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Symmetry of the face in old age reflects childhood social status

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ABSTRACT

The association of socioeconomic status (SES) with a range of lifecourse outcomes is robust, but the causes of these associations are not well understood. Research on the developmental origins of health and disease has led to the hypothesis that early developmental disturbance might permanently affect the lifecourse, accounting for some of the burden of chronic diseases such as coronary heart disease. Here we assessed developmental disturbance using bodily and facial symmetry and examined its association with socioeconomic status (SES) in childhood, and attained status at midlife. Symmetry was measured at ages 83 (facial symmetry) and 87 (bodily symmetry) in a sample of 292 individuals from the Lothian Birth Cohort 1921 (LBC1921). Structural equation models indicated that poorer SES during early development was significantly associated with lower facial symmetry (standardized path coefficient −.25, $p = .03$). By contrast, midlife SES was not significantly associated with symmetry. The relationship was stronger in men (−.44, $p = .03$) than in women (−.12, $p = .37$), and the effect sizes were significantly different in magnitude ($p = .004$). These findings suggest that SES in early life (but not later in life) is associated with developmental disturbances. Facial symmetry appears to provide an effective record of early perturbations, whereas bodily symmetry seems relatively imperturbable. As bodily and facial symmetries were sensitive to different influences, they should not be treated as interchangeable. However, markers of childhood disturbance remain many decades later, suggesting that early development may account in part for associations between SES and health through the lifecourse. Future research should clarify which elements of the environment cause these perturbations.

1. Introduction

Early life socioeconomic status (SES)—variously assessed using parental income, education, and occupational prestige—is associated with attained status in offspring as well as with their health, morbidity, and longevity (Doyle et al., 2009; Heckman, 2007). Whereas adoption studies suggest that these cross-generational influences are in part transmitted genetically (Björklund et al., 2007), the early environment might also play an important role. In particular, an influential suggestion has been that the link between early and later life SES lies in dysregulation of basic developmental biological processes such as cellular division, growth and hormonal signalling during foetal and perinatal development. This is predicted to be particularly important for the chronic disease burden associated with SES, including coronary heart disease and type-II diabetes Anderson and Armstead (1995). It is further suggested that deprivation-linked dysregulation acts as a signal to the organism to adapt its life history strategy to a shorter, early-reproducing life-cycle. Thus, early events come to programme life history strategy (Barker, 1995, 2007; McMillen and Robinson, 2005). If early life SES exerts its effects on the individual's adult life

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by disordering the processes of growth (rather than, for instance, by better access to education), then this should be manifested in biomarkers of developmental perturbation such as reduced bodily symmetry, with differences between bilateral body parts reflecting the noise induced in growth by dysregulation of cell-division and other growth-linked processes. Here we use symmetry as a measure of developmental perturbation. This marker is potentially complementary to typical measures such as blood pressure and obesity, as it has a very early developmental presence and is not itself an explicit disease process. The present study tests associations between bodily and facial symmetry and SES, contrasting symmetry's links with childhood SES and SES attained in midlife.

Many parts of the body are genetically set to be as symmetrical as possible (Van Valen, 1962). Deviation from symmetry is therefore a sign of basic bodily processes experiencing difficulty in their normal operation and so symmetry can, potentially, provide a window on the mechanisms by which important biological and environmental factors (including SES) can affect resistance to stress and capability through the lifecourse. Symmetry can be measured in any bilateral trait, and commonly used items include finger lengths and widths, the circumference of the ankles, height and width of the ear, and landmarks on the face such as distances between the outer corners of the eye or nose and the centre of the face. Lower symmetry may arise out of higher levels of stress, infections, toxins, parasites, or possibly genetic differences allowing for relatively greater or less precision. In the latter case, low symmetry would be a side effect of a less 'precise' expression of the genetic blueprint (Bates, 2007; Bates et al., unpublished data; Furlow et al., 1997; Manning et al., 1997). Lower levels of symmetry have been associated with a range of important characteristics. Those with lower levels of bodily symmetry exhibit lower performance on reasoning tasks (Banks et al., 2010; Furlow et al., 1997; Gangestad and Thornhill, 1997) and lower fertility (Jasienska et al., 2006).

We have identified associations between lower bodily symmetry and lower intelligence, and lower facial symmetry and greater age-related cognitive decline, with effect sizes (r) of around .2 (Bates, 2007; Bates et al., unpublished data; Penke et al., 2009). Bodily symmetry, as measured in old age, is linked to childhood IQ, and appears to reflect biological processes that are highly buffered against environmental displacements. Such systems were described by Waddington (1957) as highly canalized. Whereas bodily symmetry assessed in old age is associated with cognitive ability across the lifespan, facial symmetry measured in old age is associated, in men, not with childhood IQ but rather with relative rate of cognitive decline (Penke et al., 2009). Thus facial symmetry appears to 'record' stress related to differential aging, and to retain this record into old age. Bodily symmetry is not associated reliably with SES-like variables. Two earlier studies of bodily symmetry report that stressful environments are associated with higher, rather than lower symmetry (Flinn et al., 1999; Little et al., 2002), with other studies finding the reverse outcome (Knierim et al., 2007). The two markers (bodily and facial symmetry) therefore appear to reflect different sources of perturbations, with facial symmetry providing an effective record of early life disturbances. Consequently, we will focus on associations between facial symmetry and SES. However, it remains unclear which environmental influences cause perturbations and which do not. It is also not logically necessary that exposure to disturbances at one point in time should be more important than disturbances at another point in time, and understanding the time course and action of developmental perturbation is an important goal and may inform policy where it is concerned with the relationship between social status and health. For instance, clarifying the extent to which relatively greater investment might be made in interventions in early life rather than adulthood in order to ameliorate SES inequalities may aid the optimal expenditure of public funds (see e.g. Doyle et al., 2009).

One recent study has identified a link between facial symmetry and SES. Özener and Fink (2010) examined facial symmetry in Turkish students aged 17–18 years and living in either a wealthy urban area, or a slum district. These authors found significantly lower facial symmetry in slum compared to wealthy dwelling adolescents. This supports the idea that SES differences may be reflected in facial symmetry. However, it is not clear whether these symmetry differences endure into old age, whether the effects of SES are restricted to the pre-adolescent period, or also reflect SES effects incurred in adulthood.

Here we examine an elderly sample with measures of both childhood SES and attained occupational social status at midlife, and for whom symmetry of the face and the body were measured in old age. If stress in early development or early life is a substantial contributor to developmental disturbance, we expect an association of symmetry with early life SES. If symmetry largely reflects the total accumulation of stress, then we expect also to find associations between symmetry and later-life challenges, as indexed by midlife attained SES. Finally, adult SES may mediate the effects of early life SES on symmetry. Based on our recent findings (Bates et al., unpublished data), we predicted that the early life period has a unique impact on developmental stability and, as such, early life SES should be especially associated with symmetry. We use a structural equation modelling approach to test these three hypotheses formally. Given the evidence of sex differences in associations between symmetry and cognitive decline previously identified in this sample (Penke et al., 2009), we also model males and females separately. The main focus with respect to associations with SES is on facial asymmetry.

2. Method

2.1. Participants

Participants were members of the Lothian Birth Cohort 1921 (LBC1921), an originally 550-strong sample whose initial recruitment and testing is fully described elsewhere (Deary et al., 2004). All participants were born in 1921 and took an intelligence test in the Scottish Mental Survey 1932 (SMS1932) at, on average, age 11 years. They were

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recruited for cognitive and medical tests in three waves of testing in old age. They were interviewed and tested first in wave 1 of the LBC1921 study at around age 79 years (M = 79.2, SD = .6) between 1999 and 2001. Facial asymmetry measures were collected in wave 2 at around age 83 (M = 83.4, SD = .5). Bodily asymmetry measures were collected in wave 3 at around age 87 (M = 86.7, SD = .4) in wave 3. We shall refer to these as ages 79, 83, and 87 hereinafter.

Of the initial 550 participants (234 male, 316 female), 454 were approached for wave two (335 agreed and 321 were tested, of which 145 were male and 176 female). Removing those who had died or withdrawn, 268 participants were contacted for wave 3, of whom 207 completed all measures, and 237 (109 male, 128 female) completed the questionnaires only (Deary et al., 2004; Gow et al., 2011; Starr et al., 2010).

2.2. Childhood socioeconomic status

Between age 80 and 81 years, participants were sent a self-report questionnaire that asked a series of questions on their socioeconomic status at the time of the SMS1932; in other words, their family SES at age 11. The variables used here included: crowding (measured as number of people per available room, excluding hallways and also toilets which were counted separately); presence of an indoor vs. outdoor toilet (indoor toilet scored as better SES); and the occupational class of the father and mother (coded as I (professional), II (intermediate), III (skilled), IV (semi-skilled), and V (unskilled)). Where the mother never worked occupational class was coded as V (unskilled). Participants also recorded their own highest attained job (in the case of women this could be reported as their highest attained job or the highest attained job of their husband, whichever was higher), and this was classified according to the General Register's Office Census 1951 Classification of Occupations (for full details see Johnson et al., 2010). This formed our measure of attained class. Details of the relative proportions of each class along with a summary of occupants in the home, relative crowding and toilet facilities by father's social class when the participant was aged 11 are shown in Table 1. It should be noted that, whereas occupation, toilet facilities, and income do not explicitly include evolutionarily relevant stresses such as food deprivation and parasite burden, they correlate with the likelihood of these events and mortality risk in adulthood (Davey Smith et al., 1998). Poor early life SES, but not poor midlife SES, increases the risk of death by stroke and stomach cancer in men (Davey Smith et al., 1998).

Details of smoking behaviour were examined, but only one participant was an active smoker and the majority of ex-smokers ceased smoking 20 or more years before the late life measures were taken. Consequently smoking habits were not examined further in the present study.

2.3. Symmetry measures

Facial photographs were taken for each participant in wave 2 of the LBC1921 at age 83 years. These were used to calculate horizontal facial asymmetry (HFA—the most common and best-validated measure in facial symmetry research: Grammer and Thornhill, 1994), and total facial asymmetry (TFA—comprising horizontal asymmetry and additional non-horizontal indicators of asymmetry). Full details of the procedure are described elsewhere (Penke et al., 2009) and are based on established methods (Simmons et al., 2004). For ease of understanding we have used slightly different terminology to Penke et al. and Simmons et al. but the method is the same. Briefly, photographs were taken under consistent lighting and distance conditions and with subjects holding a neutral expression. 15 bilateral pairs of facial features were subsequently identified, with horizontal asymmetry determined relative to a central midline, and vertical asymmetry relative to the horizontal plane. Asymmetry was calculated as $\sum \mathrm{abs}((L-R)/(L+R)/2)$, where L = the left trait, and R = the right trait, with absolute deviation summed across all features. A score of zero would indicate

Table 1
Social class (from childhood and participant's attained midlife social class), crowding, number of occupants per household and access to toilet facilities.

Social class	Percentage of each class by			Mean (and SD) of crowding and toilet facilities by father's social class		
	Parent		Participant			
	Father	Mother	Midlife	Number of occupants	Crowding	Access to an indoor toilet
I	8.56%	0%	22.26%	5.67 (2.14)	.94 (.63)	100
II	29.45%	18.83%	33.90%	5.11 (1.67)	1.12 (.64)	88.37
III	47.60%	47.60%	40.07%	5.26 (2.02)	1.86 (1.08)	78.42
IV	9.94%	24.32%	2.05%	5.04 (1.60)	1.97 (1.14)	72.41
V	4.45%	9.25%	1.72%	5.50 (1.51)	2.88 (1.68)	61.54
Total	100%	100%	100%	5.36 (1.85)	1.62 (1.08)	81.85

Note: Total n for each variable = 292. For father, mother and midlife attained social class, class "I" indicates the highest (professional) quintile, and class "V" the lowest (unskilled labour). Father and mother social class refers to classification of each parent when participants were aged 11. Midlife attained social class refers to the highest occupational class attained by the participant before retirement. For all subsequent columns, data are subdivided according to father's social when the participant was aged 11. Number of occupants indicates the raw number of individuals in the same house (with SD in brackets). Crowding reflects mean (and SD) of crowding (higher scores are worse—indicating more people per room). Access to an indoor toilet gives the percentage of participants with/without access to an indoor toilet for each social class band.

perfect symmetry. The greater the score on this variable, the lower symmetry is. Because faces, unlike many other body parts, tend to show directional asymmetry (a mean left–right difference significantly different from zero, indicating that the normal developmental target is asymmetrical, rather than symmetrical), we subsequently identified asymmetry about directional asymmetry using principal components analysis (Penke et al., 2009; Simmons et al., 2004). The first two unrotated components of this analysis reflect directional asymmetry and non-directional asymmetry, respectively. Factor scores on the second unrotated component were used in all analyses, thus removing the directional confound (Graham et al., 1998).

Bodily symmetry was measured at a later clinic visit—wave 3 of the LBC1921 study—at mean age 87 years. Completion rates for each measure varied: 173 participants (80 male, 93 female) completed all measurements. Using digital callipers accurate to .1 mm, we measured ear height, ear width, wrist circumference, elbow circumference, and ankle circumference on both the left and right side of the body. Each pair was measured three times, and the final score for each trait was the mean across the three measurements. Hand symmetry was assessed using digital flatbed scanning. The lengths of each digit (excluding the thumb) along with their width at the first metacarpal and the breadth of the palm were measured using digital imaging software (GIMP, available at www.gimp.org). Asymmetry was assessed by summing the 14 measures (5 physical (non-hand based), 9 digital) using the formula displayed above with 0 again indicating perfect bilateral symmetry and higher scores indicating lower symmetry (higher asymmetry). Asymmetry was log-transformed to a normal distribution. Reliability of the calliper measures was examined using intraclass correlations (ICC) between the repeated measurements, and this showed very high reliability (average $r = .998$). Likewise, for the scan data, ICC was computed on a subset of 25 subjects who were scored twice. ICC averaged across the nine measures was $r = .999$, indicating that the measurements taken from each image were highly reliable. We also examined reproducibility by conducting two separate scans for three individuals not drawn from this sample and calculating the ICC between each pair of images. Results were (r) .993, .989 and .991, further indicating reliability of the measurement process. By contrast with facial symmetry, bodily symmetry typically demonstrates no directional asymmetry (Furlow et al., 1997).

2.4. Statistical analysis

Structural equation models were tested using AMOS version 18 (SPSS Inc., 2010), with full information maximum likelihood (FIML) estimation to maximize information in the presence of missing data. Childhood deprivation was modelled as a single latent variable from the manifest variables of maternal and paternal social class, crowding of the dwelling, and access to an indoor (vs. outdoor) toilet. We evaluated the homoscedasticity of the relationship between the latent SES trait and both HFA and TFA via scatterplots and non-constant variance score tests. For HFA and TFA the non-constant variance score tests returned null results ($\chi^2 = 3.4$, $df = 1$, $p = .06$ and $\chi^2 = 2.97$, $df = 1$, $p = .09$, respectively). For clarity, the scores for the latent trait were reversed so that better (i.e. more favourable outcomes) was scored higher, with lower scores indicating the more adverse outcome.

In all models there was a path between this latent trait of childhood deprivation and midlife occupational social class (also reversed so that higher scores indicated the more favourable outcome). Based on past literature, we examined two plausible pathways from childhood deprivation to facial symmetry at age 83 and bodily symmetry at age 87. The first was a direct path between early life deprivation and late-life symmetry. The second path was indirect, in which the effect of early life deprivation was mediated via midlife social class to late-life symmetry.

These predictions concerning the associations between childhood and adult SES and symmetry in old age were examined using three models (Fig. 1). Model 1 tested the effect of both childhood deprivation and midlife occupational social class on symmetry, with direct and indirect (mediated via midlife social class) childhood deprivation effects on symmetry. Model 2 tested the effect of childhood deprivation on symmetry when the effect of midlife social class on symmetry was constrained to 0. Model 3 examined the effects of midlife social class on symmetry when the direct effect of childhood deprivation on symmetry was constrained to zero.

The goodness of fit statistics used were Root Mean Square Error of Approximation (RMSEA), Chi-square, and comparative fit indices including the Normed Fit Index (NFI), Tucker-Lewis Index (TLI), Comparative Fit Index (CFI) and Akaike Information Criterion (AIC). We examined whether HFA, TFA, or bodily asymmetry showed associations with childhood deprivation or midlife social attainment.

3. Results

Table 2 shows the bivariate correlations of the four markers of deprivation as well as facial and bodily asymmetry calculated using both pair-wise and list-wise deletion. Magnitudes of the correlations were similar for each method. The four deprivation indicators correlated significantly, between .19 and .42 (mean = .28). Facial and bodily asymmetries were not significantly correlated, and no asymmetry indicator was associated significantly with any individual SES indicator. Means and SDs for all manifest variables are shown in the far right column of the table.

3.1. Model fitting

The correlations between the SES indicators and the symmetry measures were all non-significant. However, there is an intrinsic benefit of latent variable analysis in aggregating weak signals, which is what the individual indicators provide. This aggregate is more useful than any single indicator. Models of the associations between early life SES and midlife status and old-age symmetry were tested separately using bodily asymmetry, HFA, and TFA.

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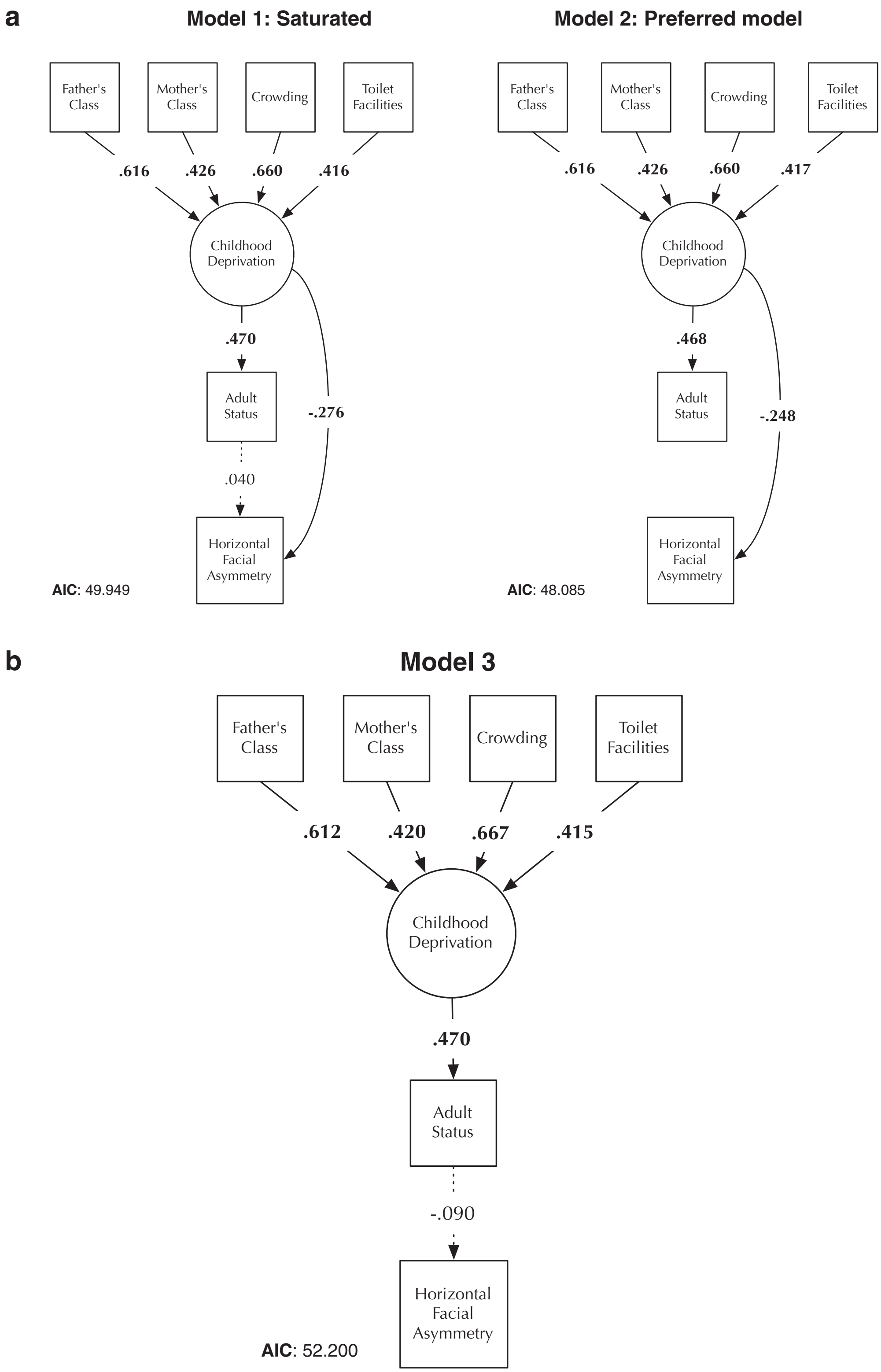

Fig. 1. Models relating early- and midlife social status to horizontal facial asymmetry at age 87 (see text for explanation and Table 3 for fit statistics). *Note*: The latent trait (deprivation) is represented as a circle, and manifest variables as rectangles. Dashed lines indicate non-significant paths. Paths constrained to 0 are not shown. For ease of understanding scores for the latent trait of childhood deprivation and scores for adult status have been reversed so that higher scores indicate a better (more favourable) outcome.

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Table 2
Correlation matrix of deprivation and asymmetry variables.

	SES of father	SES of mother	Occup. per house	Crowding index	Indoor toilet (yes/no)	Midlife SES	TFA	HFA	Bodily asymm.
SES of father	–	**.285**	−.096	**.450**	.220	**.238**	−.016	−.190	.011
SES of mother	.310	–	−.213	.180	.200	**.388**	.011	−.075	−.069
Occup. per house	−.020	−.042	–	−.054	−.022	−.038	−.098	−.023	.131
Crowding index	**.416**	**.204**	.039	–	**.479**	**.372**	.041	−.039	.017
Indoor toilet (yes/no)	**.220**	**.188**	.039	**.318**	–	.179	−.036	−.060	−.024
Midlife SES	**.257**	**.251**	.037	**.332**	**.157**	–	−.010	−.123	.075
TFA	−.099	−.158	−.035	−.114	−.106	−.085	–	–	.125
HFA	−.169	−.165	−.019	−.112	−.130	−.088	–	–	.124
Bodily asymm.	.044	−.015	.148	.028	.056	.052	.124	.124	–
Mean (SD)	2.720 (.917)	3.240 (.864)	5.360 (1.85)	1.622 (1.083)	1.181 (.386)	2.270 (.888)	−.034 (1.073)	−.017 (.997)	−4.737 (.314)

Note: Bold figures indicate statistically significant correlations. Correlations below the diagonal use pair-wise deletion. Correlations above use list-wise deletion. For pair-wise deletion n ranged between 76 and 292. For list-wise deletion, $N = 76$ for all values. As HFA is a subcomponent of TFA, correlations between the two are not shown here. SES = socioeconomic status as indexed by Social Class. Occup. per house = number of occupants per household. Bodily asymm. = bodily asymmetry. SES of father, SES of mother, number of occupants per household, crowding index, and indoor toilet variables are given for when the participant was aged 11.TFA = total facial asymmetry. HFA = horizontal facial asymmetry.

Because only facial (as opposed to bodily) asymmetry is associated with lifetime cognitive decline (Penke et al., 2009), and bodily asymmetry is inconsistently associated with deprivation (Flinn et al., 1999; Knierim et al., 2007; Little et al., 2002) we did not expect bodily asymmetry to be sensitive to SES in this sample, but we did expect significant associations between SES and facial asymmetry. The data confirmed these expectations of differential associations of bodily and facial asymmetry with SES: models including bodily asymmetry showed no significant associations with SES in childhood ($p = .79$) or adult attained SES ($p = .77$). Because bodily asymmetry was not significantly associated with deprivation, it will not be discussed further. For facial asymmetry, relationships with deprivation were strongest for HFA, as compared with TFA. For our initial modelling of the full sample we focused on HFA due to its better established validity, and then reproduced analyses for both HFA and TFA for the sex specific analyses.

Fig. 1 provides a visual comparison of the three models in which childhood and adult SES are associated with HFA. Model 1 incorporated a latent-trait model of deprivation based on our four markers of childhood status, and related this to the person's own midlife occupational social class and also included direct and indirect (mediated via midlife social class) pathways of childhood SES effects on HFA. It fitted the data well. Each of the four indicator variables had significant and substantial loadings on the latent trait of childhood deprivation. The childhood deprivation latent trait was associated significantly with midlife occupational social attainment (standardized path coefficient = .47, $p = .001$). The direct path from childhood deprivation to HFA was significant and in the predicted direction (−.28, $p = .04$); more deprived children had less symmetrical faces in old age. The path from midlife social class to HFA was near to zero (.04, $p = .70$). In Model 2, this path was dropped and this did not reduce fit significantly by comparison with Model 1 ($\chi^2(1) = .14$, $p =$ ns). Details of model fit statistics are shown in Table 3. The effect of childhood deprivation on HFA remained significant and similar in magnitude to the parameter obtained in Model 1 (−.24, $p = .04$). By contrast, Model 3, in which the path from childhood deprivation to HFA was dropped, fitted significantly less well than Model 1 ($\chi^2(1) = 4.25$, $p = <.05$). Based on both comparative fit indices and χ^2 results, Model 2 was accepted as providing the best fit to the data, indicating that childhood deprivation is directly associated with asymmetry in old age, and that the effect is not mediated

Table 3
Measures of statistical fit for models relating early– and midlife social status to horizontal and comprehensive asymmetry at age 87 (see text and Figs. 1 and 2).

	Model 1	Model 2	Model 3	Model 2b	Model 2c
RMSEA	.041	.034	.052	.064	.074
NFI	.933	.933	.910	.780	.756
TLI	.935	.955	.894	.745	.659
χ^2	11.949	12.085	16.200	13.301	14.787
CFI	.975	.981	.955	.890	.854
AIC	49.949	48.085	52.200	49.301	50.787

Note: χ^2 difference test was significant for the comparison of Models 1 and 3, but not between Models 1 and 2. RMSEA = Root Mean Square Error of Approximation, NFI = Normed Fit Index, TLI = Tucker-Lewis Index, CFI = Comparative Fit Index, AIC = Akaike Information Criterion. Model 1 examined horizontal facial asymmetry (HFA) with no paths constrained to 0. Model 2 repeated Model 1 but with the path between adult status and HFA constrained to 0. Model 3 repeated Model 1 but with the path between childhood deprivation and HFA constrained to 0. Model 2b tested Model 2 using the same variables but included only men. Model 2c tested Model 2 using the same variables except for horizontal facial asymmetry (HFA) which was replaced by total facial asymmetry (TFA), and, like Model 2b, included only men.

by midlife social class. Midlife occupational social class itself had no significant association with asymmetry.

In prior research in the same sample (Penke et al., 2009), analyses of sex differences in facial asymmetry associations yielded significant results for men but not women. Consequently, we re-ran Model 2 separately for men and women. In women there was no significant association between early life deprivation and either HFA (−.12, p = .37) or TFA (−.09, p = .52). Further details of these models are available from the authors. For men, details of model fit statistics are shown in Table 3. A visual representation of the two models in men is shown in Fig. 2. In men, the association between early life deprivation and HFA (Model 2b: −.44, p = .03) and early life deprivation and TFA (Model 2c: −.40, p = .04) were both significant. The magnitude of the effect sizes for males and females were compared by turning the two coefficients into Fisher's Z scores and testing whether the two differed significantly (for further details see McGeorge et al., 1996). For both HFA and TFA males exhibited a statistically significantly stronger relationship (p = .004 and p = .006, respectively).

4. Discussion

The results show a significant association between early life deprivation and facial (but not bodily) symmetry: those who experienced poorer early life SES had lower late life facial symmetry. The association is stronger among men, and non-significant in women. This reinforces the value of facial symmetry as a sensitive marker of developmental perturbation and suggests possible mechanisms by which SES comes to be associated with health and capability. Such mechanisms may include the level of nutrition during childhood, quality of treatment of illness, or parental behaviour in regard to smoking and/or alcohol consumption.

This research indicated distinct associations with SES for measures of bodily symmetry and facial symmetry. No single SES component was significantly related to symmetry, but all components loaded the latent trait of SES heavily, and this trait was linked to symmetry. This highlights both the value of latent trait modelling (Anderson and Gerbing, 1988) and the multidimensional nature of what is commonly viewed as "capability" (Alkire, 2008; Sen, 1999): as capability is indicated by many different variables, more accurate results will be achieved through maximizing the number of indicators. Individual differences in these two forms of asymmetry appear to capture distinct developmental processes and they are known to have different associations with lifespan intelligence. We have suggested that bodily symmetry reflects the precision of molecular assembly and three-dimensional morphology (Bates et al., unpublished data). By contrast, the arguably mostly soft-tissue symmetry indexed by facial symmetry appears more sensitive to environmental impacts and is linked to differential rates of decline in old age, rather than to more stable trait levels of ability (Penke et al., 2009). Also included in these mechanisms may be parental behaviours such as alcohol consumption, improper treatment of childhood illnesses, suboptimal provision of nutrition during child development, presence of toxins in the childhood environment, and/or smoking during pregnancy. Overall, the accumulat-

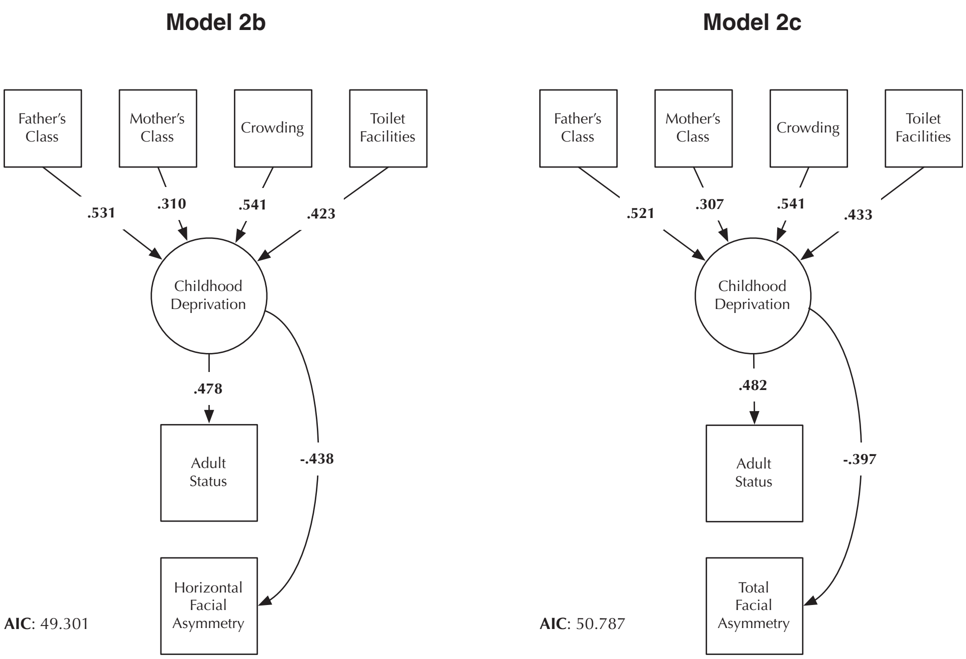

Fig. 2. Models relating early- and midlife social status to horizontal and total facial asymmetry at age 87 in men only (see text for explanation and Table 3 for fit statistics). *Note*: The latent trait (deprivation) is represented as a circle, and manifest variables as rectangles. Paths constrained to 0 are not shown. For ease of understanding scores for the latent trait of childhood deprivation and scores for adult status have been reversed so that higher scores indicate a better (more favourable) outcome.

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ing findings in this field of research support the possibility those bodily and facial symmetries are sensitive to different influences; consequently, they should not be treated as interchangeable.

As predicted from statistical links of early development with health (see e.g. Marmot, 2010) and hypotheses within a developmental origins framework (Barker, 2007), the effects of childhood deprivation were enduring: they remained detectable in facial symmetry measured, in this case, over 70 years later. The specificity of this association for early life SES rather than for self-attained midlife status (despite the latter being closer in time to the symmetry measure) further supports the hypothesis that childhood is a sensitive developmental period. While the present results suggest that facial symmetry signals environmental factors rather than genome-wide fitness, the genetic and/or epigenetic factors in facial symmetry should be elucidated further. Recent evidence that the ability to generate alternative phenotypes (based on epigenetic modification) may aid an organism under stress and decrease immediate disease susceptibility at the cost of lower fitness later in life (Feinberg and Irizarry, 2010; Frisancho, 2009) may be relevant. Taking these findings into account, it is possible that facial symmetry reflects an interaction of stress with genetic responsivity to stress.

The present study has some limitations. We suggest that facial symmetry, with its tight connections to early life development and the laying down of a symmetrical body plan, encapsulates processes which are complete prior to midlife, though they will go on to influence successful aging. The early life latent trait of deprivation, however, captured factors not included in the single-indicator midlife occupational status attainment measure (e.g. crowding and accessibility of toilet facilities). Had these measures been available in midlife, it is possible that they might have shown association to on-going influences on facial symmetry. In addition, we had only social factors in early life: biological measures of early development such as birth complications should be sought which may tap additional factors in early development. In particular it would be of value to capture direct markers of foetal development and relate these to symmetry. Furthermore, whereas the age of the participants is advantageous in capturing a lifetime of SES effects, the sample experienced a relatively affluent midlife and has lived approximately two and a half decades beyond the life expectancy of their birth cohort by the time facial measurements were taken (General Register Office for Scotland, 2010). As a side finding, these data also show substantial class mobility in 1930s Scotland, with a more than doubling of persons in class I at middle age relative to their own parents' early life. This is part of a well-known absolute upward mobility trend as a result of changes in the structure of available jobs. For more details about class mobility in this sample see Johnson et al. (2010).

A limitation of the study is that members of the cohort who experienced deprivation in midlife were less likely to reach old age or were less likely to participate in this research. However, this range restriction would be expected to lead to an under-estimate of the association of early life SES with midlife SES, as those with the worst deprivation and ill health would be more likely to die younger and less likely to respond to a research recruitment advertisement (see e.g. Marmot, 2010; Nishiwaki et al., 2005, respectively), and associations between deprivation and health are not restricted to the most deprived, but are present across the social spectrum (Marmot, 2010).

Importantly, the findings are significant in the overall sample, but sex-specific analyses indicate that significant results only emerge in men. Males exhibited a statistically significantly stronger association than women between poorer early life SES and lower late life facial symmetry. Further research with larger samples will be required to investigate whether a smaller, though still significant, association exists in women. The sample was drawn from a period where female employment—especially in more professional roles—was comparatively unusual, and midlife female attained status was recorded as either their own status, or that of their husband. Consequently, it is possible that our measures of SES in midlife were less relevant for females than for males. Alternatively, women may be more resistant to environmental stress. In prior research in the same sample (Penke et al., 2009) associations between symmetry and cognitive ability were significant for men only. It is possible that males exhibit greater associations between symmetry and a wide range of attributes due to sex differences related to the tradeoffs between bodily maintenance and reproductive success. Further research measuring female self-attributed SES would be helpful in identifying which of these hypotheses is correct.

Our data support associations of SES with markers of development in early life in the form of facial symmetry, with men who experience relatively better early life SES exhibiting higher facial symmetry in late life.

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