RESEARCH REPORT

Childhood socioeconomic status and adult health: comparing formative and reflective models in the Aberdeen Children of the 1950s Study (prospective cohort study)

Gareth Hagger-Johnson,[1] G David Batty,[1,2] Ian J Deary,[2] Sophie von Stumm[3]

[1]Department of Epidemiology and Public Health, University College London, London, UK
[2]Centre for Cognitive Ageing and Cognitive Epidemiology, Department of Psychology, The University of Edinburgh, Edinburgh, Scotland, UK
[3]Department of Psychology, University of Chichester, Chichester, UK

Correspondence to
Dr Gareth Hagger-Johnson, Department of Epidemiology and Public Health, University College London, 1–19 Torrington Place, London WC1E 6BT; g.hagger-johnson@ucl.ac.uk

Accepted 28 February 2011
Published Online First 21 April 2011

ABSTRACT

Background Health at midlife is associated with early-life socioeconomic status (SES), intelligence and education; the latter often used as a marker of SES in adulthood. SES is typically modelled as a latent construct with reflective indicators (where the construct causes the variables) but may be better operationalised as a formative trait (where the variables cause the construct). In this report, the authors explain the difference between these two approaches and evaluate reflective and formative modelling for the prediction of health outcomes.

Methods The Aberdeen Children of the 1950s Study comprises 12150 children from the Aberdeen area of Scotland, of whom 7183 completed a follow-up questionnaire in middle age. Data were available on indicators of parental SES at birth of the participant, childhood intelligence at age 11 and education and self-rated health at midlife.

Results Childhood SES predicted childhood intelligence and educational attainment in adulthood, both of which partially mediated the effects of SES on self-rated health. Both approaches produced well-fitting models (CFI>0.99, TLI>0.99 and RMSEA<0.03), detected indirect effects from parental SES to health (all ps<0.001) and accounted for similar proportions of variance in health.

Conclusions In these data, there was little difference between reflective and formative models of SES in their ability to elucidate pathways from childhood SES to adult health. Formative approaches to modelling SES seem appropriate theoretically, yet reflective models were equally informative. The outcome chosen here was self-rated health, but the models are extensible to other health outcomes. Results may differ in other data sets, suggesting that it is first appropriate to compare both strategies.

INTRODUCTION

Lower parental socioeconomic status (SES) and childhood intelligence are associated with poorer health outcomes at midlife[1–3] and reduced life expectancy.[4–9] Both educational achievement and adult SES may mediate the effects of childhood psychosocial variables on health outcomes[1 4 6]. The direction of causation for these associations has generated debate.[1 10–12] Perspectives on the causal primacy of socio-economic versus cognitive factors have lead to different modelling strategies for intelligence and SES.[11–16]

Here, we concentrate on, and formally test, one aspect of such modelling differences. It is often helpful to model SES as a latent variable, which represents only the shared variance across different indicators of SES. This removes measurement error associated with relying on one indicator only, as is typical using standard linear regression approaches. There are two approaches to modelling latent variables, however: reflective and formative. To our knowledge, no study to date has compared these approaches within prospective life course model of health. Indicators treated as reflective imply that SES is an underlying dimension that causes the observed variables (figure 1A). Arrows point from SES to the observed variables, suggesting that they are caused by SES. By contrast, indicators treated as formative are independent predictors of SES and therefore *cause* levels of SES (figure 1B). Here, arrows point from the indicators causing SES. The present study examines whether modelling parental SES as a formative trait can improve its predictive power for self-rated health, alongside a latent intelligence trait and education.

General intelligence is usually modelled as a latent variable with reflective indicators. This means that an underlying (latent) trait or dimension of cognitive ability explains the covariance among individual test scores that were used as the marker traits of intelligence. These tests might include reasoning, vocabulary, memory and other types of mental test. The cognitive test scores are thus reflective indicators, causally dependent on the latent variable (figure 1A), following the rationale of classical test theory and factor analysis.[13 14] Similarly, SES has been typically modelled as reflective.[15 16] However, it has been argued that a latent trait of SES cannot determine variables, such as occupational social class, housing tenure and car ownership.[13] Instead, it is argued that SES is informed by these variables, which are commonly referred to as 'formative indicators' (figure 1B).

The choice of modelling strategy potentially has important implications for understanding associations of SES and childhood intelligence with health inequalities in adulthood. Given that the data themselves cannot mandate a specific modelling strategy,[17] the decision to use reflective or

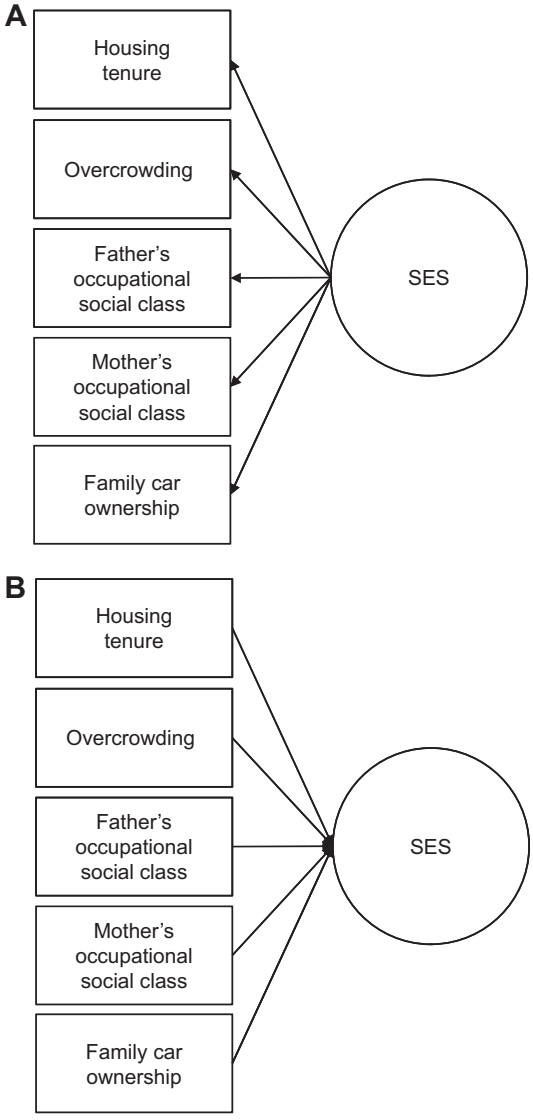

Figure 1 (A) Reflective indicator model of SES. (B) Formative indicator model of SES.

formative indicators lies with the researcher. Researchers may choose reflective indicators because they are familiar, are less restrictive,[15 16] or may have theoretical grounds for arguing that SES is an individual characteristic or trait, influencing the levels of education, income and occupational social class that people achieve (implied by figure 1A).

The aim of the current study was to evaluate empirically the impact of choosing a reflective or formative approach to formulating childhood SES in a structural model of the contributions of SES, intelligence and educational attainment to health at midlife. To this end, the study uses data from the Aberdeen Children of the 1950s (ACONF) Study,[18] a large birth cohort study from Scotland offering unusual intergenerational and life course data.

METHODS

Design/setting and participants

The ACONF Study sampled 12 150 children (6282 boys and 5868 girls) born in Aberdeen, Scotland, between 1950 and 1956. At ages 6–12, children completed mental ability tests and provided demographic information. In 1964, mothers from a random subsample (1 of 5; n=2510) provided detailed information on the family's SES and children's home environment. The surveys were linked with sociodemographic information on families from birth certificates, hospital records and Scottish population registries. The sample was followed up with a postal questionnaire between 2001 and 2003 when participants were aged 46–51 years; the response was 64% (n=7183).[18 19] Ethical approval for this revitalisation of the ACONF Study was approved by the London School of Hygiene & Tropical Medicine ethics committee, the Grampian Research Ethics Committee and the Multi-Centre Research Ethics Committee for Scotland.

Parental SES

Five variables were selected as indicators of parental SES based on either prospectively or retrospectively gathered data: mother's and father's occupation at the time of the child's birth, house tenure, overcrowding and family car ownership. Information on parents' occupational social class was extracted from obstetric hospital records and recorded on a 6-point scale, according to the Office of Population Censuses and Surveys registrar general's classification of occupations. Scores ranged from 1–6, with 1=unskilled, 2=semiskilled manual, 3=skilled manual, 4=skilled non-manual, 5=intermediate/technical and 6=professional. Data on occupational status were considered missing for unemployed fathers and fathers who died before the child was born. Previous analyses have shown that treating deceased fathers as missing did not have an impact on the representativeness of the sample.[18] For mothers whose occupation was known, occupation prior to pregnancy was recorded. Housing tenure was evaluated on a 4-point scale: 1=living with other relatives, 2=rented from council, 3=rented privately and 4=owner. The number of rooms was treated as continuous, ranging from 1 to 9. This was divided by the number of persons in the household to create an overcrowding index, where higher scores indicate less overcrowding. In the follow-up survey, the ACONF Study members recalled car ownership of their family when aged 12 years; car ownership was treated as a binary variable.

Childhood intelligence

Within six months of their 11th birthday, children completed 4 intelligence tests, including the Moray House Verbal Reasoning (I and II), arithmetic and English tests.[16] Local education authorities provided the test materials and corresponding manuals with scoring and standardisation instructions. The Moray House Verbal Reasoning test (I and II) comprised a variety of items, including finding synonyms and antonyms to a given reference word, spelling exercises and deductive reasoning problems.[20] The arithmetic test comprised two sections. The first 40-item section assessed children's ability to add, subtract, multiply and divide. The second part comprised 44-worded arithmetic problems, which required fractions and understanding of non-metric units. The English test included a set of 16 different tasks, which assessed text comprehension, grammar and spelling.[16]

Educational attainment

During the follow-up survey between 2001 and 2003, an educational attainment was recorded. The highest level of educational attainment was derived: 1=no formal qualification, 2=school-leaving qualification, 3=clerical qualification, 4=O-levels, 5=highers/Certificate of Secondary Education (CSE) , 6=Higher National Certificate (HNC) and 7=degree. In Scotland, O-levels were a certificate of secondary education, and highers/CSE were advanced school-leaving certificates enabling entry to a university.

Self-rated health

Respondents were asked to rate their general health over the past 12 months on a 4-point scale, with responses ranging from 'poor' to 'excellent'. This item is widely used in large-scale population-based studies and has shown itself to be a valid measure of health[21] and a robust predictor of later mortality risk across the full range of responses.[22]

Statistical analysis

Two competing models were fitted and compared: the first model operationalised childhood SES as a reflective construct (figure 2A), and the second model treated SES as a formative trait (figure 2B). Both models position childhood SES and childhood intelligence according to their temporal sequence, although we emphasise that both variables have unassessed, perhaps shared, causes that are external to the path diagram (eg, genetic and environmental determinants). Childhood SES was treated as the more distal variable, influencing general childhood intelligence (*g*, a mediator), adult educational attainment (a more proximal mediator) and general health (outcome variable). Direct and indirect pathways were permitted from childhood SES to *g*, education and general health. Both childhood intelligence and SES allowed not only direct paths to health at midlife but also indirect effects that were partially mediated by adult

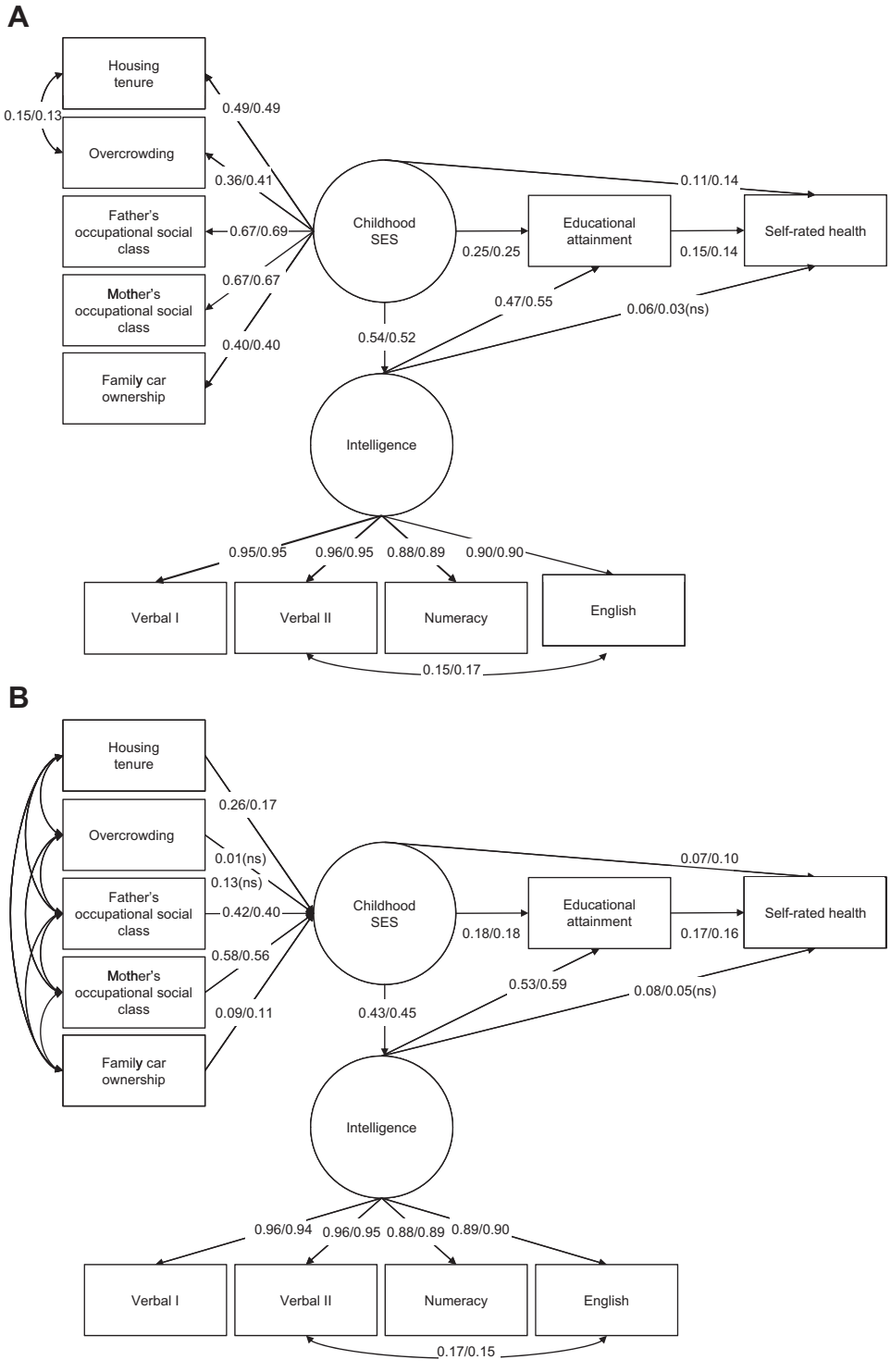

Figure 2 (A) Structural equation model with childhood SES measured as a reflective indicator model and associations with childhood intelligence, educational attainment and self-rated health in adulthood. (B) Structural equation model with childhood SES measured as a formative indicator model and associations with childhood intelligence, educational attainment and self-rated health in adulthood. ns, not significant ($p>.05$).

educational attainment. The statistical significance of indirect pathways was tested using the Sobel test which determines the significance of the indirect effect through the mediator. Both models were tested using Muthén,L.K. and Muthén, B.O. (1998-2010). Mplus User's Guide. Sixth Edition. Los Angeles, CA: Muthén & Muthén (www.statmodel.com) with full-information maximum likelihood estimation, which uses all available data (complete and incomplete) under the previously tested[16] assumption of data missing at random.

In the reflective indicator indicator model (figure 2A), the single-headed arrows flow from a reflective latent SES construct to five indicators of childhood SES. This model implies that an underlying SES trait influenced each indicator and that a unit change in the latent variable would result in a corresponding change in all five indicators simultaneously by a function of the factor loadings. The latent variable, by definition, is free from measurement error (figure 2A); one reference indicator was restricted to one to define the metric of the latent trait.

In the formative indicator model, the arrows flow from the five indicators to the formative SES trait. In this model, childhood SES is defined by the five formative indicators (figure 2B), which were allowed to correlate freely; significant and positive intercorrelations of indicators are not a formal requirement.[13] The variance of the first indicator was set to 1 to form the metric of the latent variable. To identify the model, the residual variance of the latent variable was fixed to 0. Less restrictive approaches which allow a residual error term are available[23] but these were not suitable for our hypothesised model.

RESULTS

Characteristics of the participants included in the analysis are shown in table 1. Given prior evidence for sex differences in educational attainment and health outcomes, and evidence that coefficients differed significantly by gender in preliminary analyses, results were analysed separately for men and women.

Reflective indicator model

Lagrange multiplier tests suggested that allowing two pairs of correlated error terms ('Verbal II' and 'English' and 'housing tenure' and 'overcrowding') would improve model fit. These correlated errors are substantively meaningful given that verbal skills are required to solve verbal reasoning tasks and given that better-quality housing is more likely to have additional rooms, reducing overcrowding. The fit of the final model was excellent by several criteria: $\chi^2(92)=167.15/148.57$ (men/women), $p<0.001$, Comparative Fit Index (CFI)=0.996, Tucker Lewis Index (TLI)=0.995 and Root Mean Square Error of Approximation (RMSEA)=0.020 (95% CI 0.018 to 0.022). A significant χ^2 test is typical with large sample sizes.[24] In figure 2A, the numbers of the latent trait indicators are factor loadings, which are part of the measurement model and indicate the strength of relationship between the factor and its reflective indicators. For intelligence and SES, factor loadings were significant and invariant across sexes ($p=0.07$). Parental SES was a strong correlate of intelligence and education for men and women; however, the direct effect of childhood SES on health at midlife was significant for men only.

The model implies indirect pathways, connecting childhood SES with health via intervening (mediating) variables, or mechanisms. These indirect effects can be tested for statistical significance. The indirect effect from SES to health via education was significant in men and women. A 1-SD increase in SES was associated with a 0.03 increase in health, resulting from the effect of SES on education, which influences health in turn ($p<0.01$). The indirect effect from SES to intelligence was only significant in men. A 1-SD increase in SES was associated with a 0.03 increase in health through intelligence ($p=0.02$). As shown in figure 2A, the strongest predictor of health was education, followed by SES and then intelligence. The model accounted for 8% of the variance in health for men and 7% for women. A version of the model in which parental social class and car ownership were treated as ordered categorical (polytomous) and categorical, respectively, was also tested (results not shown). There were no differences in the sign, size and significance of any pathways.

Formative indicator model

All correlations among the formative indicators were significant and positive, implied by the double-headed arrows next to the SES latent trait in figure 2B. Table 2 shows the bivariate correlations among the indicators of SES. As in the reflective model, three indirect paths to health from social class of origin were hypothesised (via education, intelligence and intelligence then education). The model showed excellent fit by several criteria for men and women, respectively ($\chi^2(30)=78.53/78.88$, $p<0.001$, CFI=0.998, TLI=0.997 and RMSEA=0.02; 95% CI 0.01 to 0.02). In figure 2B, the numbers attached to each indicator are regression weights, representing the best linear composite of variables, which maximally predict the three paths emitting from the latent variable to intelligence, education and health. In the reflective model, these values are factor loadings (the unit change

Table 1 Characteristics of participants included in the analysis

	Total		Men		Women	
Characteristic	**Mean (SD)**	**N**	**Mean (SD)**	**n**	**Mean (SD)**	**n**
Verbal reasoning I	104.06 (13.47)	11 303	103.74 (13.87)	5894	104.40 (13.02)	5409
Verbal reasoning II	104.21 (14.08)	11 270	103.59 (14.30)	5875	104.89 (13.80)	5395
Numeracy	104.65 (14.44)	9625	104.25 (14.74)	5037	105.09 (14.10)	4588
Literacy	103.53 (14.43)	9625	102.92 (14.58)	5037	104.20 (14.24)	4588
Education*	4.35 (2.13)	6964	4.55 (2.12)	3336	4.17 (2.11)	3628
Health*	3.01 (0.78)	7144	3.06 (0.78)	3428	2.97 (0.78)	3716
Childhood SES						
Housing tenure*	2.33 (0.79)	2201	2.30 (0.77)	1096	2.36 (0.81)	1105
Number of rooms*	3.71 (1.07)	2209	3.68 (1.09)	1104	3.73 (1.06)	1105
Father's occupational social class*	2.85 (1.21)	11 469	2.85 (1.22)	5952	2.86 (1.19)	5517
Mother's occupational social class*	3.12 (1.46)	10 818	3.11 (1.47)	5582	3.14 (1.45)	5236
Family owned a car, n (%)	3482 (48.9)		1646 (48.4)		1646 (48.4)	

*Treated as continuous.
SES, socioeconomic status.

Table 2 Bivariate correlations between indicators of socioeconomic status in childhood: boys (n=5826) and girls (n=6241)

	1	2	3	4	5
1. Housing tenure	—	0.32	0.42	0.30	0.23
2. Overcrowding	0.28	—	0.37	0.23	0.19
3. Father's occupational social class	0.32	0.26	—	0.45	0.30
4. Mother's occupational social class	0.27	0.21	0.44	—	0.25
5. Family owned a car	0.12	0.12	0.29	0.25	—

Correlations are below/above the diagonal for boys/girls based on all available data for each variable. Missing data are estimated using the maximum likelihood estimator, excluding 84 participants with missing data on all variables (all ps<0.01).

in the indicators per unit change in SES), but in this formative model, these values are regression weights (the unit change in SES per unit change in the indicators).[13] Mother's social class was the strongest predictor, followed by father's social class, housing quality and having a family car. Overcrowding in the family home was not significant, after allowing for its correlation with other indicators. In contrast to the reflective approach, a 1-unit change in overcrowding was not associated with a corresponding change in SES. Additionally, car ownership was a weaker predictor of SES when compared with parental social class and housing tenure. Childhood SES was similarly, albeit less strongly, associated with intelligence, education and health in the formative model compared with the reflective model. Each 1-SD increase in SES was associated with a 0.01 increase in health via intelligence and education in men (p<0.01). In women, only the indirect pathway through education was significant, with the same effect size (p=0.01). For men and women, the predictor variables accounted for 7% of the variance in health as a set.

In summary, the reflective and formative modelling strategies had little influence on the association between childhood SES and childhood intelligence and on pathways from childhood SES and intelligence to education attainment and adult health. Neither did choice of strategy influence the proportion of variance accounted for in health. Although formative indicators are substantively meaningful and theoretically plausible, reflective indicators were equally informative for these data.

DISCUSSION

The aim of our study was to evaluate the impact of two alternative modelling strategies of childhood SES (with reflective or formative indicators) in life course models illustrating associations of childhood intelligence (*g*), educational attainment and self-rated health in adulthood. Both approaches fitted the data well and were able to detect direct and indirect pathways from childhood SES to self-rated health. Additionally, they accounted for similar proportions of variance in self-rated health. The only substantively important differences concerned the significance of indicators of parental SES, which were all statistically significant in the reflective model but not in the formative model.

Both approaches showed only small differences in path parameters and suggested that childhood intelligence and education partly mediated the effects of childhood SES on health at midlife. Pathways from childhood SES to health (reflective approach) and childhood ability to health (formative approach) were significant in men but not in women; however, the differences in effect sizes were negligible across reflective and formative models. In accordance with previous findings,[8 21] education was the strongest predictor of good health, whereas the direct effects of childhood intelligence and SES were small, holding other variables in the model constant.

In the formative model, mother's and father's social class, housing tenure and car ownership were significant predictors of the 'composite' SES latent variable; overcrowding, however, was non-significant after controlling for its correlations with other indicators. In contrast, all indicators were significant in the reflective model. These differences arise because of the nature of the modelling strategy chosen. Formative constructs form a linear index that is entirely dependent on its indicators, as well as all other paths emitted from the latent variable. That is, formative indicators are not required to correlate with one another but constitute independent variables that predict a latent construct through which they may (or may not) affect other variables and constructs in a given model. In contrast, reflective indicators must be positively intercorrelated, implying internal consistency. Here, a unit change in SES produces a corresponding change in every reflective indicator. Clearly, however, an increase in SES does not result in a corresponding increase in parental occupational class, housing quality and car ownership. Although formative indicators are more conceptually attractive for this reason, indicators chosen to represent SES are often inconsistent across studies,[15 16] which may contribute to differences in results.[25] Because parental SES is simply the best linear combination of the chosen set of indicators, a different set of indicators may produce a different latent variable, with different relationships to health outcomes. In contrast, reflective constructs (eg, intelligence) replicate well and are easier to compare across studies—even when the chosen indicators differ.[14 15 26]

A key finding of the analyses conducted here is that there was very little difference in the ability of each modelling strategy—treating childhood SES as a formative or reflective construct with respect to its marker variables—to elucidate direct and indirect pathways from childhood SES to educational and health outcomes in later life. This may not be the case for other studies. We recommend comparing both strategies as a sensitivity analysis before concluding that results are equivalent. The similarities we observed were not inevitable. Replications in other cohort studies would be particularly informative, particularly if there is a wider range of different SES indicators that were shown to produce different results. Again, given the present data, the differences in the formation of a childhood SES construct from being a reflective to a formative one did not appear to enhance its predictive power or to ameliorate any psychometric limitations that SES measurement might have over, say, intelligence measurement.

Analyses were based on a large intergenerational cohort, with prospective data available on indicators of childhood SES and childhood intelligence, as well as educational attainment and psychological health in adulthood. By comparing two different modelling strategies, we were able to evaluate the minimal impact each choice had on the relationship observed between parental SES and later outcomes. The present study is the first to demonstrate the limited impact of modelling parental SES with formative indicators in an intergenerational cohort designed to evaluate the impact of biological and social variables across the life course.[18 19] Other cohorts, particularly with different indicators of childhood SES, may not produce equivalent results.

Limitations of the current study include attrition and missing data patterns, which may have distorted some model estimates. However, we used maximum likelihood estimation so that the models were informed by all data available. Additionally, data were not available on parental intelligence, which might be related to childhood SES and childhood intelligence, introducing a confounding factor. Intelligence has both genetic and

What is already known on this subject

- Parental SES and childhood intelligence (*g*) are intercorrelated predictors of health outcomes in later life.
- SES is often modelled as a latent construct with *reflective* indicators (where the construct causes the indicators). Alternatively, SES can be modelled using *formative* indicators (where the indicators cause the construct). Taking the life course approach, the impact of each modelling strategy on later health prediction is not known.

What this study adds

- Using data from the *ACONF* cohort Study, reflective and formative constructs of childhood SES were evaluated in relation to childhood intelligence, education and health status at midlife.
- Notably, results were found to differ negligibly across model strategies. Although the formative approach is theoretically and statistically a more adequate approach, reflective modelling was more convenient and equally informative for these data. Both strategies should be compared in other studies.

environmental determinants, with gene × environment interactions further complicating attempts to isolate the unique component of each.[27–29] Although childhood SES was shown to predict intelligence, disentangling the contribution of genetic and environmental factors was beyond the scope of our analysis. Finally, the current models did not include adult SES as an additional mediating variable, only educational attainment. This was deliberate in order to achieve clarity in comparing two conceptualisations of childhood SES.

In conclusion, we found that the choice of model (reflective vs formative) does make a difference in how we conceptualise parental SES but makes little difference in its association with important life course outcomes. Formative indicators provide an opportunity to evaluate the specific contribution of each indicator, but reflective indicators are easier to model within the structural equation modelling framework. Although we found no important differences, readers may want to compare reflective and formative approaches to modelling SES—including childhood and adult SES—in their own data, to better understand the relative contribution of social and cognitive factors in childhood to health inequalities.

Acknowledgements Funding from the Biotechnology and Biological Sciences Research Council (BBSRC), Engineering and Physical Sciences Research Council (EPSRC), Economic and Social Research Council (ESRC) and Medical Research Council (MRC) is gratefully acknowledged. The authors are grateful to the ACONF Study participants, study team and steering group. We thank Heather Clark for maintaining and building the data set.

Funding Prof Deary and Dr Batty are members of The University of Edinburgh Centre for Cognitive Ageing and Cognitive Epidemiology, part of the cross-council Lifelong Health and Wellbeing initiative (G0700704/84698). David Batty is a Wellcome Trust Career Development Fellow.

Competing interests None.

Ethics approval This study was conducted with the approval of the London School of Hygiene & Tropical Medicine ethics committee, the Grampian Research Ethics Committee and the Multi-Centre Research Ethics Committee for Scotland.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Singh-Manoux A,** Ferrie JE, Lynch JW, *et al*. The role of cognitive ability (intelligence) in explaining the association between socioeconomic position and health: evidence from the Whitehall II prospective cohort study. *Am J Epidemiol* 2005;**161**:831—9.
2. **Singh-Manoux A,** Sabia S, Kivimaki M, *et al*. Cognition and incident coronary heart disease in late midlife: the Whitehall II study. *Intelligence* 2009;**37**:529—34.
3. **Whalley LJ,** Deary IJ. Longitudinal cohort study of childhood IQ and survival up to age 76. *BMJ* 2001;**322**:819.
4. **Batty GD,** Shipley MJ, Mortensen LH, *et al*. IQ in late adolescence/early adulthood, risk factors in middle-age and later coronary heart disease mortality in men: the Vietnam Experience Study. *Eur J Cardiovasc Prev Rehabil* 2008;**15**:359—61.
5. **Batty GD,** Shipley MJ, Gale CR, *et al*. Does IQ predict total and cardiovascular disease mortality as strongly as other risk factors? Comparison of effect estimates using the Vietnam Experience Study. *Heart* 2008;**94**:1541—4.
6. **Batty GD,** Shipley MJ, Mortensen LH, *et al*. IQ in late adolescence/early adulthood, risk factors in middle age and later all-cause mortality in men: the Vietnam Experience Study. *J Epidemiol Community Health* 2008;**62**:522—31.
7. **Galobardes B,** Lynch JW, Davey Smith G. Childhood socioeconomic circumstances and cause-specific mortality in adulthood: systematic review and interpretation. *Epidemiol Rev* 2004;**26**:7—21.
8. **Galobardes B,** Lynch JW, Smith GD. Is the association between childhood socioeconomic circumstances and cause-specific mortality established? Update of a systematic review. *J Epidemiol Community Health* 2008;**62**:387—90.
9. **Galobardes B,** Smith GD, Lynch JW. Systematic review of the influence of childhood socioeconomic circumstances on risk for cardiovascular disease in adulthood. *Ann Epidemiol* 2006;**16**:91—104.
10. **Singh-Manoux A.** Commentary: is it time to redefine cognitive epidemiology? *Int J Epidemiol* 2010;**39**:1369—71.
11. **Wilkinson R,** Pickett KE. Economic development and inequality affect IQ. A response to Kanazawa. *Br J Health Psychol* 2007;**12**:161—6.
12. **Deary IJ,** Johnson W. Intelligence and education: causal perceptions drive analytic processes and therefore conclusions. *Int J Epidemiol* 2010;**39**:1362—9.
13. **Bollen K,** Lennox R. Conventional wisdom on measurement: a structural equation perspective. *Psychol Bull* 1991;**110**:305—14.
14. **Bollen KA.** Latent variables in psychology and the social sciences. *Annu Rev Psychol* 2002;**53**:605—34.
15. **Hagger-Johnson GE,** Shickle DA, Roberts BA, *et al*. Direct and indirect pathways connecting cognitive ability with cardiovascular disease risk: socioeconomic status and multiple health behaviors. *Psychosom Med* 2010;**72**:777—85.
16. **von Stumm S,** Macintyre S, Batty DG, *et al*. Intelligence, social class of origin, childhood behavior disturbance and education as predictors of status attainment in midlife in men: the Aberdeen Children of the 1950s Study. *Intelligence* 2009;**38**:202—11.
17. **Howell RD,** Breivik E, Wilcox JB. Reconsidering formative measurement. *Psychol Methods* 2007;**12**:205—18.
18. **Batty GD,** Morton S, Campbell D, *et al*. 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 influences on health. *Paediatr Perinat Epidemiol* 2004;**18**:221—39.
19. **Leon DA,** Lawlor DA, Clark H, *et al*. Cohort profile: the Aberdeen Children of the 1950s Study. *Int J Epidemiol* 2006;**35**:549—52.
20. **Thomson GH.** *What Are Moray House Tests?* London: University of London Press, 1940.
21. **Singh-Manoux A,** Martikainen P, Ferrie J, *et al*. What does self rated health measure? Results from the British Whitehall II and French Gazel cohort studies. *J Epidemiol Community Health* 2006;**60**:364—72.
22. **Idler EL,** Benyamini Y. Self-rated health and mortality: a review of twenty-seven community studies. *J Health Soc Behav* 1997;**38**:21—37.
23. **Edwards J.** Multidimensional constructs in organizational behavior research: an integrative analytical framework. *Org Res Methods* 2001;**4**:144—92.
24. **Barrett P.** Structural equation modelling: adjudging model fit. *Pers Individ Diff* 2007;**42**:815—24.
25. **Schöllgen I,** Huxhold O, Tesch-Römer C. Socioeconomic status and health in the second half of life: findings from the German Ageing Survey. *Eur J Ageing* 2010;**7**:17—28.
26. **Deary IJ,** Batty GD. Cognitive epidemiology. *J Epidemiol Community Health* 2007;**61**:378—84.
27. **Mackenbach JP.** Genetics and health inequalities: hypotheses and controversies. *J Epidemiol Community Health* 2005;**59**:268—73.
28. **Luciano M,** Batty GD, McGilchrist M, *et al*. Shared genetic aetiology between cognitive ability and cardiovascular disease risk factors: generation Scotland's Scottish family health study. *Intelligence* 2010;**38**:304—13.
29. **Johnson W,** Gow AJ, Corley J, *et al*. Location in cognitive and residential space at age 70 reflects a lifelong trait over parental and environmental circumstances: the Lothian Birth Cohort 1936. *Intelligence* 2010;**38**:402—11.