Skills, Schools and Synapses

James Heckman
University of Chicago

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Annapolis, Maryland
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Skills are an essential ingredient of the success of modern economies.
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A skilled workforce is a source of productivity growth, innovation and adaptability.
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It can better respond to increased uncertainty in technology and in trade patterns that is characteristic of our age.
Inequality in the labor market is largely due to inequality in skills and to long term trends in the demand for labor that favor skilled workers and have raised their wages both absolutely and relative to unskilled workers because they have become more scarce.
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The wage premia for skill (college vs. high school and high school vs. high school dropout) have increased.
March CPS full-time weekly earnings, 1963–2005
Percent change in the relative weekly wages of high school dropouts to high school graduates, CPS March 1963–2003

Percent change in the relative weekly wages of high school dropouts to college graduates, CPS March 1963–2003

![Bar chart showing percentage change in relative weekly wages.](chart.png)

- 1963-1971: -8.4%
- 1971-1979: 6.1%
- 1979-1987: -15.2%
- 1987-1995: -13.0%
- 1995-2003: -7.6%
- 1963-2003: -38.2%

Skilled workers are much less likely to participate in crime or in other social pathologies. Consider the case of crime.
Regression-adjusted probability of incarceration, by years of schooling (whites)

Source: Lochner and Moretti (2004)
Regression-adjusted probability of incarceration, by years of schooling (blacks)

Source: Lochner and Moretti (2004)
Men Incarcerated (2000) overall and by educational status

<table>
<thead>
<tr>
<th></th>
<th>Whites</th>
<th>Hispanics</th>
<th>Blacks</th>
</tr>
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<tbody>
<tr>
<td>All men, age 20–40</td>
<td>1.6%</td>
<td>4.6%</td>
<td>11.5%</td>
</tr>
<tr>
<td>High school dropouts, age 20–40</td>
<td>6.7%</td>
<td>6.0%</td>
<td>32.4%</td>
</tr>
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On many dimensions, participation in productive and pathological behaviors is closely linked to educational attainment.
On many dimensions, participation in productive and pathological behaviors is closely linked to educational attainment.

Therefore, it is a source of great concern that at a time when the demand for skill has increased, the supply of skill has slowed down.
Educational characteristics of the labor force aged 25 and over, 1980, 2000, 2020

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<tbody>
<tr>
<td>Less Than High School</td>
<td>17.3</td>
<td>-5.3</td>
<td>12.0</td>
<td>0.9</td>
<td>12.9</td>
</tr>
<tr>
<td>High School Only</td>
<td>31.5</td>
<td>6.3</td>
<td>37.8</td>
<td>3.8</td>
<td>41.6</td>
</tr>
<tr>
<td>Some Schooling Beyond High School</td>
<td>13.8</td>
<td>19.1</td>
<td>32.9</td>
<td>6.2</td>
<td>39.1</td>
</tr>
<tr>
<td>College Degree or More</td>
<td>17.3</td>
<td>18.5</td>
<td>35.8</td>
<td>7.7</td>
<td>43.5</td>
</tr>
<tr>
<td>Total</td>
<td>79.8</td>
<td>38.7</td>
<td>118.5</td>
<td>18.6</td>
<td>137.1</td>
</tr>
<tr>
<td>% With College Degree</td>
<td>21.6%</td>
<td></td>
<td>30.2%</td>
<td></td>
<td>31.7%</td>
</tr>
</tbody>
</table>

*Assumes that subsequent cohorts have same education at age 25 as the cohort age 25 in 2000.

Characteristics of the labor force aged 25 and over and components of change, 1980, 2000, 2020 (millions of workers)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>25-54</td>
<td>65.0</td>
<td>35.1</td>
<td>100.1</td>
<td>3.0</td>
<td>103.1</td>
</tr>
<tr>
<td>55-64</td>
<td>11.8</td>
<td>2.2</td>
<td>14.0</td>
<td>12.5</td>
<td>26.5</td>
</tr>
<tr>
<td>65+</td>
<td>3.0</td>
<td>1.4</td>
<td>4.4</td>
<td>4.0</td>
<td>8.4</td>
</tr>
<tr>
<td>Total</td>
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<td>118.5</td>
<td>19.4</td>
<td>137.9</td>
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</thead>
<tbody>
<tr>
<td>White Non-Hispanic – Native</td>
<td>63.0</td>
<td>21.5</td>
<td>84.5</td>
<td>2.6</td>
<td>87.1</td>
</tr>
<tr>
<td>Black Non-Hispanic – Native</td>
<td>7.6</td>
<td>4.6</td>
<td>12.2</td>
<td>2.8</td>
<td>15.0</td>
</tr>
<tr>
<td>Hispanic – Native</td>
<td>2.5</td>
<td>2.3</td>
<td>4.8</td>
<td>6.8</td>
<td>11.6</td>
</tr>
<tr>
<td>Other Non-Hispanic – Native</td>
<td>0.8</td>
<td>1.0</td>
<td>1.8</td>
<td>1.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Hispanic – Foreign Born</td>
<td>1.8</td>
<td>4.5</td>
<td>6.3</td>
<td>2.8</td>
<td>9.1</td>
</tr>
<tr>
<td>Non-Hispanic – Foreign Born</td>
<td>4.1</td>
<td>4.8</td>
<td>8.9</td>
<td>3.3</td>
<td>12.2</td>
</tr>
<tr>
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<table>
<thead>
<tr>
<th></th>
<th>Native White Workers 25-54</th>
<th>Native White Workers 55 &amp; Over</th>
<th>Workers of Color 25-54</th>
<th>Workers of Color 55 &amp; Over</th>
<th>Foreign Born Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Labor Force in 1980</strong></td>
<td>50.8</td>
<td>19.3</td>
<td>70.1</td>
<td>14.4</td>
<td>38.7</td>
</tr>
<tr>
<td><strong>Labor Growth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Labor Force in 2000</strong></td>
<td>-7.7</td>
<td>2.2</td>
<td>-10.3</td>
<td>1.6</td>
<td>-6.1</td>
</tr>
<tr>
<td><strong>Labor Force in 2020</strong></td>
<td>42.4</td>
<td>16.2</td>
<td>60.8</td>
<td>12.8</td>
<td>32.6</td>
</tr>
<tr>
<td><strong>Growth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Labor Growth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Labor Force in 2000</strong></td>
<td>24.7</td>
<td>21.3</td>
<td>21.3</td>
<td>15.1</td>
<td>31.7</td>
</tr>
<tr>
<td><strong>Labor Force in 2020</strong></td>
<td>62.4</td>
<td>24.2</td>
<td>77.7</td>
<td>24.4</td>
<td>13.7</td>
</tr>
</tbody>
</table>
Percent distribution of education among 30 year olds by year

Source: Annual March CPS Data. Three Year Centered Moving Averages

(Ellwood, 2001)
Postsecondary participation rates for adults aged 18-24, by combinations of sex and race/ethnicity, 1974-2003

NOTE: Participation includes those enrolled in postsecondary education and those who have completed (1) at least 2 years of postsecondary education (1974-1991 data), or (2) an associate's or higher degree (1992-2003 data). White and Black groups exclude those of Hispanic origin.

College enrollment rates of recent high school completers, by sex

Source: Authors calculations based on three year moving averages of NCES unpublished sources and, CPS, October 1970 to 2003 data. Table 183
Note: Recent high school completers are those who graduated or obtained a GED in the previous 12 months.
College enrollment rates of recent high school completers, by race

Source: Authors calculations based on three year moving averages of NCES unpublished sources and, CPS, October 1970 to 2003 data. Table 183
Note: Recent high school completers are those who graduated or obtained a GED in the previous 12 months
College-going among graduates is increasing.
College-going among graduates is increasing.

But when you count GEDs as dropouts, as you should, the dropout rate is increasing.
The fraction of high school dropouts in the USA, 1971–2000: Two alternative measures

Source:
Cumulative official high school dropout rate by race-ethnicity: persons 14 to 20 years old, 1973–1997
The official rate on high school dropouts disguises a substantial problem.
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Many American children taking GEDs.
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They do not complete college.

When we adjust the high school dropout rate for GEDs, the high school dropout rate is rising.
GED credentials issued as a percentage of public and private high school graduates, USA, 1960–2001

The high rate of dropout leads to a group of people with very low skills.
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Low compared to other advanced nations.
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Another way to gauge this is by looking at adult literacy in the U.S. compared to other countries.
Percentage of each gender who perform at Level 1 on the IALS Document Literacy Scale

Note: The scale scores were grouped into five levels of increasing difficulty, with Level 1 representing functional illiteracy. Levels 4 and 5 were combined. The sample is restricted to adults who are between 16–65 years of age at the time of the survey (1994 for the US and Germany, 1996 for the UK, and 1994–1995 for Sweden). Standard errors are calculated using the methodology described in IALS (2002).
To an economist, the sluggish response of the supply of skills is an enigma — when the rate of return has increased, the supply response should lead to many more educated workers, not less.
The increase in education is concentrated among the most affluent American families.
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This trend threatens to perpetuate and enhance inequality across income groups and race groups.
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Threatens workforce productivity because more of our future workers are coming from disadvantaged families.
The most common explanation for gaps in college attendance is tuition costs.
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Tuition has been rising.
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Tuition has been rising.

To many, this suggests that we should subsidize tuition.
Cameron and Heckman (1998) show that tuition explains little of the gap in college going between the affluent and less affluent, between rich and poor, between majorities and minorities.
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Controlling for ability at the age college decisions are made, minorities are more likely to enroll in college.
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Controlling for ability at the age college decisions are made, minorities are more likely to enroll in college.

Tuition costs cannot explain the dramatic gaps in high school dropping out.
Gaps in test scores are substantial between the affluent and the poor; between majority group members and minority group members.
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This suggests that perhaps the schools are to blame.
Gaps in ranks or achievement across race groups and across income groups open up early, before schools can have any effect.
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- Absolute levels of test scores grow. Percentage ranks are stable.
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Schools add knowledge.
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• But gaps open up as early as they are measured.
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In a statistical sense, gaps can be closed by controlling for family traits.
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• Absolute levels of test scores grow. Percentage ranks are stable.
• Schools add knowledge.
• But gaps open up as early as they are measured.
• In a statistical sense, gaps can be closed by controlling for family traits.
• Consistent with Coleman Report (1966).
Average percentile rank on PIAT-Math score, by income quartile

![Graph showing average percentile rank on PIAT-Math score by income quartile. The graph displays data points for four income quartiles across different ages (6, 8, 10, 12). The lowest income quartile shows the lowest scores, followed by the second, third, and highest income quartiles, respectively.](image-url)
Average percentile rank on PIAT-Math score, by race
Average percentile rank on anti-social score, by income quartile (whites)
Average percentile rank on anti-social score, by race

![Graph showing average percentile rank on anti-social score by race. The graph displays data for Hispanic, Black, and White individuals across different age groups.](image-url)
Average percentile rank on anti-social score, by income quartile
Controlling for early family factors eliminates a lot of the gaps in ranks.
Residualized average PIAT-Math score percentiles, by income quartile

* Residualized on maternal education, maternal AFQT (corrected for the effect of schooling) and broken home at each age.
Residualized average PIAT-Math score percentiles, by race

* Residualized on maternal education, maternal AFQT (corrected for the effect of schooling) and broken home at each age
Residualized average anti-social score percentile, by income quartile

* Residualized on maternal education, maternal AFQT (corrected for the effect of schooling) and broken home at each age
Residualized average anti-social score percentile, by race

* Residualized on maternal education, maternal AFQT (corrected for the effect of schooling) and broken home at each age.
Family factors matter.
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A source of concern because, as we have seen, a greater fraction of American children are being born to disadvantaged families.
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A source of concern because, as we have seen, a greater fraction of American children are being born to disadvantaged families.

While the situation is improving, there is still a major problem with child environments.
Trends in unhealthy child environments

Data for births and birth rates are from Ventura and Bachrach (2000). Data for children living with one parent are available at the census bureau at http://www.census.gov/population/socdemo/hh-fam/tabCH-1.txt. Data for children living in poverty is available at www.childtrendsdb.org/
Abilities Are Multiple

To understand the sources of difference in schooling, and participation in a variety of social pathologies, and even the development of animal species, we need to appreciate that there are multiple abilities.
Much public policy discussion is devoted to cognitive scores or "smarts".
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NCLB focuses on achievement on a test score at a certain age to measure success or failure in schools.
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Yet an emerging body of evidence shows that, as is intuitively obvious and commonsensical, much more than smarts are required.
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- Motivation,
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- Attention,
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- Motivation,
- Attention,
- Self Esteem,
- Time Preference.
Their importance tends to be underrated in current policy discussions because they are not easily measured.
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Evidence from the GED program (Heckman and Rubinstein, 2001).
The GED program is a second chance program given to secondary school dropouts.
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We have already seen that participation in the GED program is growing.
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GEDs are required to pass a test of cognitive abilities.
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Level relatively low—at the grade 8 to grade 10 level.
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We have already seen that participation in the GED program is growing.

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Level relatively low—at the grade 8 to grade 10 level.

Test is successful in its own terms.
Density of age adjusted AFQT scores, GED recipients and high school graduates with twelve years of schooling

Source: Heckman, Hsee and Rubinstein (2001)
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Density of age adjusted AFQT scores, GED recipients and high school graduates with twelve years of schooling

Source: Heckman, Hsee and Rubinstein (2001)
Yet GEDs earn at the rate of high school dropouts.
GEDs are as “smart” as ordinary high school graduates.
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- They lack noncognitive skills.
GEDs are as “smart” as ordinary high school graduates.
They lack noncognitive skills.
The GEDs are the wise guys who can’t finish anything.
GEDs are as “smart” as ordinary high school graduates.

- They lack noncognitive skills.
- The GEDs are the wise guys who can’t finish anything.
- Most branches of the military recognize this in their recruiting strategies.
There is a lot of evidence that both cognitive and noncognitive skills are important.
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Both cognitive and noncognitive skills matter in a variety of aspects of life.
Cognitive and noncognitive ability are important determinants of schooling and socioeconomic success.
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In the U.S., schooling gaps have more to do with ability deficits than family finances in the school-going years.
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Those with higher abilities of both types are more likely to take post-school company job training.
Cognitive and noncognitive ability are important determinants of schooling and socioeconomic success.

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Those with higher abilities of both types are more likely to take post-school company job training.

Look at effects of both cognitive and noncognitive skills on many measures of social performance.
Probability of being a 4-year college graduate, by ability

Note: This figure plots the probability of a given behavior associated with moving up in one ability distribution for someone after integrating out the other distribution. For example, the lines with markers show the effect of increasing noncognitive ability after integrating the cognitive ability. Source: Heckman, Stixrud, and Urzua (2006).
Ever been in jail by age 30, by ability (males)

Note: This figure plots the probability of a given behavior associated with moving up in one ability distribution for someone after integrating out the other distribution. For example, the lines with markers show the effect of increasing noncognitive ability after integrating the cognitive ability. Source: Heckman, Stixrud, and Urzua (2006).
Probability of being single with children (females)

Note: This figure plots the probability of a given behavior associated with moving up in one ability distribution for someone after integrating out the other distribution. For example, the lines with markers show the effect of increasing noncognitive ability after integrating the cognitive ability.  Source: Heckman, Stixrud, and Urzua (2006).
Probability of being a high school dropout by age 30 (males)
Probability of being a high school dropout by age 30 (males) (cont.)

Notes: The data are simulated from the estimates of the model and our NLSY79 sample. We use the standard convention that higher deciles are associated with higher values of the variable. The confidence intervals are computed using bootstrapping (200 draws).
Probability of being a 4-year college graduate by age 30 (males)
Probability of being a 4-year college graduate by age 30 (males) (cont.)

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Probability of incarceration by age 30 (males)
Probability of incarceration by age 30 (males) (cont.)

Notes: The data are simulated from the estimates of the model and our NLSY79 sample. We use the standard convention that higher deciles are associated with higher values of the variable. The confidence intervals are computed using bootstrapping (200 draws).
Probability of daily smoking by age 18 (males)
Probability of daily smoking by age 18 (males) (cont.)

Notes: The data are simulated from the estimates of the model and our NLSY79 sample. We use the standard convention that higher deciles are associated with higher values of the variable. The confidence intervals are computed using bootstrapping (200 draws).
Mean log wages by age 30 (males)
Notes: The data are simulated from the estimates of the model and our NLSY79 sample. We use the standard convention that higher deciles are associated with higher values of the variable. The confidence intervals are computed using bootstrapping (50 draws).
How do these early differences in abilities arise?
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- Is the difference due to genetics?
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They used an achievement test score measurement at 14 to show that genes were important.

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This score has been shown to be affected by schooling and family environments.

But possibly, with better measures, they are right.
Evidence on epigenetics suggests that the genes vs. environment distinction is obsolete.
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- A large body of recent work suggests that gene-environmental interactions are central to explaining human (and animal) development.
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- MOA gene expression is modified by the environment.
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- A large body of recent work suggests that gene-environmental interactions are central to explaining human (and animal) development.
- MOA gene expression is modified by the environment.
- Suomi: short allele / long allele species are affected differently by the environment.
Evidence on epigenetics suggests that the genes vs. environment distinction is obsolete.

- A large body of recent work suggests that gene-environmental interactions are central to explaining human (and animal) development.
- MOA gene expression is modified by the environment.
- Suomi: short allele / long allele species are affected differently by the environment.
Evidence that shows that family backgrounds eliminate test score gaps is correlational in nature.
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We cannot know true causal effect without some further assumption because of some possible unmeasured third common cause.

There is evidence from experimental interventions that avoids some of the interpretive problems with the correlational evidence.
The most reliable data come from experiments that provided substantial enrichment of the early environments of children living in low-income families.
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Two of these investigations, the Perry Preschool Program and the Abecedarian Program, are the most informative for the purposes of this discussion because they employed a random assignment design and collected long-term follow-up data.
These longitudinal studies demonstrated substantial, positive effects of early environmental enrichment on a range of cognitive and “non-cognitive” skills, schooling achievement, job performance, and social behaviors, long after the intervention ended.
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Data from non-controlled assessments of Head Start and the Chicago Child-Parent Centers programs suggest similar conclusions. The data from Head Start represent only short-term effects.
The Perry Program was an intensive preschool program that was administered to 58 disadvantaged, black children in Ypsilanti, Michigan between 1962 and 1967.
Early Intervention Programs for Disadvantaged Children

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- The treatment consisted of a daily 2.5 hour classroom session on weekday mornings and a weekly 90 minute home visit by the teacher on weekday afternoons. The length of each preschool year was 30 weeks.
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- The treatment consisted of a daily 2.5 hour classroom session on weekday mornings and a weekly 90 minute home visit by the teacher on weekday afternoons. The length of each preschool year was 30 weeks.
- The control and treatment groups have been followed through age 40.
The Abecedarian Program involved 111 disadvantaged children, born between 1972 and 1977, whose families scored high on a risk index. The mean age at entry was 4.4 months.
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The program was a year-round, full-day intervention that continued through age 8. The children were followed up until age 21, and the project is ongoing.
In both the Perry and Abecedarian Programs there was a consistent pattern of successful outcomes for treatment group members compared with control group members.
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For the Perry Program, an initial increase in IQ disappeared gradually over 4 years following the intervention, as has been observed in other studies.
However, in the more intensive Abecedarian Program, which intervened earlier (starting at age 4 months) and lasted longer (until age 8), the gain in IQ persisted into adulthood (21 years old).
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This early and persistent increase in IQ is important because IQ is a strong predictor of socioeconomic success.
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Positive effects of these interventions were also documented for a wide range of social behaviors.

At the oldest ages tested (Perry: 40 yrs; Abecedarian: 21 yrs), individuals scored higher on achievement tests, reached higher levels of education, required less special education, earned higher wages, were more likely to own a home, and were less likely to go on welfare or be incarcerated than individuals from the control groups.
Perry preschool program: educational effects, by treatment group

Notes: *High achievement defined as performance at or above the lowest 10th percentile on the California Achievement Test (1970).
Perry preschool program: economic effects at age 27, by treatment group

- Never on Welfare as Adult*:
  - Treatment (29%)
  - Control (14%)

- Own Home:
  - Treatment (36%)
  - Control (13%)

- Earn +$2,000 Monthly:
  - Treatment (29%)
  - Control (7%)

Perry preschool program: arrests per person before age 40, by treatment group

Source: Perry Preschool Program. Juvenile arrests are defined as arrests prior to age 19.
Perry did not raise IQ.
- Perry did not raise IQ.
- It raised noncognitive skills.
Perry preschool program: IQ, by age and treatment group

Source: Perry Preschool Program. IQ measured on the Stanford–Binet Intelligence Scale (Terman & Merrill, 1960). Test was administered at program entry and each of the ages indicated.
• Other similar programs
Academic and social benefits at school exit for CPC participants


- **HS Graduation**
  - No-program group: 39%
  - Program group: 50%

- **Special Education**
  - No-program group: 25%
  - Program group: 14%

- **Grade Repeater**
  - No-program group: 38%
  - Program group: 23%

- **Juvenile Arrest**
  - No-program group: 25%
  - Program group: 17%
Abecedarian academic outcomes


- Special Education: 25% (Special), 48% (No-program)
- Grade Repeater: 31% (Special), 55% (No-program)
- HS Graduation: 67% (Special), 51% (No-program)
- College: 13% (Special), 36% (No-program)
Other benefits of Abecedarian

![Bar chart showing comparisons between No-program group and Program group for Skilled Job or Higher Education at age 21 and Smoker at age 21. Source: Barnett (2004).]
Intervening at an early enough age can actually raise IQ of the participants.
Abecedarian program: IQ, by age and treatment group

Many studies have shown that these aspects of behavior translate directly or indirectly into high economic return. An estimated rate of return (the return per dollar of cost) to the Perry Program is in excess of 17%.
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This high rate of return is much higher than standard returns on a stock market equity and suggests that society at large can benefit substantially from these kinds of interventions.
The evidence from these intervention studies shows the following.
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First, skills beget skills.
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That is, all capabilities are built on a foundation of capacities that are developed earlier.
This principle stems from two characteristics that are intrinsic to the nature of learning:
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- Early learning confers value on acquired skills, which leads to self-reinforcing motivation to learn more;
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- Early learning confers value on acquired skills, which leads to self-reinforcing motivation to learn more;
- Early mastery of a range of cognitive, social, and emotional competencies makes learning at later ages more efficient and therefore easier and more likely to continue.
Technology of skill formation

\[ S_{t+1} = f(S_t, I_t) \]

Skill at time \( t + 1 \)
Skill at time \( t \)
Investment
Two polar cases

- “Leontief cases” and perfect substitution.

\[ S_{t+1} = \min (S_t, I_t) \]
Two polar cases

- “Leontief cases” and perfect substitution.

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- A polar opposite is the case of perfect substitutes

\[ S_{t+1} = a S_t + b I_t \]
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- Leads to ideas of critical and sensitive periods.
Two polar cases

- “Leontief cases” and perfect substitution.

\[ S_{t+1} = \min(S_t, l_t) \]

- A polar opposite is the case of perfect substitutes

\[ S_{t+1} = a S_t + b l_t \]

- Leads to ideas of critical and sensitive periods.
- Language in humans is an example of sensitive periods.
Second language learning

![Graph showing English Proficiency Score (mean) vs Age of Arrival in U.S. (years)]

- The graph illustrates the decline in English proficiency scores with age of arrival in the U.S.
- Scores are highest for native speakers and decrease significantly with increasing age of arrival.
Sensitive period for second language acquisition. English language proficiency scores as a function of age of arrival in the United States for a group of Chinese and Korean adult immigrants ($n = 46$). All subjects were students or faculty at the University of Illinois and had been in the U.S. for at least 10 years prior to testing. The test measured a variety of grammatic judgements. From Johnson and Newport (1989).
Romanian adoption study supports this

<table>
<thead>
<tr>
<th>Age of Adoption (Months):</th>
<th>Within-UK Adoptees</th>
<th>Romanian Orphans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>Before 6</td>
</tr>
<tr>
<td>Weight at Adoption</td>
<td>-</td>
<td>-2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.7)</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.7)</td>
</tr>
<tr>
<td>Height at Adoption</td>
<td>-</td>
<td>-1.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.6)</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-2.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.4)</td>
</tr>
<tr>
<td>Denver Developmental</td>
<td>-</td>
<td>76.5</td>
</tr>
<tr>
<td>Scale at Adoption</td>
<td>-</td>
<td>48.1</td>
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<td></td>
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<td>(48.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(25.4)</td>
</tr>
</tbody>
</table>

See Rutter et al. (1998) and O’Connor et al. (2000) for more details on the analysis.
Romanian adoption study supports this (cont.)

<table>
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</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>Before 6</td>
</tr>
<tr>
<td>Weight at Age 4</td>
<td>0.45</td>
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</tr>
<tr>
<td></td>
<td>(0.79)</td>
<td>(0.92)</td>
</tr>
<tr>
<td>Height at Age 4</td>
<td>0.25</td>
<td>-0.29</td>
</tr>
<tr>
<td></td>
<td>(0.91)</td>
<td>(0.89)</td>
</tr>
<tr>
<td>Denver Developmental</td>
<td>117.7</td>
<td>115.7</td>
</tr>
<tr>
<td>Scale at Age 4</td>
<td>(24.3)</td>
<td>(23.4)</td>
</tr>
<tr>
<td>McCarthy GCI at Age 4</td>
<td>109.4</td>
<td>105.9</td>
</tr>
<tr>
<td></td>
<td>(14.8)</td>
<td>(17.9)</td>
</tr>
</tbody>
</table>

See Rutter et al. (1998) and O’Connor et al. (2000) for more details on the analysis.
Romanian adoption study supports this (cont.)

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<tr>
<td></td>
<td>6</td>
<td>Before 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age 6-24</td>
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<tr>
<td></td>
<td></td>
<td>Age 24-42</td>
</tr>
<tr>
<td>Weight at Age 6</td>
<td>0.30 (0.90)</td>
<td>0.02 (0.97)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.25 (0.96)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.85 (0.98)</td>
</tr>
<tr>
<td>Percentage with Denver</td>
<td>2 (1)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Developmental Scale at</td>
<td></td>
<td>5 (2)</td>
</tr>
<tr>
<td>Age 6 Below 70</td>
<td></td>
<td>18 (7)</td>
</tr>
<tr>
<td>McCarthy GCI at Age 6</td>
<td>117 (17.8)</td>
<td>114 (18.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>99 (19.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90 (23.8)</td>
</tr>
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</table>

See Rutter et al. (1998) and O’Connor et al. (2000) for more details on the analysis.
Similar results found in animal studies

- Experimental evidence on macaque monkey population supports this conclusion.
Similar results found in animal studies

- Experimental evidence on macaque monkey population supports this conclusion.
- Draw on the work of Judy Cameron, Oregon National Primate Research Center.
Studies of Monkeys

- Surrogate mother provided at:
  - 1 month
  - 1.5 month
  - 2 month
  - None

Graph showing time spent self-comforting (%) vs. age (months) with different markers for each condition.
A model of critical and sensitive periods

Consider a simple model—two periods of childhood (taken from Cunha and Heckman, 2006).
A model of critical and sensitive periods

- Consider a simple model—two periods of childhood (taken from Cunha and Heckman, 2006).
- Human Capital $S_2$ in Period 2:

$$S_2 = \left[ \gamma l_1^\phi + (1 - \gamma) l_2^\phi \right]^{\frac{1}{\phi}}$$
A model of critical and sensitive periods

- Consider a simple model—two periods of childhood (taken from Cunha and Heckman, 2006).
- Human Capital $S_2$ in Period 2:

$$S_2 = \left[ \gamma I_1^\phi + (1 - \gamma) I_2^\phi \right]^{\frac{1}{\phi}}$$

- $I_1$ is early investment; $I_2$ is late investment.
The ratio of early to late investment in human capital as a function of the skill multiplier for different values of complementarity.
This figure shows the optimal ratio of early to late investments, $\frac{L_1}{L_2}$, as a function of the skill multiplier parameter $\gamma$, for different values of the complementarity parameter $\phi$, assuming that the interest rate $r$ is zero. The optimal ratio $\frac{L_1}{L_2}$ is the solution of the parental problem of maximizing the present value of the child’s wealth through investments in human capital, $h$, and transfers of risk-free bonds, $b$. In order to do that, parents have to decide how to allocate a total of $M$ dollars into early and late investments in human capital, $I_1$ and $I_2$, respectively, and risk-free bonds. Let $q$ denote the present value as of period “3” of the future prices of one efficiency unit of human capital: $q = \sum_{t=3}^{T} \frac{w_t}{(1+r)^t}$. The parents solve

$$\max \left( \frac{1}{1+r} \right)^2 [qh + b]$$

subject to the budget constraint

$$I_1 + \frac{I_2}{(1+r)} + \frac{b}{(1+r)^2} = M$$

and the technology of skill formation:

$$h = \left[ \gamma I_1^\phi + (1 - \gamma) I_2^\phi \right]^\frac{1}{\phi}$$

for $0 < \rho < 1$, $0 \leq \gamma \leq 1$, and $\phi \leq 1$. From the first-order conditions it follows that $\frac{L_1}{L_2} = \left[ \frac{\gamma}{(1-\gamma)(1+r)} \right]^{\frac{1-\phi}{\phi}}$. This ratio is plotted in this figure when $\phi \to -\infty$ (Leontief), $\phi = -0.5$, $\phi = 0$ (Cobb-Douglas) and $\phi = 0.5$ and for values of the skill multiplier $\gamma$ between 0.1 and 0.9.
Recent work by Cunha and Heckman estimates this technology and shows the relative effectiveness of early and late interventions.
Comparison of Different Investment Strategies  
Disadvantaged Children: First Decile in the Distribution of Cognitive and Non-Cognitive Skills at Age 6  
Mothers are in First Decile in the Distribution of Cognitive and Non-Cognitive Skills at Ages 14-21

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Changing Initial Conditions - Moving Children to the 4th Decile of Distribution of Skills only through Early Investment</th>
<th>Adolescent Intervention: Moving Investments at Last Transition from 1st to 9th Decile</th>
</tr>
</thead>
<tbody>
<tr>
<td>High School Graduation</td>
<td>0.4109</td>
<td>0.6579</td>
<td>0.6391</td>
</tr>
<tr>
<td>Enrollment in College</td>
<td>0.0448</td>
<td>0.1264</td>
<td>0.1165</td>
</tr>
<tr>
<td>Conviction</td>
<td>0.2276</td>
<td>0.1710</td>
<td>0.1773</td>
</tr>
<tr>
<td>Probation</td>
<td>0.2152</td>
<td>0.1487</td>
<td>0.1562</td>
</tr>
<tr>
<td>Welfare</td>
<td>0.1767</td>
<td>0.0905</td>
<td>0.0968</td>
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Comparison of Different Investment Strategies
Disadvantaged Children: First Decile in the Distribution of Cognitive and Non-Cognitive Skills at Age 6
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<tr>
<th></th>
<th>Baseline</th>
<th>Changing Initial Conditions - Moving Children to the 4th Decile of Distribution of Skills</th>
<th>Changing Initial Conditions and Performing Adolescent Intervention</th>
<th>Changing Initial Conditions and Performing a Balanced Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>High School Graduation</td>
<td>0.4109</td>
<td>0.6579</td>
<td>0.8477</td>
<td>0.9135</td>
</tr>
<tr>
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</tr>
<tr>
<td>Conviction</td>
<td>0.2276</td>
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<td>0.1083</td>
</tr>
<tr>
<td>Probation</td>
<td>0.2152</td>
<td>0.1487</td>
<td>0.1009</td>
<td>0.0815</td>
</tr>
<tr>
<td>Welfare</td>
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<td>0.0905</td>
<td>0.0415</td>
<td>0.0259</td>
</tr>
</tbody>
</table>
Using the estimated technology to simulate balanced interventions

![Graph showing score in cognitive skills over age for different interventions: Simulated Perry Control, Simulated Perry Treatment, and Simulated Perry Plus Follow Up.](image-url)
Using the estimated technology to simulate Perry preschool with follow up
The evidence strongly supports early initial investment that is sustained.
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Optimal distribution of investment:
• The evidence strongly supports early initial investment that is sustained.

• Optimal distribution of investment:
  • Invest early? Yes.
The evidence strongly supports early initial investment that is sustained.

Optimal distribution of investment:

- Invest early? Yes.
- But must be followed up to be effective.
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Optimal distribution of investment:

- Invest early? Yes.
- But must be followed up to be effective.

This is a consequence of complementarity.
Skills matter.
Skills matter.

America has a skills problem. Rising inequality is a signal of this problem.
Skills matter.

America has a skills problem. Rising inequality is a signal of this problem.

More than smarts is required.
Summary

- Skills matter.
- America has a skills problem. Rising inequality is a signal of this problem.
- More than smarts is required.
- NCLB and a lot of American social policy focus only on smarts.
Skills matter.

America has a skills problem. Rising inequality is a signal of this problem.

More than smarts is required.

NCLB and a lot of American social policy focus only on smarts.

Skill gaps emerge early and can be traced in part to adverse early environments.
Schools and tuition do not matter as much as is often thought.
Summary

- Schools and tuition do not matter as much as is often thought.
- Late remediation not very effective.
Summary

- Schools and tuition do not matter as much as is often thought.
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- Remediation can work, but is costly.
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Social policy should be directed toward the malleable early years.
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- Schools and tuition do not matter as much as is often thought.
- Late remediation not very effective.
- Remediation can work, but is costly.
- Social policy should be directed toward the malleable early years.
- Evidence from human and animal species supports this conclusion.