0.01 ns
		2+	-0.07 ns	-0.03 ns
	Number of Sisters *(Ref: 0)*	1	-0.11 ***	0.01 ns
		2+	0.01 ns	-0.02 ns
	Sex of Child *(Ref: Male)*	Female	-0.21 ***	0.01 ns
	Mother's Age *(Ref:<25)*	25-29	-0.32 ***	0.01 ns
		30-34	-0.37 ***	0.02 ns
		35+	-0.19 ***	-0.01 ns
	Father's Age *(Ref: <25)*	25-29	-0.34 ***	0.03 *
		30-34	-0.38 ***	0.04 *
		35+	-0.33 ***	0.03 *
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.34 ***	-0.01 ns
		Unrelated Male	0.33 ***	-0.02 ns
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.26 ***	0.01 ns
		A-level	-0.37 ***	0.02 ns
		Degree	-0.47 ***	0.04 **
	Household Income *(Ref: <£200 per week)*	£200-299	-0.27 ***	0.01 ns
		£300-399	-0.45 ***	0.03 ns
		£400+	-0.62 ***	0.03 *
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.26 ***	0.02 *
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	-0.47 ***	0.00 ns
		Owned Outright	-0.47 ***	0.02 ns
Social Support	Social Network Score *(Ref: Low)*	Med	-0.28 ***	-0.02 ns
		High	-0.64 ***	0.01 ns
	Social Support Score *(Ref: Low)*	Med	-0.38 ***	0.02 *
		High	-0.53 ***	0.03 *
Other	Ethnicity of Child *(Ref: White)*	Non-White	0.19 *	-0.01 ns
	Maternal Employment (Ref: No)	Yes	-0.16 ***	0.01 ns
	Mat Emotional Problems (*Ref: Low*)	Med	0.25 ***	-0.01 ns
		High	0.55 ***	-0.01 ns

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
All models include a constant and age term.

Table A.10 Univariate associations of each independent variable and the hyperactivity score

			Initial Status (at 3y11m) Coefficient (B)	**Rate of Change (per year)** Coefficient (B)
Family Structure	Family Size *(Ref: 1)*	2	0.18 **	-0.10 ***
		3	0.09 ns	-0.09 ***
		4	0.13 ns	-0.10 ***
		5 +	0.08 ns	-0.04 ns
	Number of Older Siblings *(Ref: 0)*	1	0.22 ***	-0.07 ***
		2	-0.14 ns	-0.02 ns
		3+	0.02 ns	-0.03 ns
	Number of Younger Siblings *(Ref: 0)*	1	-0.01 ns	0.02 ns
		2+	0.07 ns	-0.02 ns
	Number of Brothers *(Ref: 0)*	1	-0.08 ns	-0.03 *
		2+	-0.23 *	-0.01 ns
	Number of Sisters *(Ref: 0)*	1	0.14 **	-0.02 ns
		2+	0.10 ns	-0.03 ns
	Sex of Child *(Ref: Male)*	Female	-0.57 ***	-0.05 ***
	Mother's Age *(Ref:<25)*	25-29	-0.47 ***	0.03 *
		30-34	-0.73 ***	0.06 ***
		35+	-0.86 ***	0.07 **
	Father's Age *(Ref: <25)*	25-29	-0.26 **	-0.01 ns
		30-34	-0.47 ***	0.01 ns
		35+	-0.63 ***	0.03 ns
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.16 *	0.04 *
		Unrelated Male	0.67 ***	-0.02 ns
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.31 ***	0.00 ns
		A-level	-0.73 ***	0.04 *
		Degree	-1.28 ***	0.10 ***
	Household Income *(Ref: <£200 per week)*	£200-299	-0.19 **	-0.01 ns
		£300-399	-0.44 ***	-0.01 ns
		£400+	-0.58 ***	0.00 ns
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.18 ***	-0.02 ns
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	-0.54 ***	0.00 ns
		Owned Outright	-0.64 ***	0.03 ns
Social Support	Social Network Score *(Ref: Low)*	Med	-0.29 **	-0.03 ns
		High	-0.68 ***	-0.01 ns
	Social Support Score *(Ref: Low)*	Med	-0.39 ***	-0.01 ns
		High	-0.79 ***	0.01 ns
Other	Ethnicity of Child *(Ref: White)*	Non-White	0.08 ns	0.01 ns
	Maternal Employment (Ref: No)	Yes	-0.10 *	0.00 ns
	Mat Emotional Problems (*Ref: Low*)	Med	0.41 ***	0.01 ns
		High	0.99 ***	0.00 ns

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
All models include a constant and age term.

Table A.11 Univariate associations of each independent variable and the emotional problems score

			Initial Status (at 3y11m) Coefficient (B)	**Rate of Change (per year)** Coefficient (B)
Family Structure	Family Size *(Ref: 1)*	2	0.12 **	-0.02 ns
		3	0.05 ns	-0.02 ns
		4	0.06 ns	-0.03 ns
		5 +	0.08 ns	-0.02 ns
	Number of Older Siblings *(Ref: 0)*	1	-0.21 ***	0.00 ns
		2	-0.38 ***	-0.04 ns
		3+	-0.15 ns	-0.02 ns
	Number of Younger Siblings *(Ref: 0)*	1	0.27 ***	-0.02 *
		2+	0.32 ***	-0.04 **
	Number of Brothers *(Ref: 0)*	1	0.03 ns	-0.01 ns
		2+	-0.12 *	0.00 ns
	Number of Sisters *(Ref: 0)*	1	0.07 ns	0.00 ns
		2+	-0.07 ns	0.00 ns
	Sex of Child *(Ref: Male)*	Female	0.07 ns	0.04 ***
	Mother's Age *(Ref:<25)*	25-29	-0.12 **	-0.01 ns
		30-34	-0.20 ***	0.00 ns
		35+	-0.26 ***	0.00 ns
	Father's Age *(Ref: <25)*	25-29	-0.07 ns	-0.01 ns
		30-34	-0.14 *	0.00 ns
		35+	-0.18 **	0.00 ns
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.21 ***	0.02 ns
		Unrelated Male	0.19 *	-0.03 ns
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.09 *	-0.01 ns
		A-level	-0.15 **	-0.02 ns
		Degree	-0.04 ns	-0.02 ns
	Household Income *(Ref: <£200 per week)*	£200-299	-0.10 *	0.01 ns
		£300-399	-0.15 ***	-0.01 ns
		£400+	-0.21 ***	-0.03 ns
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.14 ***	-0.01 ns
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	-0.14 **	-0.02 ns
		Owned Outright	-0.11 ns	-0.01 ns
Social Support	Social Network Score *(Ref: Low)*	Med	-0.08 ns	-0.05 **
		High	-0.25 ***	-0.04 ns
	Social Support Score *(Ref: Low)*	Med	-0.25 ***	0.01 ns
		High	-0.36 ***	0.01 ns
Other	Ethnicity of Child *(Ref: White)*	Non-White	0.00 ns	0.00 ns
	Maternal Employment (Ref: No)	Yes	-0.06 *	0.00 ns
	Mat Emotional Problems (*Ref: Low*)	Med	0.29 ***	0.02 ns
		High	0.70 ***	0.03 *

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
All models include a constant and age term.

Table A.12 Univariate associations of each independent variable and the conduct problems score

			Initial Status (at 3y11m) Coefficient (B)	**Rate of Change (per year)** Coefficient (B)
Family Structure	Family Size *(Ref: 1)*	2	0.08 *	-0.01 ns
		3	0.11 *	0.00 ns
		4	0.12 ns	0.02 ns
		5 +	0.20 *	0.04 ns
	Number of Older Siblings *(Ref: 0)*	1	0.06 ns	-0.02 **
		2	0.04 ns	-0.03 *
		3+	0.04 ns	0.02 ns
	Number of Younger Siblings *(Ref: 0)*	1	0.02 ns	0.04 ***
		2+	0.12 *	0.03 *
	Number of Brothers *(Ref: 0)*	1	0.04 ns	0.01 ns
		2+	-0.02 ns	0.04 **
	Number of Sisters *(Ref: 0)*	1	0.03 ns	-0.01 ns
		2+	0.12 *	-0.03 ns
	Sex of Child *(Ref: Male)*	Female	-0.13 ***	-0.01 ns
	Mother's Age *(Ref:<25)*	25-29	-0.34 ***	0.00 ns
		30-34	-0.37 ***	0.00 ns
		35+	-0.36 ***	-0.02 ns
	Father's Age *(Ref: <25)*	25-29	-0.22 ***	-0.02 ns
		30-34	-0.33 ***	-0.01 ns
		35+	-0.28 ***	-0.02 ns
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.37 ***	-0.02 ns
		Unrelated Male	0.38 ***	-0.04 *
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.22 ***	-0.01 ns
		A-level	-0.32 ***	0.00 ns
		Degree	-0.43 ***	0.00 ns
	Household Income *(Ref: <£200 per week)*	£200-299	-0.26 ***	0.02 ns
		£300-399	-0.36 ***	0.00 ns
		£400+	-0.41 ***	0.00 ns
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.20 ***	-0.01 ns
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	-0.41 ***	-0.02 ns
		Owned Outright	-0.34 ***	-0.03 ns
Social Support	Social Network Score *(Ref: Low)*	Med	-0.26 ***	-0.01 ns
		High	-0.45 ***	-0.01 ns
	Social Support Score *(Ref: Low)*	Med	-0.27 ***	0.00 ns
		High	-0.42 ***	0.01 ns
Other	Ethnicity of Child *(Ref: White)*	Non-White	0.26 **	-0.03 ns
	Maternal Employment (Ref: No)	Yes	-0.06 *	0.00 ns
	Mat Emotional Problems *(Ref: Low)*	Med	0.28 ***	0.00 ns
		High	0.66 ***	-0.01 ns

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
All models include a constant and age term.

Table A.13 Univariate associations of each independent variable and the peer problems score

			Initial Status (at 3y11m) Coefficient (B)	**Rate of Change (per year)** Coefficient (B)
Family Structure	Family Size *(Ref: 1)*	2	-0.25 ***	-0.05 ***
		3	-0.22 ***	-0.05 ***
		4	-0.13 ns	-0.06 ***
		5 +	0.16 ns	-0.13 ***
	Number of Older Siblings *(Ref: 0)*	1	-0.11 **	-0.02 *
		2	-0.03 ns	-0.01 ns
		3+	0.20 *	-0.02 ns
	Number of Younger Siblings *(Ref: 0)*	1	-0.05 ns	0.00 ns
		2+	-0.03 ns	0.01 ns
	Number of Brothers *(Ref: 0)*	1	-0.06 ns	-0.01 ns
		2+	-0.07 ns	-0.03 ns
	Number of Sisters *(Ref: 0)*	1	-0.11 ***	0.01 ns
		2+	0.01 ns	-0.02 ns
	Sex of Child *(Ref: Male)*	Female	-0.21 ***	0.01 ns
	Mother's Age *(Ref:<25)*	25-29	-0.32 ***	0.01 ns
		30-34	-0.37 ***	0.02 ns
		35+	-0.19 ***	-0.01 ns
	Father's Age *(Ref: <25)*	25-29	-0.34 ***	0.03 *
		30-34	-0.38 ***	0.04 *
		35+	-0.33 ***	0.03 *
	Father Figure Status *(Ref: Biological Father)*	Mother Alone	0.34 ***	-0.01 ns
		Unrelated Male	0.33 ***	-0.02 ns
Socio-economic Measures	Mother's Education *(Ref: <O-level)*	O-level	-0.26 ***	0.01 ns
		A-level	-0.37 ***	0.02 ns
		Degree	-0.47 ***	0.04 **
	Household Income *(Ref: <£200 per week)*	£200-299	-0.27 ***	0.01 ns
		£300-399	-0.45 ***	0.03 ns
		£400+	-0.62 ***	0.03 *
	Neighbourhood *(Ref: <V. Good)*	V. Good	-0.26 ***	0.02 *
	Home Ownership *(Ref: Rented)*	Mortgaged/Buying	-0.47 ***	0.00 ns
		Owned Outright	-0.47 ***	0.02 ns
Social Support	Social Network Score *(Ref: Low)*	Med	-0.28 ***	-0.02 ns
		High	-0.64 ***	0.01 ns
	Social Support Score *(Ref: Low)*	Med	-0.38 ***	0.02 *
		High	-0.53 ***	0.03 *
Other	Ethnicity of Child *(Ref: White)*	Non-White	0.19 *	-0.01 ns
	Maternal Employment (Ref: No)	Yes	-0.16 ***	0.01 ns
	Mat Emotional Problems *(Ref: Low)*	Med	0.25 ***	-0.01 ns
		High	0.55 ***	-0.01 ns

ns – non significant, * - p<0.05, ** - p<0.01, *** - p<0.001
All models include a constant and age term.