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Dying young and living fast: variation in life history across English neighborhoods

Daniel Nettle
Centre for Behaviour and Evolution, Institute of Neuroscience, Newcastle University, Henry Wellcome Building, Framlington Place, Newcastle, NE2 4HH, UK

Where the expected reproductive life span is short, theory predicts that individuals should follow a "fast" life-history strategy of early reproduction, reduced investment in each offspring, and high reproductive rate. I apply this prediction to different neighborhood environments in contemporary England. There are substantial differences in the expectation of healthy life between the most deprived and most affluent neighborhoods. Using data from the Millennium Cohort Study ($n = 8660$ families), I show that in deprived neighborhoods compared with affluent ones, age at first birth is younger, birthweights are lower, and breastfeeding duration is shorter. There is also indirect evidence that reproductive rates are higher. Coresidence of a father figure is less common, and contact with maternal grandmothers is less frequent, though grandmaternal contact shows a curvilinear relationship with neighborhood quality. Children from deprived neighborhoods perform less well on a verbal cognitive assessment at age 5 years, and this deficit is partly mediated by parental age and investment variables. I suggest that fast life history is a comprehensible response, produced through phenotypic plasticity, to the ecological context of poverty, but one that entails specific costs to children. *Key words:* birthweight, breastfeeding, grandmothering, humans, life-history theory, parental investment, reproductive strategies. *[Behav Ecol]*

Humans exhibit extensive intraspecific variation in life-history parameters, such as age at first childbirth, total fertility rate, and per-offspring parental investment. Such variation may reflect adaptive responses, produced by phenotypic plasticity, to local ecological conditions (Quinlan 2007; Low et al. 2008; Nettle 2009). For example, theory predicts that as the expected duration of adult reproductive life span becomes shorter, individuals should reduce their age at first reproduction and increase their reproductive rate (Charnov 1991; Stearns 1992). Correspondingly, Low et al. (2008) showed that, across countries, female life expectancy is strongly but nonlinearly associated with age at first birth, with earlier onset of reproduction where mortality rates are high (see also Walker et al. 2006). Moreover, indicators of prevailing mortality risk, such as disease burdens, robustly predict total fertility rates across human societies (Guegan et al. 2001).

Increasing reproductive rate can generally only be achieved by reducing per-offspring investment. Thus, we should expect that parental investment variables will be inversely related to age at reproduction and reproductive rate and will be conditioned by the same ecological factors. In support of this view, Quinlan (2007) found that in societies living in harsh environments, such as where famine and warfare are frequent or disease burden high, weaning is earlier and parental involvement with each child is relatively reduced. Thus, high-mortality environments apparently produce a coordinated suite of behavioral responses, affecting the timing of reproductive events and the amount of investment in each child, a suite henceforth referred to as the "fast" life-history strategy (sensu Promislow and Harvey 1990; Bielby et al. 2007).

The studies discussed above investigated between-society variation in human life history, but there is also considerable variation within developed world populations, variation that may have similar ultimate causes (Chisholm 1993). For example, childbearing is shifted earlier in urban US neighborhoods, which have relatively high mortality and morbidity rates (Wilson and Daly 1997; Geronimus et al. 1999;), and breastfeeding and birthweights differ with socioeconomic position (Dubois and Girard 2006; Kohlhuber et al. 2008; Mortensen et al. 2008). Given that life expectancies are lower for families of lower socioeconomic position, this could be interpreted as a predictable shift toward a faster life-history strategy.

In this paper, I examine patterns of life history across different environments, represented by different levels of neighborhood socioeconomic deprivation, in contemporary England. I extend previous literature in 2 main ways. First, previous studies of the effect of the social environment on life-history strategies in developed populations have tended to focus on a single outcome, such as age at parenthood (Geronimus et al. 1999), birthweight (Dubois and Girard 2006), or caregiving behavior (Lawson and Mace 2009), whereas as the environment becomes harsher, a whole suite of behaviors should be expected to change in a coordinated manner. I thus examine how 6 life-history variables—age at first parenthood, birthweight, duration of breastfeeding, maternal and paternal involvement with the child, and grandmaternal contact frequency—all change across the range of environmental conditions.

Second, I explore the consequences as well as the triggers of fast life history. If life history is speeded up, investment in each child is reduced, and thus, there should be detectable detrimental effects on offspring. The role of parental investment as a mediator between socioeconomic conditions and child developmental outcomes is widely recognized (e.g., Guo and Harris 2000; Mortensen et al. 2002; Conger and Donnellan 2007; Nettle 2008). However, again, these studies tend to consider only one parental investment variable at a time, whereas here I can simultaneously consider the impact of all 6 parental life-history variables on child development.

The data for this study come from the Millennium Cohort Study (MCS, Hansen 2008). The MCS is a longitudinal

Address correspondence to D. Nettle. E-mail: daniel.nettle@ncl.ac.uk.
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investigation of a large, nationally representative sample of British babies born during 2000 and 2001. Data are available from the year after birth and 3 and 5 years of age and include parent interviews, anthropometric measures, and assessments of child cognitive development. The data can be linked to characteristics of the neighborhood where the family lived at the time of the child's birth. England is divided for census purposes into around 32 000 neighborhoods (called lower super output areas, mean population approximately 1500 persons), each of which has been assigned an Index of Multiple Deprivation (ODPM 2004). This measure is a composite of multiple variables relating to income, employment, health deprivation, education and skills, barriers to housing and services, crime, and the overall environment. The neighborhoods have been divided into deciles based on their Index of Multiple Deprivation. I use this 10-point scale as my measure of neighborhood quality.

It is important for the aims of this study to show that neighborhood quality does indeed affect life expectancy. Bajekal (2005) calculated life expectancies for each decile of English neighborhoods. He used a larger geographical unit than used in the MCS (the electoral ward, which has a mean population of 5500 instead of 1500) and an earlier version of the Index of Multiple Deprivation, and so the comparison is not exact, but the data are indicative. As Figure 1 shows, life expectancies increase modestly as neighborhood quality increases. However, variation in total life expectancy does not capture the inequalities in health prospects within developed populations well because the additional burden in deprived areas is mainly chronic poor health rather than mortality (Wood et al. 2006). Accordingly, the difference across the neighborhood types in the expectation of "healthy" life, which is the number of years of good health a person would expect at current mortality and morbidity rates, is much more dramatic than that in total life expectancy (Figure 1). Chronic poor health reduces the expected time available for reproduction and parenting, and its prevalence should be expected to affect life-history decisions just as mortality does (Ellis et al. 2009).

Given, then, large differences in healthy life expectancies across the different neighborhood types, we should expect that age at first childbearing, birthweight, duration of breastfeeding, and maternal involvement with the child should all increase as neighborhood quality increases. The interbirth interval should also increase. Unfortunately, exact interbirth intervals are not available in the data, but I use the growth of family size against maternal age to make inferences about reproductive rates. I also examine paternal involvement with the child. Though the literature on fast life-history strategies mainly focuses on mothers, harsh conditions will also affect male decisions, for example, about whether to invest in existing children or seek new reproductive opportunities. Finally, I examine how the frequency of contact with the maternal grandmother varies with neighborhood quality. Grandmaternal care is widespread and consequential in human societies (Sear and Mace 2008) and has previously been shown to have positive impacts on the children of working mothers in the MCS (Hansen and Hawkes 2009). Here, one might make predictions in either direction. In low-quality neighborhoods, grandmothers may have more grandchildren to allocate attention to, and thus, their per-grandchild investment might be lower. On the other hand, if fathers in low-quality neighborhoods are investing less, then maternal grandmothers may try to compensate. This would predict if anything a higher frequency of grandmaternal contact in low-quality neighborhoods.

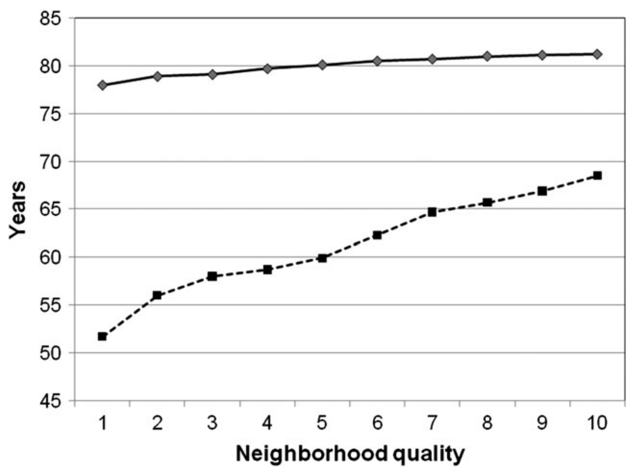

Figure 1
Female total life expectancy (solid line, diamonds) and healthy life expectancy (dashed line, squares), for deciles of English electoral neighborhoods classified by an Index of Multiple Deprivation. Data from Bajekal (2005).

The costs of fast parental life history would ideally be measured in terms of long-term reproductive value of the offspring (Nettle 2008; Kaptijn et al. 2010). However, the MCS cohort are still young children, and so this is not yet possible. Studies of the impact of parental investment in preindustrial societies use child survival as an outcome measure (Sear and Mace 2008), but in an affluent population with very low infant mortality rates, this is not appropriate. I therefore used a cognitive assessment of verbal ability at age 5 years as a measure of child development. Cognitive measures in childhood predict educational attainment and future social mobility in the British population (Nettle 2003), and childhood socioeconomic conditions and parental input have been shown to impact on cognitive development (Guo and Harris 2000; Bradley and Corwyn 2002; Mortensen et al. 2002; NICHD 2005; Conger and Donnellan 2007; Evans and Schamberg 2009). Thus, verbal ability may be a reasonable proxy for important aspects of development that are sensitive to parental investment and will impact on the child's reproductive value when he or she becomes an adult. I thus test for effects of parental life-history variables on verbal ability and also whether parental life-history variables mediate the relationship between neighborhood quality and child verbal ability.

In addition, I test for interaction effects between neighborhood quality and amount of parental investment in predicting child cognitive development. One hypothesis for why there is no positive relationship between available resources and family size in developed populations is that the effectiveness of parental investment increases with increasing socioeconomic position (Kaplan 1996; Kaplan et al. 1998). This leads to families of higher socioeconomic position increasing their investment in each child rather than increasing the number. A previous study using British data found an interaction effect consistent with this hypothesis, with fathers of higher socioeconomic position having a more dramatic impact on their children's cognitive development when they invested than fathers of lower socioeconomic position did (Nettle 2008). The current study provides an opportunity to replicate and extend this finding.

METHODS

I selected families from the MCS cohort who resided in a neighborhood in England (i.e., excluding Scotland, Wales, and Northern Ireland), which could be assigned to one of the deciles of neighborhood quality (using variable "aimdscoe"; 1 = lowest quality neighborhoods and 10 = highest quality). Neighborhood quality is treated as categorical except for the analyses predicting cognitive development for which it is treated as continuous. I additionally excluded any cases where the mother was not the main respondent of the 2001–2002 survey (fewer than 1% of cases) and all cases where the child's ethnicity was not classified as "White British" in variable "adm06e00." This is because the intention was to identify differences in behavior across social ecologies among people whose basic cultural background was similar, and including people of different ethnicities, who are nonrandomly distributed across neighborhoods, would complicate the interpretation. After these exclusions, there were 8660 families in the sample (619–1202 in each of the neighborhood qualities), although degrees of freedom for particular analyses are somewhat lower because of missing data, which are due to both nonresponse to particular items and sample attrition in the later interviews.

Measures of life-history strategy

The mean age of women at first birth for each neighborhood quality was found by computing mean maternal age for just those families where there were no older siblings reported (variable "adoths00" = 0). Birthweight in kilograms (BWT) was recorded at birth. The duration of breastfeeding in months (BFD) was derived from responses given by the mother in the parent interview at 1 year. Any responses given in days or weeks were converted into months, and responses of "not at all" or "less than one day" were taken as 0 months. If breastfeeding was still continuing at time of interview (exact baby age = 10–12 months), it was taken as 12 months. Maternal activities with the child (MATACT) was based on the parent interview at 5 years and was derived from variables asking about mother's frequency of 7 activities with the child (reading to the child, telling stories, doing music, drawing and painting, physically active play, indoor play with games or toys, and visits to the park or playground). These were all measured on the same scale of increasing frequency, and in the MCS cohort as a whole, all correlated positively with each other (Cronbach's $\alpha = 0.72$). I therefore took their mean as the MATACT score.

Paternal involvement with the child was assessed using the same 7 questions about activities with the child in the partner interview of 2006–2007. Note that these items reflect investment by the mother's current partner, which is most often the biological father of the child but in some cases is the stepfather. Again, all 7 items correlated positively with each other in the MCS cohort as a whole (Cronbach's $\alpha = 0.73$), and I took the mean of the 7 items as the PATINV score. There were 1330 families where, in 2006–2007, there was no partner of the mother eligible for interview. PATINV was set to 0 in these cases. Maternal grandmaternal contact frequency (MGM) was recorded by the mother's response to questioning in the 1-year interview on a scale of increasing frequency from "never" to "every day." Where the maternal grandmother was coresident, the variable was coded as "every day." Note that this variable is missing (rather than "never") if the maternal grandmother was not alive at time of interview, and so any variation in it is not due to differences in grandmaternal life expectancy.

Cognitive development

The cognitive development variable is an ability score derived from performance on the British Ability Scales naming vocabulary task (VOCAB, Elliott 1996), which was professionally administered in 2006–2007. This is a measure of verbal intellectual development. Two other British Ability Scales tasks, pattern construction and picture similarities, were also administered at this time. Performance on them was positively correlated to the naming vocabulary score ($r = 0.33$ and 0.35). I have repeated the analysis presented below with all 3 cognitive tasks rather than just naming vocabulary, with essentially similar results (data not shown), and do not consider the other tasks further here.

Analysis

I used general linear models to test for differences across neighborhood qualities in each of the life-history variables, first with no covariates and then where appropriate adjusting for sex of child, maternal age, and number of previous children. Tests of multivariate significance are based on Pillai's trace. To get some idea of reproductive rates, I performed a general linear model analysis of total number of children (2006–2007) by neighborhood quality, controlling for maternal age, and also tested for an interaction between neighborhood quality and maternal age in predicting family size, which would indicate that families grow faster in some neighborhood contexts than in others.

To examine the effects of parental strategy, I examined whether VOCAB is predicted by the parental life-history measures, both with and without control for neighborhood quality. I also test for interactions between the parental life-history measures and neighborhood quality, which if significant would indicate that neighborhood quality modifies the effectiveness of parental investment. Third, I used path analysis to examine the extent to which socioeconomic variation in VOCAB performance is explained by variation in parental life-history strategy.

RESULTS

Descriptive statistics for the main study variables are shown in Table 1.

Patterns of parental life history

For women with no previous children, MATAGE varies significantly across neighborhood qualities ($F_{9,3752} = 77.67$, $P < 0.001$). Figure 2 (first panel) shows the pattern, with age at first birth becoming later as neighborhoods become more affluent. The rest of the life-history variables (BWT, BFD, MATINV, PATINV, and MGM) are all aspects of parental investment in existing offspring, and they all should be expected to be reduced in the lower quality neighborhoods. To test this, I performed a multivariate general linear model with neighborhood quality and sex of child as factors, age of mother and number of previous children as covariates, and the 5 parental investment variables as the dependents. Overall, there was a significant main effect of neighborhood quality on the set of parental investment variables ($F_{45,23825} = 5.03$, $P < 0.001$). There are also main effects of mother's age ($F_{5,4761} = 107.46$, $P < 0.001$), number of previous children ($F_{5,4761} = 64.28$, $P < 0.001$), and sex of child ($F_{5,4761} = 11.62$, $P < 0.001$), but the neighborhood quality–by–sex of child interaction is not significant ($F_{45,23825} = 0.65$, ns). Table 2 presents the effects of each predictor on each parental investment variable separately.

Neighborhood quality significantly affects all the parental investment measures except for MATACT (Figure 2). Increasing neighborhood quality is associated with increased levels of BWT, BFD, and PATINV. The low level of PATINV in the lowest deciles is due to it being more likely that there is no partner of the mother (hence, PATINV = 0). Once zeroes are excluded, there is no effect of neighborhood quality on PATINV ($F_{9,5102} = 0.74$, ns). MGM shows a curvilinear relationship, highest in intermediate-quality neighborhoods but still has its absolute lowest levels in the lowest quality neighborhoods.

The effect of sex of child on parental investment overall was largely due to the higher BWT of boys though mothers also did slightly more activities with girls than with boys (Table 2).

Table 1
Descriptive statistics for the main variables considered in the study

Variable	MCS variable name(s)	Complete records	Mean (standard deviation)
Mother's age at child's birth (MATAGE, years)	admagb00	8658	28.59 (5.93)
BWT, kg	adbwgta0	8656	3.37 (0.58)
BFD duration (months)	Derived from ambfeva0, ambfeaa0, ambfeeda0, ambewa0, and ambefema0	8600	3.01 (3.91)
MATACT (1–6)	Derived from cmreofa0, cmsitsa0, cmplmua0, cmpamaa0, cmactia0, cmgamea0, and cmwalka0	7035	3.18 (0.71)
PATINV (0–6)	Derived from cpreofa0, cpsitsa0, cpplmua0, cppamaa0, cpactia0, cpgamea0, and cpwalka0	6434	2.29 (1.34)
MGM (1–7)	amsemo00	6333	5.26 (1.73)
Naming vocabulary ability score (VOCAB)	cdnvabil	6969	109.90 (14.64)
Sex of child	ahcsexa0	8660	Male = 4445, female = 4215
Number of older siblings (2000–2001)	From adtots00; NB includes twins of study child	8660	0.87 (0.99)
Number of children in household (2006–2007)	cdtots00	7036	2.32 (0.99)

Maternal age had a weak positive effect on BWT, a moderate positive effect on PATINV, and a substantial positive effect on BFD. The number of previous children had slight positive effects on BWT and on MGM but substantial negative effects on BFD, MATACT, and PATINV.

To test for differences in reproductive rate by neighborhood quality, I first used a general linear model to examine the effect of neighborhood quality on total number of children in the household by 2006–2007, with age of mother included as a covariate. There is a significant effect of neighborhood quality ($F_{9,7025} = 14.42$, $P < 0.001$). The estimated marginal means show that women in the lowest quality neighborhoods have slightly larger family sizes for their age (Figure 3). Next, I added an interaction term between neighborhood quality and maternal age. The interaction is significant ($F_{9,7016} = 2.68$, $P < 0.01$), and the parameter estimates indicate that the effect of maternal age on family size is stronger in the lower quality neighborhoods ($B = 0.28$ for decile 1 and $B = 0.16$ for decile 2 against 0 for decile 10). This implies that families grow faster where neighborhood quality is low.

Effects of parental life history on child cognitive development

In a general linear model with VOCAB score as the dependent variable, sex of child as a factor, and 6 parental life-history variables as covariates (MATAGE, BWT, BFD, MATACT, PATINV, and MGM), there are significant effects of all 6 life-history variables on VOCAB (all P's <0.05). The parameter estimates are $B = 0.30$ for MATAGE, $B = 0.84$ for BWT, $B = 0.41$ for BFD, $B = 1.51$ for MATACT, $B = 1.26$ for PATINV, and $B = 0.33$ for MGM. In a second model, I additionally included neighborhood quality as a covariate. There is a significant effect of neighborhood quality on VOCAB score ($F_{1,4731} = 77.97$, $P < 0.001$), but the effects of the life-history variables all remain significant with similar parameter estimates (data not shown). Next, I added interaction effects between each of the parental investment variables and neighborhood quality to the model. The only interaction effect that was significant at $P < 0.05$ was between neighborhood context and MGM. The parameter for this effect was negative ($B = -0.14$), indicating that maternal grandmother involvement has less of an effect on VOCAB as neighborhood quality increases.

Finally, I performed a path analysis using multiple regression to examine whether parental life-history variables mediated the relationship between neighborhood quality and VOCAB score. The results are shown in Figure 3. The unmediated β coefficient for VOCAB score on neighborhood quality is 0.21. Including the parental life-history variables reduces this to 0.13, and there are significant (albeit weak) mediation pathways via MATAGE, BFD, PATINV, and MGM. Thus, part of the reason that children from higher quality neighborhoods perform better at this cognitive task is that they have older mothers, receive more breastfeeding, receive more paternal involvement, and receive more input from their maternal grandmothers.

DISCUSSION

Key findings

Life-history strategies differ quite markedly across groups of English neighborhoods defined by different levels of socioeconomic deprivation. In the lowest quality neighborhoods, mothers begin childbearing younger, birthweights are lower, breastfeeding is shorter, father figures are more likely to be absent, and maternal grandmothers have less frequent contact with children, compared with affluent neighborhoods. The only variables that showed no patterning across the different neighborhood qualities were activities such as reading and playing engaged in by the mother or by the father figure if present. These results are not attributable to differences in ethnicity. Nor are the differences in the parental investment variables reducible to maternal age or the number of previous children because they persist when these factors are adjusted for. Related to the reduced investment in each child, families grow somewhat faster in low-quality neighborhoods, although these differences are modest compared with the substantial neighborhood differences in investment variables, such as breastfeeding. Thus, people in most disadvantaged areas are clearly following "faster" typical life-history strategies, as life-history theory would predict given the higher rates of mortality

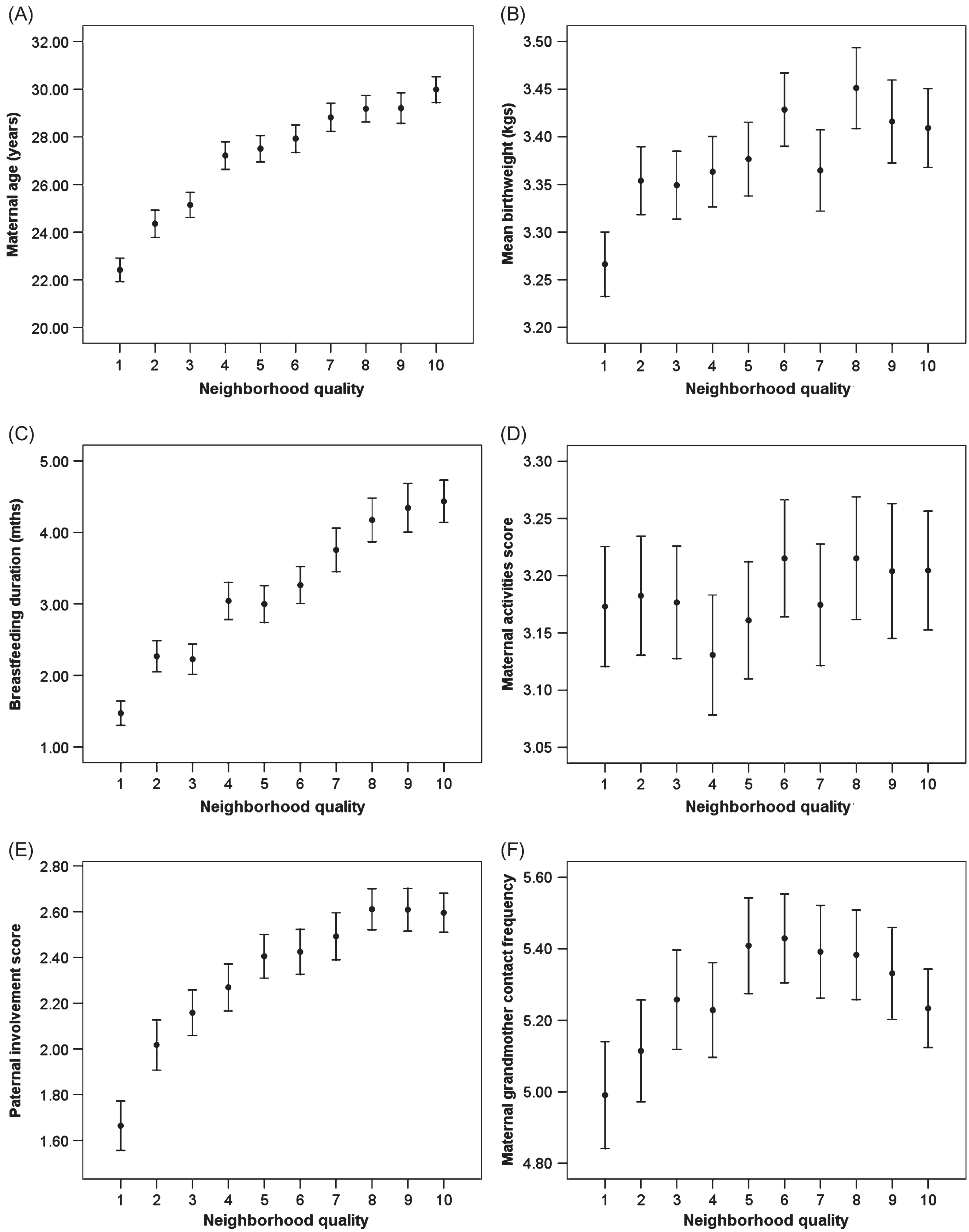

Figure 2
Mean and 95% confidence intervals for maternal age at first birth, birthweight, duration of breastfeeding, maternal activities, paternal involvement, and frequency of contact with the maternal grandmother, for each of the 10 qualities of neighborhood (1 = most deprived, 10 = most affluent).

Table 2

Effects of predictor variables on each of the 5 parental investment measures

Predictor	BWT	BFD	MATACT	PATINV	MGM
Neighborhood quality	$F_{9,4765} = 2.76$*	$F_{9,4765} = 10.76$*	$F_{9,4765} = 0.75$	$F_{9,4765} = 9.74$*	$F_{9,4765} = 4.06$*
Sex of child	$F_{1,4765} = 49.92$*	$F_{1,4765} = 0.09$	$F_{1,4765} = 5.05$**	$F_{1,4765} = 0.15$	$F_{1,4765} = 2.64$
Neighborhood quality × Sex	$F_{9,4765} = 0.88$	$F_{9,4765} = 0.60$	$F_{9,4765} = 0.47$	$F_{9,} = 0.66$	$F_{9,4765} = 0.50$
Maternal age	$F_{1,4765} = 4.98$**, $B = 0.004$	$F_{1,4765} = 320.68$*, $B = 0.19$	$F_{1,4765} = 2.66$	$F_{1,4765} = 226.03$*, $B = 0.05$	$F_{1,4765} = 3.69$
Older siblings	$F_{1,4765} = 8.71$*, $B = 0.03$	$F_{1,4765} = 26.51$*, $B = -0.32$	$F_{1,4765} = 185.25$*, $B = -0.15$	$F_{1,4765} = 137.83$*, $B = -0.23$	$F_{1,4765} = 6.34$**, $B = 0.07$

Parameter estimates are included for continuous covariates where there is a significant effect. *$P < 0.01$; **$P < 0.05$.

and morbidity that typify these ecologies (Charnov 1991; Chisholm 1993; Stearns 1992).

On the face of it, it might seem implausible that the ecological differences within this one developed country could be sufficient to favor such divergent life-history strategies. However, the socioeconomic gradients in morbidity in England are very striking. Let us assume, for example, that women were following a heuristic equivalent to "begin childbearing at such an age that you can on average still expect to be in good health until the time your oldest grandchild is 5." Taking the healthy life expectancies shown in Figure 1 and assuming that age at first birth remains the same in the next generation, women in the lowest quality neighborhoods would need to have their first child no later than 23.35, whereas in the most affluent group of neighborhoods, women could afford to wait until 31.75. This difference is rather close to that actually observed (Figure 2).

The shifts in life history across different types of neighborhood were not restricted to mothers. Men also showed reduced investment (as indicated by coresidence of a father figure with the child) in the lower quality neighborhoods. They may speed up their life history by shifting from paternal investment in existing children to mating effort and the formation of subsequent families. Involvement of the maternal grandmother was also reduced in the lowest quality neighborhoods. However, grandmaternal contact differed from the other parental investment variables, which tended to show patterns of continuous increase with increasing neighborhood quality, by showing a curvilinear pattern (Figure 2). The decrease in grandmaternal contact frequencies in the top decile may reflect greater geographical mobility among affluent professionals, which will result in greater travel distances and thus less frequent contact, or else increased ability to use paid childcare in the most affluent areas. However, this is unlikely to be the explanation for the reduction in grandmaternal contact in the lowest quality as compared with the middle deciles. Here, grandmothers may have more sets of grandchildren, due to larger family sizes and consequently be dividing their investment more thinly.

Parents speeding up their life history have costs in terms of child development. Analysis of performance on a naming vocabulary task at age 5 years showed that maternal age, birthweight, breastfeeding, maternal activities, paternal involvement, and grandmaternal contact all have independent positive effects on verbal ability. This is consistent with a number of previous findings on factors influencing cognitive development in this and other cohorts (Mortensen et al. 2002; Nettle 2008; Hansen and Hawkes 2009). The results confirm previously demonstrated relationships between poor socioeconomic conditions and cognitive development and the partial mediation of those relationships by parenting behaviors (Guo and Harris 2000; Bradley and Corwyn 2002; NICHD 2005; Conger and Donnellan 2007; Evans and Schamberg 2009). A substantial part—though by no means all—of the reason that children from poorer neighborhoods performed less well on the naming vocabulary task was the lower parental investment that they received (Figure 4).

There was no evidence that parental investment is any less effective at improving child outcomes in the deprived versus affluent neighborhoods. The only interaction between neighborhood quality and parental investment involved maternal grandmother contact, and this became more effective at improving cognitive development in the lower quality

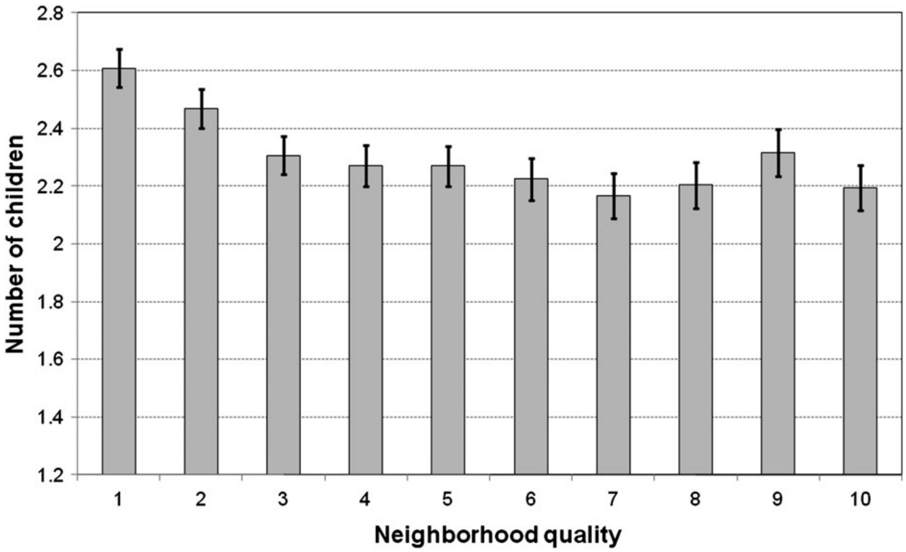

Figure 3
Mean and 95% confidence interval for the number of children in the household (2006–2007), with age of mother controlled, by neighborhood quality.

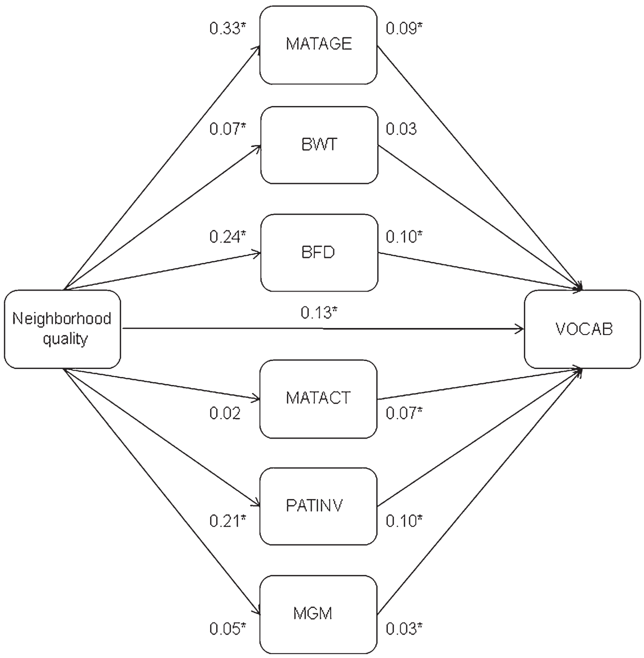

Figure 4
Path diagram showing the mediation of the effect of neighborhood quality on naming vocabulary score by parental life-history variables. $*P < 0.05$.

neighborhoods. The reason for this may be that, with fewer co-resident fathers, maternal grandmothers become more important as caregivers in these areas. However, this study is not an exhaustive test of the hypothesis that parental investment becomes more effective with increasing socioeconomic position (c.f., Kaplan 1996; Kaplan et al. 1998). It only examined one outcome measure, and that at only 5 years of age, and, more importantly, it used neighborhood-level rather than individual-level socioeconomic variables. It is more likely to be individual-level skills and resources that determine the effectiveness of parental investment. Nettle (2008), using an older cohort of children and individual-level socioeconomic measures, did find evidence of paternal involvement having a greater effect on cognitive development at age 11 years when fathers were of higher socioeconomic position.

The results shed light on several of the trade-offs involved in reproductive decisions in contemporary England. As maternal age increases, so too do birthweight and duration of breastfeeding, indicating that women are able to make larger somatic investments when they themselves are older (Borja and Adair 2003). Increasing maternal age also increases paternal involvement, presumably because older women are partnered to older men more willing or able to become involved with the child. On the other hand, the more siblings the child has, the shorter the breastfeeding, the less the maternal activities, and the less the paternal involvement. This is consistent with many other studies showing that parental investment is a scarce resource, which becomes divided into smaller shares as family size increases (Downey 1995, 2001; Lawson and Mace 2009). The only investment variable patterned in the opposite direction is grandmaternal contact. When there are more children in the house, the maternal grandmother visits more often on average. However, her investment may be more thinly divided within those visits.

There were rather few differences in parental investment according to the sex of the child. As expected, boys were heavier at birth than girls, and mothers did slightly more activities at age 5 years with girls than with boys, but otherwise, investment was equal in the 2 sexes. This differs from previous studies that have found differential involvement with boys by British fathers (Nettle 2008; Lawson and Mace 2009). Such gendered differences may emerge when children are older. There were also no interactions between neighborhood quality and sex of child. One might predict that in the harshest environments, daughters would be favored, as they might have higher reproductive value under these circumstances. However, no such interactions were in fact observed, in keeping with the results of a large US study (Keller et al. 2001).

Issues of causal interpretation

One possible objection to the interpretation given here is that the causal direction could be the other way around. That is, the large differences in mortality and morbidity between neighborhoods could be a consequence of the reproductive strategies people follow rather than their cause. This is unlikely to be the whole explanation. For example, there are strong social gradients in mortality even when the analysis is restricted to individuals who have never had children (Green et al. 1988), and social gradients in childhood mortality and morbidity persist when parental age and family size are controlled for (Petrou et al. 2006). Thus, at least some of the excess mortality and morbidity in poor neighborhoods is extrinsic, meaning that it is not conditional on individuals' behavior or that of their parents (Stearns 1992). It can therefore be properly invoked as a cause of behavior.

However, this is not to deny that the health differences between neighborhoods may be increased or exacerbated by behavioral decisions. Producing babies with low birthweight, for example, affects their long-term health prospects (Andersen and Osler 2004) and biases them in turn toward developing a fast life-history strategy (Nettle et al. 2009). Thus, there are feedback cycles among behavioral decisions, which will amplify or maintain fast life-history behavior once some extrinsic cue has initiated it. In addition, different components of the fast strategy synergize with each other. Lack of male investment makes it more difficult for women to continue breastfeeding because a critical role for male partners in humans appears to be to support breastfeeding (Quinlan RJ and Quinlan MB 2008). Such feedback loops between extrinsic and intrinsic variables are common in life-history evolution (Robson and Kaplan 2003) and can produce time lags in the behavioral response to changing environmental conditions.

Another issue relevant to the causal interpretation of the results is that although low-quality neighborhoods are characterized by increased mortality and morbidity, they differ from high-quality neighborhoods in numerous other ways too. For example, age at first reproduction may respond to women's labor market opportunities. When these are poor, as they will often be in low-quality neighborhoods, the financial benefits of delaying motherhood are lessened, and this is potentially a separate effect from that of lower healthy life expectancy. The current study has not attempted to tease apart which aspects of neighborhood quality are most important, and this is a priority for future research. However, invoking life expectancy as a probable key driver of the life-history differences seems reasonable because both theory (Stearns 1992; Chisholm 1993; Ellis et al. 2009) and cross-cultural evidence (Low et al. 2008) point to its relevance.

CONCLUSION

Social gradients in parenting behaviors have been documented before (Dubois and Girard 2006; Kohlhuber et al. 2008; Mortensen et al. 2008; Nettle et al. 2009). However, the existing literature describes them more often than attempting to explain them, and moreover, the different behaviors are usually treated piecemeal rather than being conceived of as parts of an overall life-history strategy. The parenting behaviors of the poorest sectors of society have often been stigmatized by mainstream media and policy makers (Geronimus 2003; Duncan 2007). It is not my intention to add to such stigmatization. On the contrary, the central premise of the behavioral ecological perspective taken in this study is that behavior is best seen as an adaptive response, produced through phenotypic plasticity, to the environment, which the individual faces. Much as Geronimus et al. (1999) argued for parts of the urban United States, it is completely comprehensible—predictable, even —that people in the poorest areas of England will follow a somewhat accelerated life-history strategy, given the increased risks of premature mortality and morbidity that they face. These behaviors are not mistakes or negligence, so much as coherent strategic responses to the context in which people have to live. However, as with any life-history decision, there are costs as well as benefits, and those costs fall on the development of each individual child. Behavioral ecology thus has considerable potential as an integrative framework for understanding socially patterned behavior within contemporary developed world settings. It tends to suggest that in addition to, or perhaps more urgently than, trying to educate individuals in poor areas about parenting decisions, government should be addressing the structural inequalitiesthat means that people in different parts of this small country experience such different ecological regimes.

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