Education

Cognitive and emotional outcomes after prolonged education: a quasi-experiment on 320 182 Swedish boys

Anton Lager,[1,2,3,4,*] Dominika Seblova,[1,3,4] Daniel Falkstedt[1] and Martin Lövdén[4]

[1]Department of Public Health Sciences, Karolinska Institutet, Stockholm, Sweden, [2]Swedish Institute for Social Research, Stockholm University, Stockholm, Sweden, [3]Centre for Epidemiology and Community Medicine, Stockholm County Council, Stockholm, Sweden and [4]Aging Research Center, Karolinska Institutet and Stockholm University, Stockholm, Sweden

*Corresponding author. Department of Public Health Sciences, Karolinska Institutet, 171 77 Stockholm, Sweden. E-mail: anton.lager@ki.se

Abstract

Background: Cognitive and socio-emotional abilities are powerful predictors of death and disease as well as of social and economic outcomes. Education is societies' main way of promoting these abilities, ideally so that inequalities by socioeconomic background are reduced. However, the extent to which education serves these cognitive, social-emotional and equality objectives is relatively unknown and intensively debated. Drawing on a Swedish school reform that was explicitly designed as a massive quasi-experiment, we assessed differential impact of education on intelligence and emotional control across childhood socioeconomic position. We also assessed initial differences in abilities by childhood socioeconomic position and how well childhood socioeconomic position and abilities predict all-cause mortality.

Methods: The Swedish comprehensive school reform, rolled out during the 1950s, extended compulsory education from 8 to 9 years in some municipalities whereas others were kept as controls for the sake of evaluation. We followed eight full cohorts of Swedish boys born between 1951 and 1958, who lived in 1017 municipalities with known experimental status (344 336 boys) and whose childhood socioeconomic position was known (320 182 boys). At conscription, intelligence was measured by four subtests and emotional control (calm and efficient responses in various situations) was rated by a military psychologist. Both measures were standardized to have a mean of 100 and standard deviation of 15. All-cause mortality was recorded until 49–56 years of age.

Results: The reform had an average positive impact on intelligence of 0.75 IQ units (95% confidence interval (CI): 0.54, 0.97; $P < 0.0005$). The impact on emotional control was negative; -0.50 units (95% CI: -0.72, -0.28; $P < 0.0005$). Both effects differed by socioeconomic background so that the average IQ difference between sons of high non-manual and unqualified manual workers was reduced from 16.32 to 15.57 units and the

difference in emotional control was reduced from 6.50 to 5.63 units. All-cause mortality was predicted by low childhood socioeconomic position [hazard ratio (HR) = 1.15 [95% CI: 1.11, 1.20], $P < 0.0005$], low intelligence [HR = 1.39 (95% CI: 1.34, 1.44), $P < 0.0005$] as well as low emotional control [HR = 1.61 (95% CI: 1.55, 1.67), $P < 0.0005$] in mutually adjusted models.

Conclusions: Extending compulsory education promoted intelligence but lowered emotional control, and reduced disparities over social background in both. Emotional control was the strongest predictor of all-cause mortality. Our results are in line with the idea that education is important in our efforts to achieve healthy, competent and fair societies, but much more work is needed to understand the links between education and non-cognitive skills.

Key words: Intelligence, emotional control, education, quasi-experiment, mortality

---

Key Messages

- Both cognitive and socio-emotional abilities are malleable during adolescence.
- Extending education from 8 to 9 years promoted intelligence but lowered emotional control, and reduced socio-economic disparities in both.
- Both intelligence and emotional control predicted mortality up to age 49–56, independently of each other and of socioeconomic background.

Introduction

Persons' cognitive and emotional states can change after a disease[1–5] but are also powerful predictors of it.[6–15] Society's main way of promoting individual development of cognitive and socio-emotional abilities is education, ideally so that inequalities by childhood conditions are reduced. For example, the US Department of Education hopes to foster 'lifelong learners who can adapt to the constant changes in the diverse and technology-driven workplaces of the global economy', improve 'social-emotional and cognitive outcomes' and 'close achievement and opportunity gaps',[16,17] and China aims at 'all round development of morality, intelligence and physique'.[18]

The extent to which education serves these cognitive, socio-emotional and equality objectives is, however, relatively unknown and intensively debated. Studies have reported effects of education on intelligence (for example, through improved comprehension, abstract thinking, logical reasoning, problem-solving and planning) that may be causal.[19–21] Yet, the concept of intelligence as a fixed ability that is difficult to improve is widespread, often in reference to it being highly heritable[22,23] and to small effects of specific training programmes.[24,25]

Socio-emotional abilities are also viewed from two opposing positions. There is an experimental literature concerned with promoting socio-emotional abilities (for example, through improved recognition and handling of your own and others' emotions). Such relatively short, structured and intense interventions often successfully develop new skills.[26] In contrast, classical differential personality psychology studies the 'big five personality traits' (neuroticism, conscientiousness, openness, agreeableness and extroversion) as fixed and heritable.[27,28] However, most capacities measured in the personality literature by instruments such as the Big Five Inventory (e.g. the ability to deal with stress, nervousness, impulsiveness, shyness, rudeness, curiosity, planning, attention to detail, trust and cooperation)[29] are, in fact, capacities that educational policy makers hope to promote via the school system.

This study contributes to both of these debates by assessing the impact of a Swedish compulsory-school reform on intelligence scores and ratings of emotional control for boys at the compulsory military conscription. This reform, rolled out during the 1950s, extended compulsory education from 8 to 9 years. The reform was explicitly designed as a quasi-experiment, in which the change was implemented in some municipalities and others were kept as controls for the sake of evaluation.[30] This quasi-experiment provided us with the opportunity to examine associations that have previously been assessed, at best,

either in 'natural' experiments (i.e. studies in which the exposure was not manipulated for the sake of evaluation, but changed for other reasons) or more laboratory-like settings.

In addition, we assessed differential effects of prolonged education on abilities by childhood socioeconomic position (measured by parental socioeconomic position), examined the initial differences in abilities by childhood socioeconomic conditions and validated the real-life importance of all measures by using them to predict adult all-cause mortality.

Methods

Ethical approval

This work was approved by the Regional Ethical Review Board (DNR 2005/556-31) in Stockholm, Sweden.

Design

The reform was rolled out over more than 10 years. It was designed as a quasi-experiment in which municipalities similar to those that underwent the reform were kept in the old school system as controls for the sake of evaluation. There are boys exposed to the old and the new school system in each cohort except in the youngest one. Many of the municipalities, however, had introduced the reform before our first cohort started school. Thus, the design underpinning our analyses can mainly be thought of as quasi-experimental with post-measurements of the outcome. As a sensitivity test, we limited our analyses to municipalities for which we had outcome data both before and after the introduction of the reform. This gave us a measurement of the outcomes in each municipality before the reform, which limited our sample size and reduced power but improved the design. Data from the reform have been used in previous studies in the fields of epidemiology and economics.[31–33]

Sample

The study population consisted of eight full cohorts of boys born in Sweden between 1951 and 1958, who were living in Sweden at the time of the 1960 and 1965 censuses. This gave us a total of 427 181 men (between 51 980 and 54 597 in each cohort) in 1030 municipalities. These cohorts were chosen because they were assessed in the same way at military conscription. It was not possible to determine experimental status (reform exposure) for 36 234 (8.5%) of the boys because in 13 (1.3%) of the

1030 municipalities, including some large ones, school districts did not overlap with municipalities.

Conscription records were available for 383 525 (98.1%) of the remaining 390 947 boys. Those who did not come to the conscription office included individuals with severe physical or mental disability. Full data on date of conscription, intelligence test results and emotional control were available for 344 336 men: 88.1% of the 390 947 from municipalities with known reform status and 80.6% of all 427 181. These 344 336 men constituted the effective sample. However, most analyses were conducted on the 320 182 men with known childhood socioeconomic position (81.9% of the 390 947 from municipalities with known reform status and 75.0% of all 427 181). Of these 320 182 men, 277 608 (86.7%) were exposed to the reform as boys.

In our pre-post analyses (i.e. analyses restricted to boys from municipalities for which we have intelligence data both before and after the reform), the sample with full data on experimental status, date of conscription, intelligence, emotional control and childhood socioeconomic position was reduced to 142 221 (44.4% of the 320 182 with full data, 36.4% of the 390 947 from municipalities with known reform status and 33.3% of all 427 181). Of these 142 221, a total of 99 647 (70.1%) were exposed to the reform.

Childhood socioeconomic position

Socioeconomic position in childhood was derived from either 1960 or 1965 census data. It was defined on the basis of parental occupations grouped according to Statistics Sweden's *Swedish Socio-economic Classification* (SEI), an equivalent of the Erikson, Golthorpe and Portocarero social class scheme.[34] If the father's and mother's socioeconomic position differed, the highest one was used. The smallest group, sons of academic professionals ($n = 1273$), was combined with the group of high non-manual workers.

The intervention: the comprehensive school reform

Prior to 1949, Sweden had a complex, multi-track system for lower education. The system included two major school entities: elementary school and junior secondary school. The reform studied here added a year to lower compulsory education, prolonging it from 8 to 9 years. It also simplified the system by abolishing early tracking into junior secondary school, a more academic pre-reform track often taken by children of higher socioeconomic backgrounds. As a result, more children became eligible for and

attended upper secondary school. The reform also introduced some changes to the curriculum. For example, English was introduced as a compulsory subject in grades 4 and 5.

Starting in 1949 and continuing for more than 10 years, the reform was implemented in over 1000 municipalities. It proceeded gradually, municipality by municipality. The reform was explicitly designed as a quasi-experiment with comparable experiment and control groups. This was done to evaluate the effect of the reform before deciding whether to implement it nationally.

In the current study, boys' experimental status was determined by municipality of residence at the time of the 1960 census for those born 1951–53 (i.e. age 7–9 years) and the 1965 census for those born 1954–58 (i.e., age 7–11 years). The reform has previously been used for similar analyses of a sub-sample of 10% of two cohorts.[33]

Education before the date of conscriptions

The reform was expected to impact length of education differentially for those of different socioeconomic backgrounds. To assess the amount of time the reform prolonged schooling for different groups, we used 1990 data on educational attainment from the educational register. For each individual, it was assumed that all time in school that could have taken place before conscription indeed took place before conscription. Those with missing information on education were recoded as having the lowest possible length of schooling.

Intelligence

Intelligence was measured at conscription with four subtests: A) Instructions, 40 items measuring verbal ability (e.g. 'strike the fourth number, put a ring around the second'); B), Concept discrimination, 40 items measuring verbal and reasoning abilities in which the task is to choose the one of five concepts that does not belong; C) Paper form board, 25 items measuring visuospatial ability in which the task is to pick one of four sets of pieces that can form a given figure (a variation of the Minnesota Paper Form Board);[35] and D) Technical comprehension, 52 items (a figure is shown and questions about a technical problem asked). The conscription intelligence tests have been extensively used in research.[6]

A latent variable, estimated using maximum likelihood and manifested by the scores on four subtests at conscription, was formed using structural equation modelling on all 413 511 individuals test results available in our data set (including those that were missing e.g. the date of conscription). There were satisfactory loadings (A = 0.87; B = 0.84;

C = 0.61; D = 0.66) on the common latent factor, and the model had a good fit (comparative fit index = 0.982, standardized root mean square residual = 0.025, degrees of freedom = 2, chi^2 = 12436). On the basis of this model, we extracted factor scores to represent general intelligence in our multilevel analyses (see below). The scores were standardized to have a mean of 100 and a standard deviation of 15 units.

Emotional control

The Swedish military aimed to identify men who were potential officer material and who could be expected to perform in real and stressful wartime situations. Therefore, in addition to the intelligence tests, all conscripts underwent an interview with an experienced psychologist. They talked about the conscript's situation at school and/or work, at home and in spare time, engaging in detailed discussion of topics such as stress-related absenteeism, dropping out of school or work and personal conflicts in these settings.

High scores (4–5) in emotional control were given for responding calmly and efficiently in most situations, for high stress tolerance and for low anxiety. Low scores (1–2) were given for low stress tolerance, high anxiety and documented psychosomatic symptoms. Previous research using this variable suggests that emotional control predicts outcomes such as suicidal and health-compromising behaviour.[11,36] The variable was standardized in the same way as the IQ scores, i.e. to have a mean of 100 and a standard deviation of 15 units.

Mortality

Mortality in all participants was followed up in the Swedish National Cause of Death Register from date of conscription to the end of 2007 or emigration. At the end of the follow-up period, the men were 49 to 56 years old.

Statistical analyses

To evaluate the impact of the reform on years in school by date of conscription, intelligence and emotional control, we applied multilevel linear regressions with fixed municipality effects and standard errors clustered at the municipal level. We adjusted for month of birth categorically, i.e. we created one dummy variable for each birth month beginning in January 1951 and ending in December 1958, to eliminate possible confounding due to seasonality of births and/or cohort differences. Using categorical variables allows this confounding to take any form. Similarly, we adjusted for age at testing categorically, using months. That is, we used one dummy variable for each age: the youngest individual was conscripted at the age of 186 months (15.5

years) and the oldest at the age of 342 months (28.5 years). The median age at conscription was 222 months (18.5 years); 98% were conscripted between the ages of 207 months (17.3 years) and 248 months (20.7 years).

The impact of the reform on years in school, intelligence and emotional control was assessed: (i) in all men for whom we had information about childhood socioeconomic position; and (ii) in analyses stratified by childhood socioeconomic position, which included the men for whom information on childhood socioeconomic position was missing. Given that emotional control has clear cognitive aspects, i.e. that higher cognitive skills (e.g. observing and analysing one's reactions) can help in regulating emotions,[37] we also assessed the impact on emotional control adjusted for the effect on intelligence. To test the robustness of standard errors, we used 200 bootstrap replications on simplified versions of our models. The interpretations of the results did not change.

To give a full picture, we compared the estimated means from the same statistical model for boys non-exposed to the reform and exposed to the reform, who were born in March 1955 (median birth month) and conscripted at the age of 18.5 years (median age). Note, however, that the impact of the reform is assumed to be the same, irrespective of birth month or age at conscription. The estimated effects of the reform are also summarized in Figure 1. The estimates of emotional control adjusted for intelligence are for a boy with an IQ of 100 who was born in March 1955 and was conscripted at the age of 18.5 years.

To validate our measures against a hard endpoint, we used childhood socioeconomic position, intelligence and emotional control to predict all-cause mortality until the age of 49 to 56 years. Cox proportional hazards regressions were used with age as the underlying time variable (starting from the age of conscription). Baseline hazards were stratified on and standard errors clustered at the municipal level. In these analyses, we used univariate and mutually adjusted models to compare mortality in equally large vulnerable groups: sons of unqualified manual workers, boys with low intelligence and boys with low emotional control. Estimates were also derived from models in which intelligence and emotional control were entered metrically, i.e. estimates related to one IQ and one emotional control (EC) unit. All of these models were adjusted for month of birth (categorically) and for experimental status. In the mutually adjusted models, socioeconomic status was entered categorically; intelligence and emotional control were entered metrically.

Results

Intelligence at conscription was 0.75 IQ units higher (95% CI: 0.42, 1.09; $P < 0.0005$) in those with known socioeconomic status exposed to the reform ($n = 277\,608$) than those not exposed ($n = 42\,574$) (Figure 1, Table 1).

In contrast, the reform negatively affected emotional control, corresponding to minus 0.50 units (95% CI: -0.85, -0.15; $P = 0.005$) on average (Figure 1, Table 1). We hypothesized that this negative effect of the reform on emotional control would be even more pronounced after adjustment for the positive effect of the reform on IQ, and
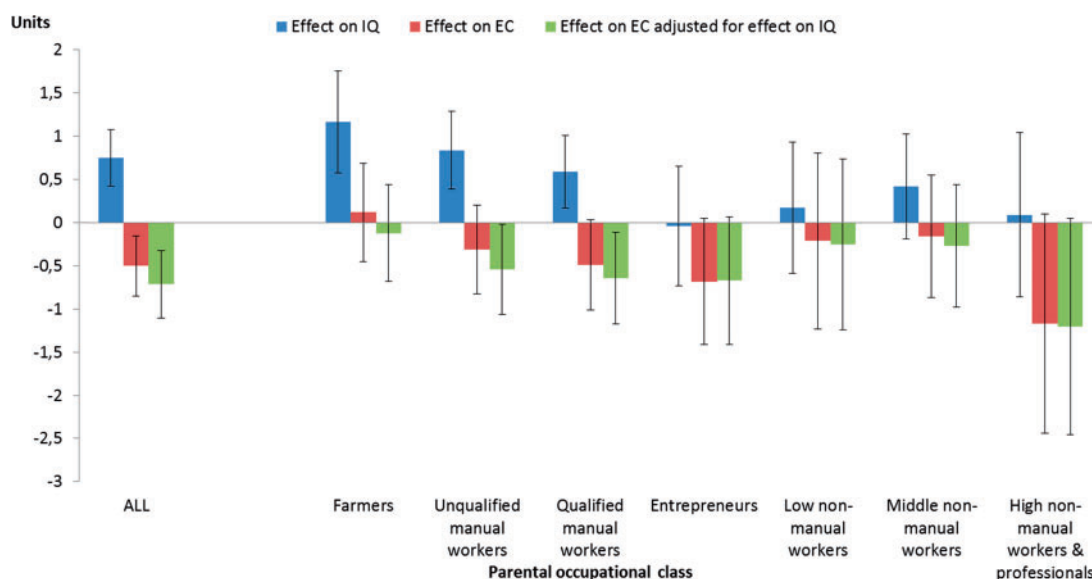
Figure 1. Effects of the Swedish comprehensive school reform on intelligence (IQ), emotional control (EC) and emotional control after adjusting for the effect on IQ. Point estimates and 95% confidence intervals. Units are standardized to have a mean of 100 and a standard deviation of 15. Groups are ordered by the reform's effect on years in school by date of conscription, ranging from 0.70 years (sons of farmers) to 0.16 years (sons of high non-manual workers and professionals).

Table 1. Effects of the Swedish comprehensive school reform on years in school by date of conscription, intelligence (IQ), emotional control (EC) and emotional control after adjustment for the effect on intelligence. Results of the stratified analyses are ordered by the effect of the reform on years in school

Childhood socioeconomic position (n)	Years in school by time of conscription: non-exposed	Years in school by time of conscription: exposed (95% CI), P-value for effect of reform	Intelligence in IQ units: non-exposed	Intelligence in IQ units: exposed (95% CI) P-value for effect of reform	EC in units: non-exposed	EC in units: exposed (95% CI) P-value for effect of reform	EC, adjusted for the effect on IQ* in units: non-exposed	EC, adjusted for the effect on IQ* in units: exposed (95% CI) P-value for effect of reform
All with information on childhood socioeconomic position ($n = 320\ 182$)	9.89	10.40 (10.37, 10.44) **P < 0.0005**	100.37	101.13 (100.79, 101.46) **P < 0.0005**	102.59	102.09 (101.74, 102.44) **P = 0.005**	102.49	101.78 (101.39, 102.17) **P = 0.0005**
Farmers ($n = 33\ 779$)	9.48	10.18 (10.12, 10.25) **P < 0.0005**	98.32	99.49 (98.90, 100.08) **P < 0.0005**	101.09	101.22 (100.64, 101.80) P = 0.672	101.45	101.33 (100.77, 101.88) P = 0.669
Unqualified manual workers ($n = 82\ 964$)	9.61	10.20 (10.15, 10.25) **P < 0.0005**	96.16	97.00 (96.55, 97.44) **P < 0.0005**	100.91	100.60 (100.09, 101.11) P = 0.229	101.97	101.43 (100.91, 101.95) **P = 0.040**
Qualified manual workers ($n = 81\ 256$)	9.74	10.31 (10.26, 10.37) **P < 0.0005**	98.20	98.78 (98.37, 99.20) **P = 0.006**	101.12	100.64 (100.12, 101.16) *P = 0.069*	101.59	100.95 (100.42, 101.49) **P = 0.019**
Entrepreneurs ($n = 28\ 184$)	9.97	10.42 (10.35, 10.49) **P < 0.0005**	100.21	100.17 (99.47, 100.87) P = 0.919	102.67	101.99 (101.26, 102.72) *P = 0.067*	102.61	101.94 (101.21, 102.68) *P = 0.073*
Low non-manual workers ($n = 26\ 165$)	10.30	10.62 (10.52, 10.72) **P < 0.0005**	104.52	104.69 (103.93, 105.45) P = 0.666	104.08	103.88 (102.86, 104.89) P = 0.687	102.86	102.61 (101.62, 103.60) P = 0.615
Middle non-manual workers ($n = 49\ 111$)	10.43	10.69 (10.63, 10.75) **P < 0.0005**	106.35	106.76 (106.16, 107.37) P = 0.175	104.89	104.73 (104.02, 105.44) P = 0.654	103.22	102.95 (102.23, 103.66) P = 0.454
High non-manual workers & professionals ($n = 18\ 723$)	10.77	10.93 (10.83, 11.03) **P = 0.002**	112.48	112.57 (111.62, 113.52) P = 0.853	107.41	106.23 (104.97, 107.50) *P = 0.069*	104.27	103.07 (101.82, 104.32) *P 0.061*
Data on childhood socioeconomic position missing ($n = 24\ 154$)	9.49	10.15 (10.07, 10.24) **P < 0.0005**	96.55	96.93 (95.99, 97.87) P = 0.429	97.21	97.09 (96.31, 98.32) P = 0.828	98.23	98.23 (97.29, 99.16) P = 0.999

*IQ = 100. Estimated effects with
P-values < 0.05 in boldface and < 0.10 in italics.

Table 2. All-cause mortality in vulnerable groups of equal size (proportion of the whole sample in %) from date of conscription until age 49–56 in crude and adjusted models (hazard ratios, 95% CI, P-values), with standard errors clustered at the municipal level

	Crude HR (95% CI), P-value	HR (95% CI), P-value, adjusted for possible confounders (i.e. intelligence estimate adjusted for socioeconomic position; emotional control estimate adjusted for socioeconomic position and intelligence)	HR (95% CI), P-value, adjusted for possible confounders and mediators (socioeconomic position adjusted for intelligence and emotional control; intelligence adjusted for socioeconomic position and emotional control)
Low childhood socioeconomic position (26%)	1.29 (1.23, 1.34), P < 0.0005	[1.29 (1.23, 1.34), P < 0.0005]	1.15 (1.11, 1.20), P < 0.0005
Low intelligence (25%)	1.64 (1.55, 1.72), P < 0.0005	1.58 (1.50, 1.65), P < 0.0005	1.39 (1.33, 1.45), P < 0.0005
Low emotional control (25%)	1.80 (1.71, 1.90), P < 0.0005	1.61 (1.54, 1.69), P < 0.0005	[1.61 (1.54, 1.69) P < 0.0005]

Point estimates with P-value < 0.05 in boldface; total number of deaths = 12 765. Estimates in brackets stem from the same model as estimates in the previous column.

this also seems to have been the case [−0.71 units on average (95% CI: −1.10, −0.32; P < 0.0005)].

The results, presented in Figure 1 and Table 1, suggest that the reform's impact on time spent in school, intelligence and emotional control was socioeconomically graded. Tests of interactions between the reform and socioeconomic status (coded as a metric variable) gave the following P-values: P < 0.0005 for time in school; P = 0.067 for IQ; P < 0.0005 for emotional control; and P < 0.0005 for emotional control adjusted for the effect on IQ. Sons of farmers and workers gained more than one half-year, illustrating that a majority of these boys would not have attended a ninth year in school if it had not been mandatory. Sons of farmers and workers also gained in intelligence thanks to the reform. In contrast, sons of entrepreneurs and non-manual workers gained less than one half-year, illustrating that a majority of them would have attended a ninth year in school even without the reform (but in a junior secondary school). For them, the reform had no clear impact on intelligence.

In sensitivity analyses in which we limited the sample to boys from municipalities for which we have intelligence data before and after the reform (n = 142 221), the overall effect on years of education and intelligence persisted [0.49 years in school (0.45-0.53), P < 0.0005, and 0.64 IQ units (0.34-0.94), P < 0.0005]. However, the estimated effect on emotional control lost strength: −0.05 units (−0.39-0.28, P = 0.754), and −0.22 units after adjusting for IQ (−0.56−0.12, P = 0.206).

The reform reduced socioeconomic differences in educational length, intelligence and emotional control (Table 1). The average difference in educational length at conscription between sons of farmers and sons of high non-manual workers decreased from 1.29 years to 0.75

years. The IQ difference between sons of unqualified manual and high non-manual workers diminished from 16.32 to 15.57 units, and the corresponding difference in emotional control (non-adjusted for IQ) dropped from 6.50 to 5.63 units.

Childhood socioeconomic position, intelligence and emotional control all predicted all-cause mortality, from conscription to the ages of 49 to 56 years (Table 2). Around half of the association between childhood socioeconomic position and mortality may have been mediated by intelligence and emotional control (HR = 1.29 vs HR = 1.15), but a clear direct association between childhood socioeconomic position and mortality remained (HR = 1.15). Intelligence was a stronger predictor of mortality than childhood socioeconomic position (HR = 1.64 vs HR = 1.29), and a substantial association remained after adjustment for the possible confounding role of childhood socioeconomic position (HR = 1.58). Around one-third of the association between intelligence and mortality may be mediated by emotional control (HR = 1.58 vs HR = 1.39). Emotional control was the strongest predictor of the three in the crude models (HR = 1.80). After adjustment for the possible confounding roles of childhood socioeconomic position and intelligence, emotional control was as predictive of mortality as was intelligence; that is, their independent contributions to premature mortality seem to be of the same magnitude (HR = 1.61 vs HR = 1.58).

All three factors displayed a clear graded association with mortality in analyses in which they were entered categorically (results not shown). In a model in which intelligence was entered metrically, one unit higher IQ was related to 1.7% lower risk of premature mortality after adjustment for the possible confounding role of childhood socioeconomic position [HR = 0.983 (95% CI: 0.981,

0.985), $P < 0.0005$]. The risk reduction corresponding to one unit higher emotional control was identical (−1.7%) after adjustment for the possible confounding role of childhood socioeconomic position and intelligence [HR = 0.983 (95% CI: 0.981, 0.984), $P < 0.0005$].

Discussion

The reform increased intelligence. This finding is in line with the findings of natural experiments[19–21] and with the results of a previous analyses conducted on a sub-sample of the boys in our cohorts.[33] Sons of farmers and manual workers gained the most and, as a result, clear initial differences in intelligence by childhood socioeconomic position were reduced, a finding that corroborates the idea that longer compulsory schooling can reduce socioeconomic disparities. A lot of current research focuses on early childhood education,[38] but our results illustrate that education can be successful even when provided in adolescence.

In contrast, being exposed to the reform was associated with lower emotional control. To interpret the possible differential impact on emotional control in children from different socioeconomic backgrounds, one must consider that the reform had different implications for different social groups. The reform's impact on years of education suggests that a majority of sons of farmers and manual workers would not have studied during the year between 15 and 16 years of age, had it not been mandatory. For these cohorts, jobs were readily available even at age 15. If the extra mandatory year in school typically replaced a year at work, the reform's positive effect on intelligence and negative effect on emotional control may reflect that work, for these boys, was on average a worse promoter of intelligence but a better promoter of emotional control. Perhaps work provided a more structured environment than school.

For sons of entrepreneurs, non-manual workers and professionals, in turn, the reform had no clear effect on intelligence, but we found suggestions of a negative effect on emotional control. The results on years of education suggest that without the reform, a majority of these boys would have been studying anyway, but in another type of school: the old junior secondary school. The signs of a detrimental effect on emotional control in those of higher socioeconomic position may suggest that in this respect and for these boys, the new school form was worse than the old one, at least initially. It is possible that teachers, when faced with a new curriculum and a new class composition, ran into problems structuring the learning environment.

Our observational data suggest that emotional control was an even stronger predictor of all-cause mortality than were intelligence and social background, a finding that is in line with previous findings.[13] In light of that result and of the possible detrimental effect of education on emotional control in our sample, it seems that socio-emotional skills should be taken into as serious consideration in epidemiological research as their cognitive counterparts.

The results regarding emotional control were not so clear in analyses of a pre-post design subsample; i.e. in the municipalities for which we had intelligence data both before and after the reform. Thus, we cannot exclude the possibility that what looks like an effect of the reform on emotional control was in reality driven by initial differences between those municipalities that introduced the reform early and those that introduced it later. However, given that these differences then must consist of something that is related neither to intelligence (for which we adjusted) nor to the socioeconomic composition of the municipality (by which we stratified), this seems unlikely.

All in all, although they only provide pieces of the puzzle, our results are in line with the idea that education may be key to healthier, more competent and fairer societies. However, at least for emotional control, different school forms may be more successful than others, and sometimes the alternative to school (e.g. work) might be better.

Author contributions

A.L. had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: A.L. Acquisition of data: A.L. Analysis and interpretation of data: A.L., D.S., D.F., M.L. Drafting of manuscript: A.L., D.S. Critical revisions of the manuscript for important intellectual content:D.F., M.L. Statistical analysis: A.L. Obtained funding: M.L.

Conflict of interest: There are no conflicts of interests.

References

1. Iwashyna TJ, Ely EW, Smith DM, Langa KM. Long-term cognitive impairment and functional disability among survivors of severe sepsis. *JAMA* 2010;**304**:1787-94.

2. Ehlenbach WJ, Hough CL, Crane PK *et al*. Association between acute care and critical illness hospitalization and cognitive function in older adults. *JAMA* 2010;**303**:763-70.

3. Yaffe K, Kanaya A, Lindquist K *et al*. The metabolic syndrome, inflammation, and risk of cognitive decline. *JAMA* 2004;**292**:2237-42.

4. Atlantis E, Fahey P, Cochrane B, Smith S. Bidirectional associations between clinically relevant depression or anxiety and COPD: a systematic review and meta-analysis. *Chest* 2013;**144**:766-77.

5. Harris EC, Barraclough BM. Suicide as an outcome for medical disorders. *Medicine* 1994;**73**:281-96.

6. Calvin CM, Deary IJ, Fenton C *et al*. Intelligence in youth and all-cause-mortality: systematic review with meta-analysis. *Int J Epidemiol* 2011;**40**:626-44.

7. Dickson H, Laurens KR, Cullen AE, Hodgins S. Meta-analyses of cognitive and motor function in youth aged 16 years and younger who subsequently develop schizophrenia. *Psychol Med* 2012;**42**:743-55.

8. Falkstedt D, Sorjonen K, Hemmingsson T, Deary IJ, Melin B. Psychosocial functioning and intelligence both partly explain socioeconomic inequalities in premature death. A population-based male cohort study. *PLoS One* 2013;**8**:e82031.

9. Batty GD, Wennerstad KM, Davey Smith G *et al*. IQ in early adulthood and mortality by middle age: cohort study of 1 million Swedish men. *Epidemiology* 2009;**20**:100-09.

10. Jokela M, Batty GD, Deary IJ, Silventoinen K, Kivimaki M. Sibling analysis of adolescent intelligence and chronic diseases in older adulthood. *Ann Epidemiol* 2011;**21**:489-96.

11. Allebeck P, Allgulander C, Fisher LD. Predictors of completed suicide in a cohort of 50,465 young men: role of personality and deviant behaviour. *BMJ* 1988;**297**:176-78.

12. Christensen MV, Kessing LV. Do personality traits predict first onset in depressive and bipolar disorder? *Nord J Psychiatry* 2006;**60**:79-88.

13. Roberts BW, Kuncel NR, Shiner R, Caspi A, Goldberg LR. The power of personality, the comparative validity of personality traits, socioeconomic status, and cognitive ability for predicting important life outcomes. *Perspect Psychol Sci* 2007;**2**:313-45.

14. Jokela M, Batty GD, Nyberg ST *et al*. Personality and all-cause mortality: individual-participant meta-analysis of 3,947 deaths in 76,150 adults. *Am J Epidemiol* 2013;**178**:667-75.

15. Heckman J. Policies to foster human capital. *Res Econ* 2000;**54**:2.

16. *Strategic Plan for Fiscal Years 2014-2018*. Washington, DC: US Department of Education, 2013.

17. *Strategic Plan for Fiscal Years 2011-2014*. Washington, D.: US Department of Education, 2012.

18. *Higher Education Law of the People's Republic of China*. Beijing: Ministry of Education, 1998.

19. Gustafsson J. Schooling and intelligence: Effects of track of study on level and profile of cognitive abilities. *Int Educ J* 2001;**2**:166.

20. Ceci SJ. How much does schooling influence general intelligence and its cognitive components? A reassessment of the evidence. *Dev Pscychol* 1991;**27**:703-22.

21. Brinch CN, Galloway TA. Schooling in adolescence raises IQ scores. *Proc Natl Acad Sci U S A* 2012;**109**:425-30.

22. Davies G, Tenesa A, Payton A *et al*. Genome-wide association studies establish that human intelligence is highly heritable and polygenic. *Mol Psychiatry* 2011;**16**:996-1005.

23. Deary IJ, Penke L, Johnson W. The neuroscience of human intelligence differences. *Nat Rev Neurosci* 2010;**11**:201-11.

24. Shipstead Z, Redick TS, Engle RW. Is working memory training effective? *Psychol Bull* 2012;**138**:628-54.

25. Lövden M, Bäckman L, Lindenberger U, Schaefer S, Schmiedek F. A theoretical framework for the study of adult cognitive plasticity. *Psychol Bull* 2010;**136**:659-76.

26. Greenberg MT, Weissberg RP, O'Brien MU *et al*. Enhancing school-based prevention and youth development through coordinated social, emotional, and academic learning. *Am Psychol* 2003;**58**:466-74.

27. Nettle D. The evolution of personality variation in humans and other animals. *Am Psychol* 2006;**61**:622-31.

28. Costa PT, McGrae RR. Longitudinal stability of adult personality. In: Hogan R, Johnson JA, Briggs SR (eds). *Handbook of Personality Psychology*. San Diego, CA: Academic Press, 1997.

29. John OP, Naumann LP, Soto CJ. Paradigm shift to the Integrative Big-Five Trait Taxonomy: history, measurement, and conceptual issues. In: John OP, Robins RW, Pervin LA (eds). *Handbook of Personality: Theory and Research*. New York, NY: Guilford Press, 2008.

30. Holmlund H. *A Researcher's Guide to the Swedish Compulsory School Reform. WP 9/2007*. Stockholm: Swedish Institute for Social Research, Stockholm University, 2007.

31. Spasojevic J. *Effects of Education on Adult Health in Sweden: Results from a Natural Experiment*. New York, NY: City University of New York, 2003.

32. Lager A, Torssander J. Causal effect of education on mortality in a quasi-experiment on 1.2 million Swedes. *Proc Natl Acad Sci U S A* 2012;**109**:8461-66.

33. Meghir C, Palme M, Simeonova E. *Education, Cognition and Health: Evidence from a Social Experiment. Working paper*. Stockholm: Stockholm University, 2013.

34. Erikson R, Goldthorpe JH. *The Constant Flux: A Study of Class Mobility in Industrial Societies*. Oxford, UK: Oxford University Press, 1992.

35. Likert R, Quasha WH. *Minnesota Paper Form Board Test*. New York, NY: Psychological Corporation, 1941.

36. Potijk MR, Janszky I, Reijneveld SA, Falkstedt D. Risk of coronary heart disease in men with poor emotional control: a prospective study. *Psychosom Med* 2016;**78**:60-67.

37. Verhaeghen P, Hertzog CK (eds). *The Oxford Handbook of Emotion, Social Cognition, and Problem Solving in Adulthood*. New York, NY: Oxford University Press, 2014.

38. Heckman JJ. Skill formation and the economics of investing in disadvantaged children. *Science* 2006;**312**:1900-02.