

What are the Crucial Ages for Productive Interventions in Human Capital Development? Early Childhood, Adolescence, the Transition to Postsecondary Education, and Later Life

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Question 1: At What Ages Should We Invest in Formal Human Capital?

* In other words, do we have theory about this?

Question 2: Are There Some Ages When We Are Likely Under- or Overinvesting?

* What do we know about the productivity of investments by age?

The Ages of Greatest Interest and the Main Arguments *For*

Very early childhood (0-4)

• Best argument for: neuroscience plus endogenous growth of *basic* skills

Early adolescence (10-15, depending on the sex)

 Best argument for: neuroscience of frontal lobe development plus endogenous growth of *advanced* skills

Usual transition to post-secondary education (18-21):

 Best argument for: students are more autonomous and can specialize in skills that match their abilities

Later investments in education (age 35+)

 Best argument for: people understand the skills they need; no third party payer problem

The Ages of Greatest Interest and the Main Arguments *Against*

Very early childhood (0-4)

 Best argument against: early cognitive gains often appear to fade out quickly (controversial)

Early adolescence (10-15, depending on the sex)

 Best argument against: perhaps some people are incapable of developing advanced cognitive skills

Usual transition to post-secondary education (18-21):

• Best argument against: by this age, students' cognitive trajectories are fairly set

Later investments in education (age 35+)

• Best argument against: by this age, investments have a short horizon to pay out

1. Cognitive skills are *not* well measured by years of education ("educational attainment") & the problem is getting worse over time.

• Think of debasement or inflation.

• The decrease in selection on skill is the underlying cause of this problem.

2. Although test-based measures of cognitive skill are *highly* imperfect, they are very important to outcomes such as earnings. Moreover, the importance of (measured) cognitive skill for earnings is increasing, while the importance of educational attainment is falling.

3. Neuroscience informs us about the ages at which cognitive skills are most plastic and which *types* of cognition are most plastic at each age.

4. Society does not invest the same amount in education at each age, suggesting that we either have a grand theory of the productivity of investing at each age or just *unthinking* about the problem.

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Cognitive skills are not well measured by educational attainment & the problem is getting worse over time





Percentage of 32-35 Year Olds with Specified Educational Attainment, by Year



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Although test-based measures of cognitive skill are *highly* imperfect, they are very important to outcomes such as earnings. Moreover, the importance of (measured) cognitive skill for earnings is increasing, while the importance of educational attainment is falling.



Neuroscience informs us about the ages at which cognitive skills are most plastic and which *types* of cognition are most plastic at each age.

Neuroscience indicates that Basic Cognitive Skills develop in *Very Early Childhood*

Recent neuroscience based on brain dissection and longitudinal MRI studies demonstrates that very early childhood (-3 months to 3 years) is crucial in the development of the sensorimotor, parietal, and temporal cortexes of the brain.

□ Starting before birth, there is exuberant neuron creation in these cortexes.

- □ Then an intense period of synaptic pruning starting from 2 months to ~3 years.
- Myelination speeds up and reinforces the pruned neural circuits.
- All this makes these cortexes unusually *plastic* in very early childhood.

The cortexes in question are crucial for the development of motor, language, visual, hearing, basic literacy, basic numeracy, and social skills ("non-cognitive skills").





Neuroscience indicates that Advanced Cognitive Skills develop in *Early Adolescence*

Recent neuroscience based on brain dissection and longitudinal MRI studies demonstrates that early adolescence is crucial in the development of the frontal cortex of the brain.

□ Just before early adolescence, there is exuberant neuron creation in the frontal lobe.

- Then an intense period of synaptic pruning starting at age 10-11 for females, 11-12 for males.
- Myelination speeds up and reinforces the pruned neural circuits.
- All this makes the frontal lobe unusually *plastic* for a few years starting in early adolescence.
- □ Frontal lobe development continues well past early adolescence, but Advanced Cognitive Skill trajectories start to "harden" by age 14.5 for females, 15.5 for males.





What are Advanced Cognitive Skills?

> Higher order cognition that cannot take place until the brain's frontal lobe has developed:

Higher reasoning, logic, abstraction, critical thinking, synthesis.

Planning and self-regulation.

> Examples:

- Algebra and higher level math require translation of problems into equations, solving of abstract problems for a solution, and proofs, as opposed to (even difficult) rational numbers reasoning such as multiplication, division, fractions, percentages, etc.
- In history coursework, analysis of cause and effect require critical thinking, not just summarization of facts, organized narratives, and recognition of similarities among historical events.

"You're likely familiar with the idea that the early years—`0 to 3' is the popular shorthand--are a time during which children's experiences make a major, lasting difference in how their brains develop and the lives unfold.... But most people don't realize that adolescence is a second period of heightened malleability.

The fact that the adolescent brain is malleable is both good and bad news, though. As neuroscientists are fond of saying, plasticity cuts both ways. By this they mean that the brain's malleability makes adolescence a period of tremendous opportunity--and great risk." —Age of Opportunity, Steinberg "The abilities that develop in adolescence... are not as necessary for survival as are those that develop early in life. You can live without being able to reason logically....

Unlike elementary skills, whose development is tightly regulated by pre-programmed biology, evolution left more room for variation in the development of complex abilities. That's why there's so much variation in how well different people reason..., but far less variation in how well people see, hear, and walk.

In the past, not all environments demanded... advanced cognitive abilities.... In today's world, though, where formal education is increasingly important for success, people who are bad at reasoning, planning, and self-regulation are at a serious disadvantage, and the fact that the development of these abilities is highly sensitive to environmental influence is a mixed blessing.... For people... in favorable circumstances [during early adolescence], the plasticity of these brain systems is wonderful. For those who [aren't], this same plasticity can be disastrous."

-Age of Opportunity, Steinberg.

Advanced Cognitive Skill trajectories are already hardening by age 15.

Male math score transitions, ages 15.5 to 17.5

			10 Deci	les of Matł	n in Grade 1	12 (age 17.:	5 on averag	ge)	101	
	1	2	3	4	5	6	7	8	9	10
1	62.2	28.3	5.7	2.3	0.9	0.2	0.5	0.0	0.0	0.0
2	28.7	43.5	18.3	5.7	2.9	0.8	0.2	0.0	0.0	0.0
3	8.0	26.2	32.7	18.1	9.3	4.0	1.3	0.4	0.0	0.0
4	0.9	8.6	21.9	31.4	20.7	11.8	2.9	2.0	0.0	0.0
5	1.1	3.3	10.4	18.0	27.1	24.1	12.6	3.3	0.0	0.0
6	0.7	1.5	4.0	8.8	20.8	30.5	22.8	9.7	1.3	0.0
7	0.3	1.0	0.8	2.3	9.6	23.9	31.8	24.2	5.6	0.3
8	0.0	0.3	0.4	0.6	2.6	7.9	19.7	37.5	24.8	6.3
9	0.0	0.0	0.0	0.6	1.0	1.3	5.7	21.5	40.7	29.3
10	0.0	0.0	0.0	0.2	0.1	0.5	1.5	5.2	21.6	70.9

How to interpret? The row labeled "8" shows that a male who scores in decile 8 at age 15.5 has a 2.6% probability of scoring in decile 5 at age 17.5, a 37.5% probability of scoring in decile 8 at age 17.5, and a 6.3% probability of scoring in decile 10 age 17.5. The interpretation of the other cells in analogous. Source: National Education Longitudinal Study.

But skill trajectories are more *plastic* in the early adolescent period, so that a male who ends 5th grade at one level is likely to end 8th grade at another.

Math Aptitude Transitions from Age 8.5 to Age 10.5, Males

		10 Deciles of Math in Grade 5 (age 10.5 on average)												
		1	2	3	4	5	6	7	8	9	10			
	1	51.3	23.9	11.3	6.4	3.8	1.9	0.9	0.4	0.2	0.0			
	2	26.3	26.8	18.1	13.0	7.6	4.4	2.3	1.0	0.4	0.1			
	3	14.5	22.0	19.6	17.4	12.5	7.0	4.2	1.8	0.8	0.2			
	4	7.7	15.4	17.3	19.1	16.5	11.7	6.9	3.5	1.6	0.4			
	5	3.5	9.1	13.4	17.3	18.3	15.6	11.7	7.0	3.2	0.8			
Wg	6	1.3	4.7	8.0	13.0	17.1	18.1	16.5	12.0	7.2	2.0			
on 8	7	0.7	2.1	4.4	8.5	13.7	16.6	18.6	17.1	13.6	4.9			
5.	8	0.3	0.9	2.2	4.6	8.2	12.6	17.8	21.2	21.4	10.9			
e 8	9	0.1	0.3	0.7	1.7	3.8	7.2	12.4	19.6	28.9	25.2			
(ag	10	0.0	0.1	0.1	0.4	1.0	1.9	4.6	10.4	24.8	56.8			

How to interpret? The row labeled "8" shows that a male who scores in decile 8 at age 8.5 has a 8.2% probability of scoring in decile 5 at age 10.5, a 21.2% probability of scoring in decile 8 at age 10.5, and a 10.9% probability of scoring in decile 10 age 10.5. The interpretation of the other cells in analogous. Source: Early Childhood Longitudinal Study—Kindergarten Cohort.

10 Deciles of Math in Grade 3

Male math score transitions, ages 10.5 to 13.5

	10 Deciles of Math in Grade 8 (age 13.5 on average)											
	1	2	3	4	5	6	7	8	9	10		
1	67.4	23.1	5.4	1.9	1.4	0.5	0.3	0.0	0.0	0.0		
2	29.2	32.9	22.2	9.3	3.5	1.5	0.3	0.6	0.6	0.0		
3	10.6	23.6	25.8	18.7	11.7	6.5	2.4	0.3	0.5	0.0		
4	3.6	12.7	19.0	21.6	20.0	11.4	7.0	3.9	0.8	0.0		
5	1.5	3.4	11.1	17.6	24.1	21.7	11.1	6.8	2.4	0.5		
6	1.0	1.4	8.4	11.2	20.1	18.4	19.1	11.0	8.1	1.2		
7	0.0	1.0	4.0	7.3	13.0	16.5	21.6	19.3	12.0	5.3		
8	0.0	1.4	0.9	3.9	6.1	15.0	19.1	22.7	20.2	10.9		
9	0.2	0.2	0.8	1.0	3.3	6.6	14.9	23.6	26.9	22.4		
10	0.0	0.0	0.0	0.2	0.8	2.2	6.2	13.6	24.6	52.4		

How to interpret? The row labeled "8" shows that a male who scores in decile 8 at age 10.5 has a 6.1% probability of scoring in decile 5 at age 13.5, a 22.7% probability of scoring in decile 8 at age 13.5, and a 10.9% probability of scoring in decile 10 age 13.5. The interpretation of the other cells in analogous. Source: Early Childhood Longitudinal Study—Kindergarten Cohort.

Male math score *transitions*, ages 15.5 to 17.5

		101	10 Deci	les of Matł	1 in Grade 1	12 (age 17.:	5 on averag	ge)	101	
	1	2	3	4	5	6	7	8	9	10
1	62.2	28.3	5.7	2.3	0.9	0.2	0.5	0.0	0.0	0.0
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How to interpret? The row labeled "8" shows that a male who scores in decile 8 at age 15.5 has a 2.6% probability of scoring in decile 5 at age 17.5, a 37.5% probability of scoring in decile 8 at age 17.5, and a 6.3% probability of scoring in decile 10 age 17.5. The interpretation of the other cells in analogous. Source: National Education Longitudinal Study.

Female Reading scores in Top 2 & Bottom 2 Deciles*, age 5 to 17.5



Male Reading scores in Top 2 & Bottom 2 Deciles*, age 5 to 17.5



Female Math scores in Top 2 & Bottom 2 Deciles*, age 5 to 17.5



Male Math scores in Top 2 & Bottom 2 Deciles*, age 5 to 17.5



Society does not invest the same amount in education at each age, suggesting that we either have a grand theory of the productivity of investing at each age or are just *unthoughtful* about the problem. At what ages do we actually invest in cognitive skill development?

I emphasize the cost of instruction because this what we can pin down by age.

Early childhood is difficult to judge because of the value and productivity of caregivers' time.

K-12 costs are quite straightforward because of compulsory education.

Postsecondary at traditional ages is slightly hard because of education acquired at non-Title IV vocational schools and in military service.

Older ages (35+) are somewhat difficult because some formal education is acquired on the job yet does not show up as enrollment.

Teacher Compensation Per Pupil in North Carolina



Instructional Spending Per Student, By Age



Instructional Spending Per Student, By Age Accounting for Share Enrolled



Instructional Spending Per Student, By Age Accounting for Share Enrolled



In answer to Question 1, we should now have some logical theories

> We are probably underinvesting in adolescence because spending dips then, when the frontal cortex is developing.

> We may also be underinvesting in very early childhood but we might be overinvesting in some children while underinvesting in others.

➢ We are probably overinvesting in the traditional period for postsecondary because this is where the growth in educational attainment has occurred—with a corresponding decrease in the relationship between cognitive skill and years of education.

Question 2: Are There Some Ages When We Are Likely Under- or Overinvesting?

That is, what do we know about the causal productivity of investments by age?

Three requirements for an "experiment"

- 1. The intervention must be specific to a grade or an age so that I can compare results across grades.
- The intervention must be something that could be applied at any grade—again, so that I can compare results across grades.
 e.g. It would not be useful to test an intervention that only a high school student could find useful and manageable.
- 3. The intervention must generate a causal effect on cognition that is statistically significant.

Best "experiment" is being assigned to a high versus low value-added instructor.

Distribution of Teacher Value-Added in Math, by Grade



kernel = epanechnikov, bandwidth = 0.2000

Distribution of Teacher Value-Added in Math, based on By-Grade Differences for the Same Teacher



kernel = epanechnikov, bandwidth = 0.2000

Distribution of Teacher Value-Added in Reading, by Grade



kernel = epanechnikov, bandwidth = 0.2000

Distribution of Teacher Value-Added in Reading, based on By-Grade Differences for the Same Teacher



What about the effects of instructor value-added in postsecondary school?

Problem: selection into an instructor (and course) is much more serious in postsecondary school. Thus, the literature is largely confined to freshman type math classes.

Using data from University of Phoenix (pre-Covid, pre-nearly-all-online) De Vlieger, Jacob, and Stange (2019), find magnitudes that are "substantially larger" than found in the K12 literature.

Using data from DeVry University, Bettinger *et al* (2014) find magnitudes that are comparable to those in the K-12 literature.

Using data from the Air Force Academy (which randomly assigns students to classes), Carrell and West (2010) of the Air Force Academy find much smaller magnitudes than are found in the K-12 literature.

Effect of Teacher Value-Added in Math on Math SAT/ACT Scores, by Grade in which the Teacher Taught Students



Effect of Teacher Value-Added in Reading on Verbal SAT/ACT Scores, by Grade in which the Teacher Taught Students



Effect of Teacher Value-Added in Reading on Taking AP English, by Grade in which the Teacher Taught Students



Effect of Teacher Value-Added in Math on Enrolling in 4-Year College, by Grade in which the Teacher Taught Students



Other "Experiments" & Steps

Other "experiments":

- Texas adopting much more cognitively rigorous assessments in 2011, with consequent changes in curriculum and teaching.
- Attending a successful charter school, by usual grade-of-entry for that school (e.g. middle schools versus elementary or high schools).

Using the 1958, 1970, and 1989 British cohort studies, I study cognitive skill measures from birth to age 50.

Many of the conclusions are similar—e.g. decreasing relationship between cognitive skill and educational attainment; increasing importance of cognitive skill for earnings; diverging skill trajectories in early adolescence.

Ideally, we would have value-added studies for very early childhood, but so far the most promising data (e.g. Mathematica's Headstart study) have fade-out of cognitive skills by grades 1 and 2.