Monkey see, monkey do: How do parental socioeconomic shifts influence children's cognitive outcomes?

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Abstract

With an Aberdeen birth cohort, this study examined the impact of perinatal determinants and socioeconomic status (SES) on childhood cognitive development. Via temporal measures of both SES and cognitive ability, we investigated the role of SES at birth and a change in SES during early childhood on two outcomes: (i) Cognitive ability at age 7, and (ii) Trajectory of that ability from ages 7 to 11. We employed standard econometric methodology and showcase the value of latent growth curve models, which have received minimal attention in health economics literature. Results showed that perinatal determinants, such as mother's age, parity, and gestational age, significantly explained cognitive development by age 7 and its trajectory to age 11. Importantly, there is clear evidence that SES at birth significantly impacts children's cognitive outcomes, and this impact is amplified for those who rank in the bottom half of the cognitive ladder by age 7.

Keywords: childhood cognition; socioeconomic mobility
JEL classification: I1; J10

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1. Introduction and Literature Overview

Cognition and health status are interrelated concepts that concurrently develop across the life course, with cognitive ability and mental health particularly influenced by similar underlying biological and psychosocial development processes (Richards & Hatch, 2012). For example, cognition and health status are both predicted by genetic influences, the uterine environment, and/or early childhood development. Research by Case et al. (2005) emphasizes that deprivation during the crucial period of perinatal and early childhood years can have lasting effects on adult health, particularly via reduced educational attainment and opportunities. Furthermore, education and health are strongly correlated, with cognitive ability playing a significant role in the relationship between these two outcomes (Auld & Sidhu, 2005). Therefore, understanding the perinatal determinants of cognitive ability during childhood is imperative to life course research for improving health outcomes later in life.

Recent research by Heckman (2012) contends that developmental origins of health are a key knowledge frontier in health economics. However, little research has attempted to bring together life course theories surrounding development from an epidemiological standpoint into the study of cognition and health from an economics perspective. With this multidisciplinary goal in mind, our study combines approaches from epidemiology, psychology, and economics to provide an integrated framework for understanding the determinants of changes in cognitive ability (*CogAb*) for children aged 7 to 11. Consequently, our analysis focuses on a range of predictors of childhood *CogAb* and two specific outcomes: (i) ***CogAb* at age 7**, and (ii) **the growth trajectory of *CogAb* from ages 7 to 11**. We were motivated by the knowledge that both *CogAb* and health outcomes (whether during childhood and/or adult years) are inextricably linked during the life course, and that assessing determinants of *CogAb* is a step toward better understanding the complex web of relationships that impact health outcomes.

Epidemiological Literature

Studies that have investigated determinants of childhood *CogAb* can essentially be split into two broad categories. The first focuses on perinatal determinants such as birthweight, birth order, and gestational age.[1] For example, Alderman and Behrman (2004) found that individuals who had low birthweight (<2500 grams) were at greater risk for a number of negative economic and health outcomes related to cognition later in life. At the other end of the spectrum, Cesur and Kelly (2010) found that high birthweight (>4500 grams) also resulted in adverse impacts on intelligence. In terms of birth order, most research shows that firstborn children tend to be more intelligent at age 5 and have a lower risk of developmental retardation than children born later (Boat, Campbell, & Ramey, 1986). With respect to gestational age, a recent study by Villarroel et al. (2013) found that normal gestational age of 37–<41 weeks, along with higher birthweight, and greater birth length, were associated with higher test scores for children, whereas above-average gestational age was associated with lower scores. A noteable finding by Villarroel et al. (2013) was that all birth measurements had a lower strength of association to intelligence than socioeconomic factors. This is a finding we can further explore in this study. How significant is the role of socioeconomic status (SES)? And do changes in SES significantly alter the trajectory of a child's cognitive development path? The first question has been partially tackled by Lawlor et al. (2005), who found a significant association between SES at birth and childhood intelligence levels at age 7. With the same Aberdeen data cohort as Lawlor and colleagues, we aimed to use multiple measurements of SES, and following latent growth curve modeling (LGCM) techniques, simultaneously estimated the responsiveness of *CogAb* at age 7 as well as its developmental path from ages 7 to 11, to a *change* in SES.

[1] See for example: Alderman & Behrman, 2004; Boardman, et al., 2002; Breslau, et al., 1996; Cesur & Kelly, 2010; Lawlor et al., 2005; Richards et al., 2001, 2002; Shenkin, Starr, & Deary, 2004; Shenkin et al., 2001; Villarroel, Karzulovic, Manzi, Eriksson, & Mardones, 2013.

A second group of studies investigating childhood *CogAb* involved postnatal determinants and/or interventions that might moderate or amplify perinatal predictors. Included in this research cluster are early intervention studies and those that emphasize the socioeconomic interactions in the child's early environment. Many found that SES at birth had a substantial influence on a child's *CogAb*, independent of perinatal factors.[2] Guo and Harris (2000) extended this line of research by investigating the mediating effects of poverty through characteristics of the social environment on children's intellectual development. They found that the impact of poverty was mediated by factors such as cognitive stimulation, parenting styles, and the home's physical environment. Such studies indicated that while early biological factors were important for the development of cognitive functioning, the social environment had undeniable influences on children's expression of intelligence.

Although outside this study's core focus, a substantial array of research illustrated that the abovementioned predictors of *CogAb* continue to play a role in adulthood and later life outcomes.[3] Furthermore, many of these studies found that childhood *CogAb* played a significant role in adult cognition and health (Batty & Deary, 2004; Batty, Deary, & Macintyre, 2007). For instance, Starr et al. (2004) found that lower childhood intelligence was associated with increased hypertension later in life, and Taylor et al. (2003) illustrated that lower childhood intelligence often led to increased chances of adult smoking. The increasing availability of longitudinal panel datasets has given rise to an upsurge in such studies.

Nature vs. Nurture

In attempting to quantify the determinants of *CogAb* for children, we need to be aware of the ongoing debate regarding "nature vs. nurture" and the consequent difficulty in drawing causal

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[2] Examples include: Jefferis, Power, & Hertzman, 2002; Kramer, Allen, & Gergen, 1995; McLoyd, 1998; O'Callaghan et al., 1995; Osler et al., 2003; Rowe, Jacobson, & Van den Oord, 1999; Turkheimer et al., 2003.

[3] See for example: Batty & Deary, 2004; Batty et al., 2007; Deary, Whiteman, Starr, Whalley, & Fox, 2004; Illsley, 2002 (focuses on educational attainment, rather than IQ); Starr et al., 2004; Taylor et al., 2003; Whalley & Deary, 2001.

inferences between the determinant variables and cognitive outcomes. The relationship between biological predispositions to greater intelligence and the influence of the social environment have been extensively discussed in developmental psychology, using Bronfenbrenner's (1979) ecological model of development. This model suggested that the expression of genetic traits occurred in the interaction between the child and the environment (Bronfenbrenner & Ceci, 1994). Regarding the development of cognitive function, research has found that trait heritability of intelligence increased in more advantaged conditions (Rowe, Jacobson, & Van den Oord, 1999), meaning that the potential for a child to have a higher cognitive level was accentuated with greater resources such as higher parental education and SES. Other research has found that environmental risk factors predicted over a third of the variance in *CogAb* at ages 4 and 13; and after controlling for the effects of *CogAb* in childhood, environmental risk is still a significant predictor of *CogAb* during adolescence (Sameroff, Seifer, Baldwin, & Baldwin, 1993). These results suggested that regardless of the child's inherent ability, lack of resources could undermine the development of cognitive functioning.

Contribution to the Literature

While the development of *CogAb* and the child's social environment are clearly linked, to our knowledge, no studies have yet examined how changes in family SES during early childhood impact *CogAb* development. We believe this is predominantly due to the lack of studies with multiple measures of both *CogAb* and SES, in addition to information on perinatal factors. Therefore, the following research employs the Aberdeen Children of the Nineteen-Fifties (ACONF) cohort to investigate the interplay between perinatal characteristics, early environmental influences (particularly SES), and most importantly, the change in some of these factors on determining *CogAb* at age 7, and predicting the growth trajectory in *CogAb* from ages 7 to 11.

This study makes two main contributions. First, the study adopted a mixed-methods approach, drawing on complementary methodologies from economics and psychology. This enabled us to ensure robustness of results and to showcase the value of LGCM, which has received next to no attention in health economics literature. The merit of this approach lies in its ability to simultaneously model determinants of the intercept (in the context of this research, *CogAb* at age 7), and the slope (change in *CogAb* between 7 and 11). The second contribution is the empirical analysis of mobility in a key environmental factor during childhood—SES. While past empirical analyses on the determinants of *CogAb* have investigated the SES role, this has often been via a measure at one time point. In contrast, this is the first study to pinpoint the temporal influence of *change in* SES on both the initial measure of *CogAb* at age 7, and on change in *CogAb* between 7 and 11.

Theoretical Context

Prior to quantifying the role of SES at birth and change in SES on children's cognitive outcomes, we delved into the relevant theory. In particular, Jean Piaget (1964) pioneered the classification of three developmental stages relevant to our analysis: (i) sensorimotor (birth–2 years), (ii) pre-operational (2–7 years), and (iii) concrete operational (7–11 years). The first stage relates to the age range at which toddlers start to develop knowledge of their environment by classifying and coordinating vision, and hearing with physical experiences. They also develop the ability to conceptualize that things, largely, remain constant, i.e., a new day is not an entirely new manifestation of the universe. The "preoperational" stage relates to the period during which language and motor skills develop, along with basic cognitive understandings. Children between 4 and 7 undergo the "intuitive substage," which manifests as generally heightened levels of curiosity. During this stage, children vividly project their imaginations and display a largely egocentric emotional capacity. Additionally, while nominal understanding of concepts is evident, logic and mental manipulation have not yet developed. These factors seem synonymous with the children having little understanding of cause and effect. The third "concrete operational" stage is synonymous with children starting to develop logical deduction; they begin forming concepts of morality and move away from egocentric tendencies. This stage also coincides with an important stage in brain development, whereby frontal and temporal lobes experience significant growth in capacity. It is universally believed that this brain development is the reason for the dynamic shift in intellect and understanding.

On the basis of these descriptions, we could postulate that environmental factors (such as family SES) should have a larger impact on development among children under seven. In the sensorimotor and preoperational stages, learning and intelligence is much more a product of one's levels of exposure. In the concrete operational stage, however, intelligence, based on Piaget's assumptions, is a result of a child's ability to conceptualize independently, and deduce from existing and new knowledge. Logically, in the concrete operational stage, there should be fewer incidences of verbatim "monkey see, monkey do" cognitive ability.

We therefore hypothesize that changes in family SES likely play a significant role in development of *CogAb* by age 7, but have minimal impact on the *CogAb* growth trajectory from ages 7 to 11. While literature examining specific impacts of environmental factors at certain ages is scarce, many previous studies have confirmed the general theory that environmental factors have a decreasing impact on *CogAb* as age increases (See for instance Brant et al. (2009), Bartels et al. (2002), and Humpreys and Davey (1988)).

2. Data

The ACONF is a birth cohort dataset that includes approximately 15,000 children born in Aberdeen, Scotland, between 1950 and 1956. For comprehensive details on the data collection methods, see Batty et al. (2004) and Leon et al. (2006). The data in the current study involves 7,647 children; which comprises 4,043 males and 3,604 females. The sample is reduced relative to the initial cohort because it is a subset of individuals with full data from three separate sources—the 1962 survey (when the children were between the ages of 7 and 12), linked birth data from the Aberdeen Maternal and Neonatal Database (AMND), and school level records. Summary statistics are provided for all relevant variables in Table 1.

Table 1: Descriptive Statistics (ACONF)

Variable	Definition	M (SD)
CogAb rank at age 7	Rank of cognitive ability measure at age 7	3824 (2207.22)
Change in *CogAb* rank	Change in rank of cognitive ability measure between age 7 and 11.	0.00 (1583.88)
Birth characteristics		
Maternal height	Maternal height in inches 1 = ≤ 60, 2 = 61, 3 = 62, 4 = 63, 5 = 64, 6 = 65, 7 = ≥65	3.161 (1.747)
Maternal age	Maternal age at birth in years 1 = 15–19, 2 = 20–24, 3 = 25–29, 4 = 30–34, 5 = 35–39, 6 = 40+	3.097 (1.125)
Birth order	Maternal number of births 1 = 1, 2 = 2, 3 = 3, 4 = 4, 5 = 5+	2.076 (1.133)
Gender	0 = Male, 1 = Female	0.471 (0.499)
Gestation	Gestational age in weeks 1 = < 37, 2 = 37–40, 3 = 41+	2.446 (0.572)
Birthweight	Birthweight in pounds 1 = ≤ 5.4, 2 = 5.5–6.4, 3 = 6.5–7.4, 4 = 7.5–8.4, 5 = 8.5–9.4, 6 = 9.5+	3.316 (1.108)
Gravidity	Maternal number of pregnancies 1 = 1, 2 = 2, 3 = 3, 4 = 4, 5 = 5+	2.291 (1.252)
SES		
High SES	Dummy variable = 1 if social class of Father at birth = I and II professional and skilled technical; 0 otherwise	0.094 (0.292)
Medium high SES	Dummy variable = 1 if social class of Father at birth = III non-manual; 0 otherwise	0.124 (0.329)
Medium low SES	Dummy variable = 1 if social class of Father at birth = III manual; 0 otherwise	0.484 (0.500)
Low SES	Reference group	-
Change in SES		
SES_neg2	Dummy variable = 1 if Father's social class in 1962 changed more than 1 category down; 0 otherwise	0.015 (0.122)
SES_neg1	Dummy variable = 1 if Father's social class in 1962 changed 1 category down; 0 otherwise	0.070 (0.255)
No change in SES	Reference group	-
SES_pos1	Dummy variable = 1 if Father's social class in 1962 changed 1 category up; 0 otherwise	0.144 (0.351)
SES_pos2	Dummy variable = 1 if Father's social class in 1962 changed more than 1 category up; 0 otherwise	0.049 (0.215)
Sample size		7,647

Note: M (SD) = Mean (Standard Deviation).

Measures

Cognitive ability

For the ACONF cohort, *CogAb* was measured three times, with information from routine cognitive tests administered through their schools when children were aged 7, 9, and 11. The tests conducted were the Moray House picture intelligence test at age 7 and the Schonell and Adams essential intelligence test at age 9. At age 11, a battery of Moray House tests were administered: two ability tests (verbal reasoning 1 and 2) and two attainment tests (arithmetic, English). Unfortunately, sizeable gaps exist in the attainment test scores at age 11; this resulted in our decision to focus on the two verbal reasoning tests and use an average of these for the *CogAb* measure. This is consistent with the steps taken in Lawlor et al. (2005), who focused on birth characteristics as determinants of *CogAb* at age 7.

With three different tools used to measure *CogAb* at ages 7, 9, and 11, we propose investigating determinants of the child's rank in these cognitive assessments, rather than the absolute value of these measures; thus focusing our interest on how a child's *CogAb* fares relative to their peers in this birth cohort.

At this point, we should consider the debate surrounding *CogAb* measures at school and other IQ related tests, and whether these tests reveal true cognitive ability or are more a reflection of school aptitude. While these concepts are by no means mutually exclusive, it could be argued that such achievement tests potentially miss out on, or do not fully capture "soft skills," such as personality traits, motivations, and preferences, which are key to predicting adult success in the labor market and other domains of life outcomes (Heckman & Kautz, 2012). Nevertheless, there is a general consensus that standardized school achievement tests have high statistical reliability, which implies that although test takers may have varying scores when taking the same test on different occasions, and they may have varying scores when taking the test at the same age, the scores tend generally to agree with one another, within a margin of error (Hopkins & Bracht, 1975). Additionally, in a recent summary and review of what achievement tests measure, Heckman and Kautz (2012) indicated that such tests are a very common tool employed by social scientists, and are often the best proxy available for an individual's level of *CogAb*.

As shown in Table 1, the change in rank of the *CogAb* measure from age 7 to 11 (dependent variable in forthcoming empirical analysis) has a zero mean and standard deviation of approximately 1584. The Shapiro–Francia W test and skewness/kurtosis tests for normality were also used to verify the normality of this variable's distribution.

Perinatal Characteristics

Perinatal data was sourced from the Aberdeen Maternal and Neonatal Database (AMND), and as shown in Table 1, seven of these variables were used in the forthcoming analyses to represent maternal and child characteristics at birth. These included maternal height and age at the time of birth, gravidity (number of pregnancies), birth order, gender, gestational age at birth, and birthweight.

Socioeconomic Status

Socioeconomic status (SES) was derived from paternal occupation at two points in time—birth (via AMND) and childhood (as reported in the 1962 survey, when the children were from 7 to 12 years old). At both points, fathers' occupational data was classified into six categories according to the 1950 general register (General Register Office, 1951): I–professional; II–managerial; IIINM–non-manual, skilled non-manual; IIIM–manual, skilled manual; IV–manual, semi-skilled; and V–unskilled manual. As is evident in Table 1, the six occupational categories have been collapsed into four: (i) High SES (I–professional, and II–managerial); (ii) Medium-high SES (IIINM–non-manual, skilled non-manual); (iii) Medium-low SES (IIIM–manual, skilled manual, and IV–manual, semi-skilled); and (iv) Low SES (V–unskilled manual). Observations in which the father was unemployed, deceased, or his occupation unknown were classified as missing.

Change in SES between birth and 1962, is a key indicator of change in environment and is therefore the focus of our empirical analysis, with respect to its impact on childhood cognition. Change in SES during childhood was computed by subtracting social class at birth from social class in 1962 (low SES was coded as 1, and high SES as 4). The resulting change in SES scores ranged from −3 to 3, with 0 representing no change. Table 2 further illustrates the movement across SES categories within our sample.

Table 2: SES Movement Between Birth and 1962

		SES at birth				
		Low	**Medium-low**	**Medium-high**	**High**	**Total**
SES in the 1962 survey	**Low**	1473 (64.52)	401 (10.84)	63 (6.65)	18 (2.51)	1955
	Medium-low	643 (28.16)	2840 (76.78)	86 (9.08)	34 (4.74)	3603
	Medium-high	125 (5.48)	252 (6.81)	593 (62.62)	48 (6.69)	1018
	High	42 (1.84)	206 (5.57)	205 (21.65)	618 (86.07)	1071
	Total	2283	3699	947	718	7647

Note: Socioeconomic status (SES) is proxied by paternal social class. The categories are defined as follows: Low = semi-skilled and unskilled manual (occupation class IV & V); Medium-low = skilled manual (occupation class IIIb & IIIc); Medium-high = non-manual (occupation class IIIa); and High = professional and intermediate (occupation class I & II).
Figures in parenthesis represent percent of sub-sample (based on SES level at birth).

The shaded cells indicate the number and percentage of households that stayed in the same SES category (72.2%). To the left of the shading are the families that moved up in SES category (19.3%), whereas the converse is true for families to the right of the shaded cells (8.5%). Given seven possibilities for movement (−3, −2, −1, 0, +1, +2, +3), to simplify the forthcoming analysis, we collapsed the two categories at each extreme. As shown in Table 1, this resulted in five categories converted into dummy variables representing: no change (reference group); upward movement of one category (SES_pos1); upward movement of two or three categories (SES_pos2);

downward movement of one category (SES_neg1); and downward movement of two or three categories (SES_neg2).

Data Limitations

In today's society, father's occupational class might not be an ideal proxy for family SES. However, ACONF ran during the late 1950s and early 1960s, when Aberdeen's sociocultural environment meant that very few mothers were employed. This was evident in the dataset, as information on mother's employment status was asked only in reference to her occupation prior to marriage. Similarly, the mothers' level of education varied very little across the sample. Therefore, the homogenous nature of maternal education and work characteristics motivated the use of father's occupational class as an effective proxy for family SES.

Prior to proceeding with the econometric analyses, we also examined our sample according to excluded versus included cases, i.e., comparing our final linked sample of 7,647 versus the initial cohort of 15,000. This was carried out using the Mann–Whitney test. Significant differences were found on several independent variables: mother's age at birth of the child ($z = -3.59$, $p > .01$), birthweight ($z = -3.07$, $p > .01$), gravidity ($z = -5.94$, $p > .01$), birth order ($z = -5.78$, $p > .01$), social class at birth ($z = -3.91$, $p > .01$), and social class in 1962 ($z = -2.39$, $p > .01$). Similar results were also found for the *CogAb* measures at ages 7, 9, and 11 ($z_7 = -14.02$, $z_9 = -12.03$, $z_{11} = -14.99$, $p > .01$). These results might reflect characteristics of the sampling process, wherein children well below average *CogAb* might not have completed the required cognition tests at school, and wherein students more generally disadvantaged were over-represented in missing values for the linked data. These differences between included and excluded cases mean that results of the forthcoming data analysis should be interpreted with a caveat in mind—that our sample might be under-represented with respect to the most disadvantaged families.

A final potential limitation of this analysis is that we were unable to control for school quality. Nonetheless, we are confident that Aberdeen schooling during the relevant period was relatively homogeneous. Private education was uncommon in Scotland at that time, and most children attended their local primary schools. Furthermore, teacher selection by a school was uncommon, with the vast majority being trained at the Aberdeen Teacher's Training college and then being appointed to a school by the Local Education Authority (Illsley, 2006). We therefore believe this policy created relatively homogeneous teacher quality and school quality across our population-based dataset, which included children from 44 different schools.

3. Methodology

Linear Regression & Multinomial Logit

This analysis aimed to combine methodologies from different disciplines—specifically, economics and psychology. We therefore began our empirical journey with a common tool for economists—least squares regression. The dependent variable was initially *CogAb* rank at age 7. Subsequently, we altered the dependent variable to change in *CogAb* rank from age 7 to 11. The second-stage analysis was based on quartile sub-samples, where quartiles were constructed on the child's ranked cognition at age 7. Our intention was to investigate whether there were systematic differences in the role played by birth characteristics and SES that depended on the child's ranking relative to peers at age 7. The family SES level at birth and change in SES from birth to 1962, are included in these models. As previously explained, the change in SES was denoted as either a movement up (down) of two or more SES categories; or a movement up (down) of one SES category; with no change in SES as the reference group. To our knowledge, this is the first time change in a child's environment, via change in SES is investigated with regard to its influence on a child's cognitive ability and development. We also supplemented this analysis with a multinomial logit to track determinants of substantial shifts in cognitive ranking between ages 7 and 11, based on the quartile wherein the individual's score was located at these two time points.

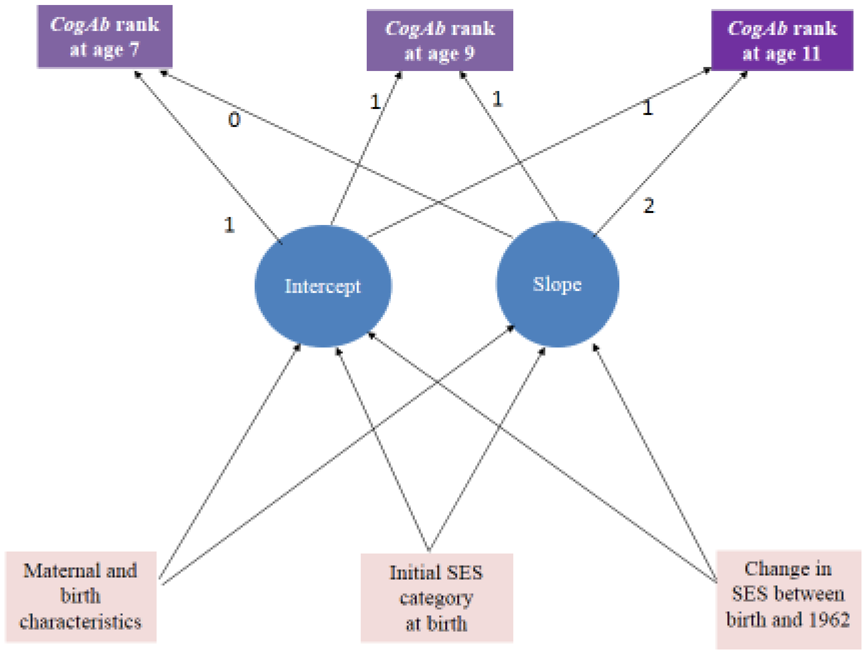
Latent Growth Curve Model

Next, we undertook LGCM to ensure full use of the unique longitudinal data at hand. This type of analysis is well placed to assess growth trajectories over time. It has been widely used in behavioral and social science, but to date has not featured prominently in health economics. This is likely due to the lack of longitudinal data with multiple measurements of the same variable, which is a condition required for such a methodology to be effective.

As early as the 1960s, growth curve models were used to model repeated measurements for dependent variables (see Potthoff & Roy, 1964). LGCM is a form of structural equation modeling that offers a number of benefits: It permits investigation of interindividual differences in change, as well as antecedents of change. The relative standing of an individual at each point in time was modeled as a function of an underlying growth process, and the best parameter values for that growth trajectory were then fitted to each individual. Curran and Willoughby (2003, p. 603) argued that LGCM resides "at an intersection between variable-centered and person-centered analysis."

LGCM accounts for both within- and between-person variance (Duncan & Duncan, 1995), provides group-level statistics such as mean intercept and growth rate, and can include both time-varying and time-invariant covariates. Figure 1 provides a useful visual impression of our analysis.

Figure 1: Pathways in Assessing Determinants of Change in Childhood *CogAb*



Note: Intercept factor loadings set to 1; slope factor loading set to 0: *CogAb* rank at age 7; 1: *CogAb* rank at age 9; 2: *CogAb* rank at age 11. Residuals and covariances are not shown for ease of interpretation.

As shown in the figure, three repeated measurements (y_1, y_2, y_3) represented the longitudinal path of the two latent variables: the intercept and the slope of the growth trajectory. The model presented assumes equally spaced time points. Therefore, to specify linear growth, the loadings of the intercept factor are constrained to one, while those for the slope are equal to the rank of measurement: 0, 1, and 2, in this case. In matrix notation, equation (1) details the relationship between the repeated measurements (y) over time, intercepts (τ), latent factors (η), factor loadings (Λ), and the disturbance variance of ε:

$$y = \tau_y + \Lambda_y \eta + \varepsilon \qquad (1)$$

The latent factors were initial status of *CogAb* rank at age 7 (η_1) and slope of change in *CogAb* rank from 7 to 11 (η_2). For identification purposes, τ_y was set to zero. We therefore expanded equation (1) to represent the model with time (t) and individual (i) points of observation:

$$y_{ti} = \lambda_{1t}\eta_{1i} + \lambda_{2t}\eta_{2i} + \varepsilon_{ti} \qquad (2)$$

As shown in the following growth equations, we modeled the latent means $(\alpha 1, \alpha 2)$ and their respective variances (ζ) around these means:

$\eta_{1i} = \alpha_1 + \zeta_{1i}$ (3) and $\eta_{2i} = \alpha_2 + \zeta_{2i}$ (4)

We could also further break down the model's variance–covariance and mean structures. The variance–covariance matrix (Σ) was a function of the factor variances and covariances (Ψ), the factor loadings (Λ), and the disturbance variances and covariance (Θ_ε). The following equations represented the population variance–covariance matrix (Σ), along with the population means of the observed variables (μ_y):

$\Sigma = \Lambda_y \Psi \Lambda'_y + \Theta_\varepsilon$ (5) and $\mu_y = \tau_y + \Lambda_y \alpha$ (6)

We must note here that the covariances between the disturbances were assumed to be zero, and the variances were assumed to be invariant across time points. The expectation of this model was that it would produce a mean structure with population observed means (ζ), which were a function of both the intercepts (ζ) and the latent variable means (α).

4. Results

Linear Regression & Multinomial Logit

Table 3 portrays five separate regression models. The first (model (0)) was based on the full sample of 7,647 individuals, where the outcome of interest was the *CogAb* ranking at age 7. Model (0) illustrates that being early in the birth order and normal gestational age drive an increase in *CogAb* rank. Shenkin et al. (2001) also found a negative association between birth order and cognitive ability at age 11, when they used the Scottish Mental Survey, as did Villarroel et al. (2013) in their cohort study of Chilean children. Having a taller, older mother also aided the child being higher on the cognitive ladder by age 7, as did an increase in birthweight—a result corroborated by findings from Alderman and Behrman (2004).

In terms of our variables of interest (SES at birth and change in SES between birth and the 1962 survey), model (0) shows that SES played a key role in determining the *CogAb* rank of a child by age 7. As expected, having high SES at birth had the greatest impact on *CogAb* rank, relative to low SES, which reduced in magnitude (while remaining highly significant) for those in families with medium-high SES, and medium-low SES at birth. Change in SES was also significant, with a drop in SES associated with a lower *CogAb* rank by age 7, and the converse being true for a rise in SES.

Table 3: Drivers of *CogAb* at 7, and the Change from 7 to 11.

Dependent variable: 7	**Rank of *CogAb* at age 7**		**Change in *CogAb* rank from age 7 to 11**							
	(0)		**(1)**		**(2)**		**(3)**		**(4)**	
Variable	**All**		**Quartile 1**		**Quartile 2**		**Quartile 3**		**Quartile 4**	
	Coeff	*(Std Error)*	*Coeff*	*(Std Error)*	*Coeff*	*(Std Error)*	*Coeff*	*(Std Error)*	*Coeff*	*(Std Error)*
Intercept	2043.86***	(135.88)	861.20***	(163.31)	−330.19	(212.35)	−584.57**	(243.10)	−661.75***	(212.07)
Maternal height	55.36***	(13.66)	−17.79	(17.94)	34.88	(21.75)	51.39**	(22.22)	17.83	(18.45)
Maternal age	300.49***	(24.16)	38.82	(31.98)	162.29***	(39.15)	121.33***	(40.69)	36.90	(32.13)
Birth order	−228.421***	(42.17)	−112.71**	(51.20)	−54.07	(68.28)	−323.04***	(73.30)	−302.04***	(64.97)
Gender	180.21***	(47.09)	113.07*	(61.86)	225.92***	(74.93)	−0.51	(77.37)	87.43	(61.93)
Gestation	93.83**	(43.09)	1.67	(51.20)	20.09	(69.38)	−150.90**	(73.67)	−119.88**	(58.85)
Birthweight	156.71***	(22.91)	54.91*	(28.09)	51.95	(36.88)	65.57*	(39.58)	61.38**	(30.55)
Gravidity	2112.47***	(39.22)	−75.78	(49.70)	−186.31***	(64.62)	79.99	(67.07)	69.23	(58.35)
High SES	2112.47***	(90.35)	978.13***	(246.41)	774.56***	(190.00)	628.10***	(154.76)	319.08***	(109.76)
Medium high SES	1381.84***	(82.21)	465.87***	(151.80)	538.88***	(140.93)	696.12***	(127.24)	362.30***	(109.19)
Medium low SES	705.32***	(57.96)	96.96	(69.44)	274.58***	(88.68)	187.98*	(98.87)	−40.59	(98.41)
SES_neg2	−1003.36***	(214.71)	−1035.53***	(237.34)	−390.12	(362.59)	−254.35	(335.70)	−309.59	(199.30)
SES_neg1	−525.03***	(92.86)	−30.45	(121.06)	−294.44**	(139.96)	−173.85	(158.02)	−33.98	(131.78)
SES_pos1	234.05***	(69.06)	−19.44	(90.40)	15.89	(110.75)	247.72**	(108.79)	−169.83*	(98.76)
SES_pos2	521.59***	(112.87)	349.72**	(163.81)	459.65**	(188.16)	637.21***	(157.95)	60.53	(154.44)
R^2	0.1588***		0.0473***		0.0562***		0.0618***		0.0547***	

Note 1: Dependent variable in model (0) is the *CogAb* rank at age 7.

Note 2: In Models (1)–(4), the dependent variable is the change in *CogAb* rank from age 7 to 11. Each model is a quartile subsample, based on the starting *CogAb* rank of the child at age 7. Standard errors are in parenthesis and *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

The remainder of Table 3 (Models (1)–(4)) exhibits quartile sub-samples, where the dependent variable was change in *CogAb* rank from ages 7 to 11, and the subsamples were based on the quartile wherein the child was located for *CogAb* rank at age 7. This allowed us to investigate the drivers of a change in ability rank between 7 and 11, while "controlling" for the influence of the child's location in the cognition distribution at age 7. The quartile analysis provided a few key findings worth noting. First, being female appeared to be helpful in improving *CogAb* rank between 7 and 11, in the bottom two quartiles. Perhaps female children were better equipped to deal with stigma or disappointment associated with being at the bottom of the cognitive ladder with respect to their peers; or schools had greater intervention strategies for weak performances by girls relative to those by boys.

Second, the nature of the impact of SES on change in *CogAb* rank from 7 to 11, was quite different to that at age 7. In particular, model (0) showed that both SES at birth and change in SES during early childhood were important in determining *CogAb* rank at age 7. However, after age 7, models (1) to (4) show that while the impact of SES at birth continues to linger, changes in SES during childhood are less significant, with indications that large shifts in SES are required to explain a significant variation in our dependent variable. There is evidence in the majority of sub-samples that a movement up 2 or more SES categories has a significant positive influence on *CogAb* rank. Noticeably, it is only in the bottom two quartiles, that a drop in SES appears to adversely impact the change in *CogAb* rank between age 7 and 11. Hence, a downward shift in SES doesn't play a significant role if the child is ranked in the top half of cognitive tests by time they are age 7, but does have a negative impact on those ranked in the bottom half.

To further narrow the analysis, and rather than looking at change in *CogAb* rank as a continuous measure, it was prudent to explore what factors were significant in driving substantial changes in *CogAb* rank, and in particular, shifting the location in the *CogAb* distribution, specified by quartile. We employed a multinomial logit for this purpose, with no change in *CogAb* quartile denoted as the base outcome. As shown in Table 4, there were not many significant independent variables in the full sample (model (0)). In model (1), comprised of those in the lowest quartile at age 7, characteristics that increased the likelihood of an upward shift of one *CogAb* quartile were higher birthweight, lower birth order, and medium-low SES. Additionally, model (1) illustrates that SES (whether at birth or change in SES during childhood) was a key determinant with regard to the child moving up two or more quartiles in *CogAb* rank. This result also indicated the importance of sub-sample analysis. For example, in the full sample, having high SES at birth had an insignificant influence on moving up at least two *CogAb* quartiles. In contrast, if at age 7, the child was in the lowest quartile and came from a high SES family, the child was seven times more likely to move up two or more *CogAb* quartiles relative to those in a low SES family. This effect dampened (but remained significant) for those in the second quartile, where having high SES at birth meant the child was approximately three times more likely to move up two or more *CogAb* quartiles relative to their low SES counterparts. These results showed the importance of SES at birth and its possible influence on the cognition trajectory of a child even after age 7.

Interestingly, while the relative risk ratios were substantially different between the full and subsamples for SES characteristics at birth, the same cannot be said for change in SES during childhood. While, marginally higher in quartile 1 and 2, the effects of having a large shift upwards in SES (two or more categories) was relatively similar across these subsamples and not very different from the full sample. All findings pointed to a large jump in SES resulting in affected children being between 2–2.5 times more likely to shift up two or more *CogAb* quartiles.

A similar pattern holds when viewing the top half of Table 4 and assessing determinants of a downward trajectory in *CogAb* quartile. SES at birth again appeared to be instrumental in reducing the likelihood of experiencing a drop in *CogAb* quartile between ages 7 and 11, whereas change in SES had an insignificant influence in most cases (except SES_neg2 in quartile 4).

Thus far, the majority of results shown Tables 3 and 4 were intuitive and corroborated past literature on the influence of perinatal characteristics on cognitive ability. They also highlighted the important role of SES at birth and provided partial support for our hypothesis that change in SES will have minimal influence after age 7. However, we unfortunately could not ascertain from these models, whether the independent variables were a significant and contributing force to both initial *CogAb* at age 7, and the growth trajectory from 7 to 11 (while explicitly controlling for the influence of the former). In the following section, the estimates from LGCM cover this important analytical gap.

Table 4: Change in *CogAb* Quartile from 7 to 11

	(0)		(1)		(2)		(3)		(4)	
Variable	**All**		**Quartile 1**		**Quartile 2**		**Quartile 3**		**Quartile 4**	
	RRR	*(Std Error)*	*RRR*	*(Std Error)*	*RRR*	*(Std Error)*	*RRR*	*(Std Error)*	*RRR*	*(Std Error)*
Change in *CogAb* quartile = Down by 2 or 3										
Maternal height	0.96	(0.03)					0.86***	(0.05)	0.98	(0.05)
Maternal age	1.01	(0.06)					0.79**	(0.08)	0.89	(0.08)
Birth order	1.36***	(0.14)					1.42**	(0.24)	2.08***	(0.36)
Gender	0.84	(0.10)					0.83	(0.15)	0.72*	(0.12)
Gestation	1.17	(0.12)					0.97	(0.17)	1.34*	(0.21)
Birthweight	0.99	(0.05)					1.01	(0.09)	0.75***	(0.06)
Gravidity	0.84*	(0.08)					1.02	(0.16)	0.85	(0.14)
High SES	1.32	(0.31)					0.65	(0.26)	0.39***	(0.12)
Med high SES	0.96	(0.22)					0.41**	(0.16)	0.38***	(0.12)
Med low SES	1.66***	(0.24)					0.93	(0.21)	1.04	(0.24)
SES_neg2	0.67	(0.41)					0.95	(0.78)	0.96	(1.01)
SES_neg1	0.76	(0.18)					1.20	(0.40)	0.83	(0.35)
SES_pos1	1.20	(0.21)					0.89	(0.24)	1.21	(0.31)
SES_pos2	1.05	(0.30)					0.51	(0.25)	0.76	(0.28)
Change in *CogAb* quartile = Down by 1										
Maternal height	1.01	(0.02)			1.04	(0.04)	0.97	(0.03)	1.01	(0.03)
Maternal age	0.98	(0.03)			0.79***	(0.05)	0.92	(0.06)	0.90*	(0.05)
Birth order	1.02	(0.06)			1.05	(0.11)	1.06	(0.12)	1.37***	(0.16)
Gender	0.94	(0.06)			0.65***	(0.08)	1.09	(0.13)	0.96	(0.11)
Gestation	1.11*	(0.06)			1.03	(0.11)	1.08	(0.13)	1.09	(0.12)
Birthweight	1.01	(0.03)			0.96	(0.05)	0.90	(0.06)	0.96	(0.05)
Gravidity	1.00	(0.05)			1.20*	(0.12)	1.08	(0.11)	0.95	(0.10)
High SES	0.92	(0.11)			0.72	(0.23)	0.57**	(0.15)	0.56***	(0.11)
Med high SES	0.85	(0.09)			0.74	(0.17)	0.47***	(0.10)	0.55***	(0.11)
Med low SES	1.06	(0.08)			0.87	(0.12)	0.73***	(0.11)	0.89	(0.15)
SES_neg2	1.15	(0.29)			2.08	(1.23)	0.71	(0.39)	2.60**	(1.05)
SES_neg1	0.93	(0.11)			1.05	(0.23)	0.77	(0.19)	1.31	(0.31)
SES_pos1	1.07	(0.10)			0.91	(0.15)	0.77	(0.14)	1.27	(0.22)
SES_pos2	1.02	(0.15)			0.92	(0.29)	0.80	(0.21)	0.75	(0.20)
Change in *CogAb* Quartile = Up by 1										

Maternal height	1.02	(0.02)	0.98	(0.03)	1.13***	(0.04)	1.00	(0.03)		
Maternal age	0.98	(0.03)	1.09	(0.06)	0.94	(0.06)	1.05	(0.06)		
Birth order	0.92	(0.05)	0.82**	(0.08)	1.00	(0.10)	0.73***	(0.08)		
Gender	0.99	(0.06)	0.93	(0.10)	1.02	(0.12)	1.12	(0.13)		
Gestation	0.94	(0.05)	0.96	(0.09)	1.01	(0.11)	0.83*	(0.09)		
Birthweight	1.04	(0.03)	1.21***	(0.06)	0.94	(0.05)	1.07	(0.06)		
Gravidity	1.00	(0.05)	0.95	(0.09)	0.93	(0.09)	1.13	(0.12)		
High SES	0.79*	(0.10)	1.65	(0.64)	1.84**	(0.51)	1.72**	(0.40)		
Med high SES	1.00	(0.11)	1.16	(0.28)	1.50**	(0.31)	1.44*	(0.28)		
Med low SES	1.14*	(0.08)	1.31**	(0.16)	1.39**	(0.19)	1.09	(0.17)		
SES_neg2	1.16	(0.29)	0.72	(0.34)	1.38	(0.74)	0.58	(0.28)		
SES_neg1	0.85	(0.10)	0.80	(0.17)	0.62**	(0.14)	0.72	(0.17)		
SES_pos1	1.08	(0.10)	1.10	(0.17)	0.94	(0.16)	1.09	(0.18)		
SES_pos2	1.33**	(0.18)	1.20	(0.33)	1.26	(0.36)	1.71**	(0.40)		
Change in *CogAb* Quartile = Up by 2 or 3										
Maternal height	0.96	(0.03)	0.96	(0.04)	1.06	(0.05)				
Maternal age	0.99	(0.05)	1.11	(0.09)	1.22**	(0.10)				
Birth order	0.93	(0.10)	0.73**	(0.11)	0.91	(0.15)				
Gender	1.00	(0.10)	1.16	(0.17)	0.99	(0.17)				
Gestation	1.07	(0.11)	1.02	(0.13)	1.29	(0.22)				
Birthweight	1.03	(0.05)	1.14**	(0.07)	1.11	(0.10)				
Gravidity	0.94	(0.09)	0.93	(0.12)	0.79	(0.12)				
High SES	0.88	(0.20)	7.00***	(2.73)	2.99***	(1.16)				
Med high SES	1.44**	(0.25)	3.63***	(0.92)	3.00***	(0.88)				
Med low SES	1.13	(0.15)	1.37*	(0.24)	1.81**	(0.42)				
SES_neg2	0.76	(0.37)	0.12***	(0.09)	1.18	(0.84)				
SES_neg1	0.99	(0.20)	0.92	(0.25)	0.57	(0.20)				
SES_pos1	1.03	(0.16)	1.12	(0.25)	1.15	(0.30)				
SES_pos2	1.82***	(0.38)	2.24***	(0.70)	2.58***	(0.87)				
Pseudo R^2	0.0054***		0.0336***		0.0320***		0.0311***		0.0378***	

Notes: Multinomial logits, where dependent variable is change in *CogAb* quartile (no change is the base outcome). Model (0) is the full sample. Models (1)–(4) are quartile sub-samples, based on the starting *CogAb* rank of the child at age 7. Standard errors are in parenthesis and *, **, and *** denote significance at the 10%, 5%, and 1% levels respectively.

Latent Growth Curve Model

The LGCM begins with examination of a null, or unconditional model, where there are no predictors. In this model, the average *CogAb* rank at age 7 was 3814.584 ($p < .01$), and the variance of both the intercept and the slope were significant, indicating that potential predictors could be evaluated to account for the unexplained variance in the initial value of *CogAb* and change in *CogAb* over time (i.e., this variance showed that individuals differed significantly in their ranks, both *CogAb* at 7 and their growth trajectories).

Following common practice with LGCM, predictors were added to make the model conditional, i.e., the intercept and slope were adjusted for the influence of predictors. Table 5 displays the results. Significant effects on initial rank of *CogAb* (i.e., the intercept) were as follows: Mothers who are taller, older, and have had fewer pregnancies are associated with a higher *CogAb* ranking for their children at age 7. Also, female children, those who were heavier at birth, over 40-weeks gestation, and were the third child or less had significantly higher ranking in *CogAb* at 7. Furthermore, in comparison to those in the lowest SES category, all other SES groups had a higher initial ranking of *CogAb*.

Table 5: Latent Growth Curve Model on *CogAb* Ranking

	Intercept		Slope	
Maternal height	51.298***	(13.021)	0.814	(5.489)
Maternal age	297.685***	(22.814)	-3.689	(9.618)
Birth order	-198.321***	(35.186)	-33.861***	(14.834)
Gender	188.565***	(45.306)	24.297	(19.101)
Gestation	99.447**	(41.543)	-43.942**	(17.514)
Birthweight	154.694***	(22.065)	6.862	(9.302)
Gravidity	-191.079***	(35.605)	-6.158	(15.011)
High SES	2054.392***	(83.676)	-45.299	(37.277)
Medium high SES	1348.176***	(75.588)	55.255*	(31.867)
Medium low SES	680.045***	(52.049)	-34.880	(21.943)
SES_neg2	-979.127***	(184.250)	-66.219	(77.677)
SES_neg1	-500.939***	(88.548)	-14.639	(37.331)
SES_pos1	229.530***	(64.568)	-22.356	(27.221)
SES_pos2	529.609***	(104.620)	120.725***	(44.107)

Standard errors are in parenthesis and *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.
Model Fit χ^2 (85) = 3779.396, $p < .01$, CFI = .902, ILI = .902, RMSEA = .075

While all 14 covariates were significant in explaining *CogAb* at age 7, only four of these remained significant, with regard to explaining the growth in *CogAb* between ages 7 and 11 (i.e., the slope). First, birth order negatively affected the slope, and its impact was much smaller relative to its role in explaining the intercept. Second, interestingly, gestational age had a significant positive effect on the intercept, but a significant negative effect on the slope. This indicated that greater gestational age was associated with higher cognition in early childhood; however, those who were above average gestation tended to regress toward the mean of cognition over time. Effectively, the positive impacts of intrauterine growth on cognition for those with greater gestational age are most likely achieved in very early childhood and then diminish as the child ages.

Turning our focus to the SES related variables, only medium-high SES at birth and SES_pos2 were significant drivers of the slope. The former was only significant at the 10% level and had a much smaller impact relative to the role played by the same variable in determining the intercept. The positive and highly significant impact of SES_pos2 aligned with the results from Tables 3 and 4, illustrating that yes, change in SES during early childhood could impact a child's cognitive development post age 7, but only if the change was a large upward shift.

5. Conclusion

This study used a valuable historical dataset from Aberdeen, Scotland, which provided multiple measurements of childhood *CogAb* at ages 7, 9, and 11. Along with expected covariates that influence cognition, such as birth characteristics and SES at birth, this dataset also included pertinent information on change in a child's environment, via changes in paternal SES. Such information enabled empirical analysis that attempted to disentangle the role of different early childhood influences on an individual's cognitive ability at age 7, as well as the growth trajectory from age 7 to 11.

This research also aimed to showcase LGCM's value in health economics. This methodology provided a useful tool to simultaneously assess the predicted impact of relevant explanatory variables on *CogAb* at age 7 (the intercept) as well as the growth trajectory forecast from age 7 to 11 (the slope).

Overall, three key findings resulted from our empirical endeavors. First, we corroborated past findings on perinatal determinants and their impact on child *CogAb* by age 7; for example, the positive influence of being early in the birth order and a normal gestational age. Second, we showed that subsample analysis is critical when modeling cognitive development of a birth cohort. For instance, SES at birth played a minor role in determining change in *CogAb* ranking from ages 7 to 11 in the full sample, but its effects were clearer in subsample analysis. The evidence indicated a strong positive impact of having high SES at birth, in terms of pushing children up the cognitive ladder (by at least two quartiles) for those in the bottom half of the distribution.

Our third finding involved the influence of SES. Most past studies that have focussed on the impact of SES on *CogAb* of children have relied on one measure of SES, whether at birth, or at a particular time during the child's development. In this study, via temporal measures in SES, we are able to assess the influence of family SES when the child was born and changes in family SES during those crucial early development stages (newborn to primary-school age). We found a multitude of evidence pointing to the paramount importance of SES at birth, with higher levels of SES increasing the cognitive ranking of the child at age 7, and the effects persisting in the cognitive trajectory of that child from age 7 to 11. In contrast, change in SES, while influencing *CogAb* at age 7, appears to have minimal impact beyond that age. The majority of results pointed to growth trajectory in *CogAb* from ages 7 to 11 responding only to large upward SES shifts. This would be akin to a father's occupation changing from unskilled manual work, to skilled non-manual or professional work.

As a final caveat, we must note that the change in SES variable could have captured a number of other aspects in the early home environment that we were unable to distinguish in this analysis. For example, there was no measure of different parenting practices or values included in this dataset and how that may have influenced cognition. Armstrong (2012) found that when parents transferred their beliefs, such as signaling to children their "belief in a just world," this reduced the importance of parental income or SES as a determinant. Consequently, future research could delve into the mediating relationships between SES, change in SES and childhood cognition outcomes.

References

Armstrong, A. (2012). Belief in a Just World and Children's Cognitive Scores. *National Institute Economic Review, 222*(1), R7-R19. 10.1177/002795011222200102

Alderman, H. & Behrman, J. (2004). Estimated Economic Benefits of reducing Low Birth Weight in Low-Income Countries. *Health, Nutrition and Population, World Health Organisation, 35548*, 34.

Auld, M. & Sidhu, N. (2005). Schooling, cognitive ability and health. *Health Economics*, 14: 1019-1034.

Bartels, M., Rietveld, M., Van Baal, G., & D. Boomsma (2002). Genetic and environmental influences on the development of intelligence. *Behavior Genetics, 32,* 237-249.

Batty, G. D. & Deary, I. J. (2004). Early life intelligence and adult health. Emerging associations, plausible mechanisms, and public health importance. BMJ2004; 329:585–6. *British Medical Journal, 329*(7466), 2.

Batty, G. D., Deary, I. J., & Macintyre, S. (2007). Childhood IQ in relation to risk factors for premature mortality in middle-aged persons: the Aberdeen Children of the 1950s study. *J Epidemiol Community Health, 61*(3), 241-247. 10.1136/jech.2006.048215

Batty, G. D., Morton, S. M. B., Campbell, D., et al., (2004). The Aberdeen children of the 1950s cohort study: background, methods, and follow-up information on a new resource for the study of life-course and intergenerational effects on health. *Paediatric and Perinatal Epidemiology, 18*(3), 18.

Becker, G. S. (1993). *Human Capital* (3rd ed.). Chicago: The University of Chicago Press.

Boardman, J. D., Powers, D. A., Padilla, Y. C., et al., (2002). Low birth weight, social factors, and developmental outcomes among children in the United States. *Demography, 39*(2), 353-368.

Boat, B. W., Campbell, F. A., & Ramey, C. T. (1986). Preventive education and birth order as co-determinants of IQ in disadvantaged 5-year-olds. *Child: Care, Health and Development, 12*(1), 12.

Brant, A., Haberstick, B., Corley, R., Wadsworth, S., DeFries, J., & J. Hewitt (2009). The Developmental Etiology of High IQ. *Behavior Genetics, 39,* 393-405.

Breslau, N., Chilcoat, H., DelDotto, J., et al., (1996). Low birth weight and neurocognitive status at six years of age. *Biological Psychiatry, 40*(5), 389-397.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Cambridge, MA: Harvard University Press.

Bronfenbrenner, U. (1994). Ecological models of human development. In M. Gauvain & M. Cole (Eds.), *Readings on the development of children* (2nd ed., pp. 37–43). Oxford: Elsevier.

Case, A., Fertig, A., & Paxson, C. (2005). The lasting impact of childhood health and circumstance. *Journal of Health Economics*, 24: 365-389.

Cesur, R., & Kelly, I. R. (2010). From Cradle to Classroom: High Birth Weight and Cognitive Outcomes. *Forum for Health Economics & Policy, 13*(2), 1-24. 10.2202/1558-9544.1189

Curran, P., & Willoughby, M. (2003). Implications of latent trajectory models for the study of developmental psychopathology. *Development and Psychopathology*, 15(3): 581-612.

Deary, I., Whiteman, M. C., Starr, J. M., Whalley, L. J., & Fox, H. C. (2004). The Impact of Childhood Intelligence on Later Life: Following Up the Scottish Mental Surveys of 1932 and 1947. *Journal of Personality and Social Psychology, 86*(1), 130-147.

Duncan, T. & Duncan, S. (2004). An Introduction to Latent Growth Curve Modeling. *Behavior Therapy, 35*, 333-363.

General Register Office. (1951). *Classification of occupations 1950*. London.

George, A., Stokes, L., & Wilkinson, D. (2012). Does Early Education Influence Key Stage 1 Attainment? Evidence for England from the Millennium Cohort Study. *National Institute Economic Review, 222*(1), R67-R80. 10.1177/002795011222200106

Guo, G. & Harris, K. M. (2000). The mechanisms mediating the effects of poverty on children's intellectual development. *Demography, 37*(4), 431-447.

Hawkes, D. & Joshi, H. (2012). Age at Motherhood and Child Development: Evidence from the UK Millennium Cohort. *National Institute Economic Review, 222*(1), R52-R66. 10.1177/002795011222200105

Heckman, J. (2012). The developmental origins of health. *Health Economics*, 21: 24-29.

Heckman, J. & T. Kautz (2012). Hard evidence on soft skills. *Labour Economics,* 19: 451-464.

Hopkins, K. D., & Bracht, G. H. (1975). Ten-year stability of verbal and nonverbal IQ scores. *American Educational Research Journal, 12*(4), 469-477.

Humpreys, L. & T. Davey (1988). Continuity in intellectual growth from 12 months to 9 years. *Intelligence, 12,* 183-197.

Illsley, R. (2002). A City's Schools: From equality of input to inequality of outcome. *Oxford Review of Education, 28*(4), 427-445. 10.1080/0305498022000013607

Jefferis, B. J., Power, C., & Hertzman, C. (2002). Birth weight, childhood socioeconomic environment, and cognitive development in the 1958 British birth cohort study. *British Medical Journal, 325*(7359).

Jensen, A.R. (1998). The g factor: The science of mental ability. Westport, CT: Praeger.

Joshi, H. (2012). From Cradle to Career: Evidence from the British Birth Cohort Studies on the Family, Education and Employment – Introduction. *National Institute Economic Review, 222*(1), R1-R6. 10.1177/002795011222200101

Kramer, R. A., Allen, L., & Gergen, P. J. (1995). Health and social characteristics and children's cognitive functioning: results from a national cohort. *American Journal of Public Health, 85*(3), 312-318.

Lawlor, D. A., Batty, G. D., Morton, S. M. B., Deary, I. J., Macintyre, S., Ronalds, G., & Leon, D. A. (2005). Early Life Predictors of Childhood Intelligence: Evidence from the Aberdeen Children of the 1950s Study. *Journal of Epidemiology Community Health, 59*, 7. 10.1136

Leon, D. A. (2006). Cohort Profile: The Aberdeen Children of the 1950s Study. *International Journal of Epidemiology, 35*, 549-552. 10.1093/ije/dyi319

McLoyd, V. C. (1998). Socioeconomic disadvantage and child development. *American Psychologist, 53*(2), 185-204.

Neisser, U., Boodoo, G., Bouchard, T. J. J., Boykin, a. W., Brody, N., Ceci, S. J., … Urbina, S. (1996). Intelligence: Knowns and unknowns. *American Psychologist, 51*(2), 77-101. doi:10.1037/0003-066X.51.2.77

O'Callaghan, M., Williams, G. M., Andersen, M. J., et al. (1995). Social and biological risk factors for mild and borderline impairment of language comprehension in a cohort of five-year-old children. *Developmental Medicine and Child Neurology, 37*(12), 1051-1061.

Osler, M., Andersen, A. M., Due, P., & et al. (2003). Socioeconomic position in early life, birth weight, childhood cognitive function, and adult mortality. A longitudinal study of Danish men born in 1953. *Journal of Epidemiology and Community Health, 57*(11), 681-686.

Potthoff, R. & Roy, S. (1964). A generalized multivariate analysis of variance model useful especially for growth curve problems. *Biometrika*, 51: 313-326

Richards, M., Hardy, R., Kuh, D., & Wadsworth, M. (2001). Birth weight and cognitive function in the British 1946 birth cohort: longitudinal population based study. *British Medical Journal, 322*(27 January), 199-203.

Richards, M., Hardy, R., Kuh, D., et al. (2002). Birthweight, postnatal growth and cognitive function in a national UK birth cohort. *International Journal of Epidemiology, 31*(2), 342-348.

Richards, M. & Hatch, S. L. (2012). A Life course approach to the development of mental skills. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 66*(Supp 1), i26-i35. 10.1093/geronb/gbr013

Rowe, D. C., Jacobson, K. C., & Van den Oord, E. J. (1999). Genetic and environmental influences on vocabulary IQ: parental education level as moderator. *Child Dev, 70*(5), 1151-1162.

Sameroff, A. J., Seifer, R., Baldwin, A., & Baldwin, C. (1993). Stability of intelligence from preschool to adolescence: the influence of social and family risk factors. *Child development, 64*(1), 80-97.

Shenkin, S. D., Starr, J. M., Pattie, A., et al. (2001). Birth weight and cognitive function at age 11 years: the Scottish mental survey 1932. *Archives of Disease in Childhood, 85*(3), 189-197.

Shenkin, S. D., Starr, J. M., & Deary, I. J. (2004). Birth weight and cognitive ability in childhood: a systematic review. *Psychological Bulletin, 6*(130), 989-1012.

Starr, J. M., Taylor, M. D., Hart, C. L., et al. (2004). Childhood mental ability and blood pressure at midlife: linking the Scottish mental survey 1932 and the Midspan studies. *Journal of Hypertension, 22*(5), 893-897.

Taylor, M. D., Hart, C. L., Davey Smith, G., et al. (2003). Childhood mental ability and smoking cessation in adulthood: prospective observational study linking the Scottish mental survey 1932 and the midspan studies. *Journal of Epidemiology and Community Health, 57*(6), 464-465.

Turkheimer, E., Haley, A., Waldron, M., et al. (2003). Socioeconomic status modifies heritability of IQ in young children. *Psychological Science, 14*(6), 623-628.

Villarroel, L., Karzulovic, l., Manzi, J., Eriksson, J. G., & Mardones, F. (2013). Association of perinatal factors and school performance in primary school Chilean children. *Journal of Developmental Origins of Health and Disease, 4*(3), 232-238. http://dx.doi.org/10.1017/S2040174413000020

Whalley, L. J. & Deary, I. J. (2001). Longitudinal cohort study of childhood IQ and survival up to age 76. *British Medical Journal, 322*(7290), 819-823.