What is g?

William T. Dickens
The Brookings Institution

AERA Meetings

April 9, 2007

- Work I'm reporting on today is an extension of my joint work with Jim Flynn in Dickens and Flynn (2001) "Heritability Estimates vs. Large Environmental Effects: The IQ Paradox Resolved" *Psychological Review,* 108, 346-369.
- Jim's take on these issues will shortly be published in his new book *What is Intelligence*:*Beyond the Flynn Effect*
- The paper on which this presentation is based should be available by the end of the week on the Brookings Web Site (www.Brookings.edu > Scholars > Dickens > IQ Modeling > What is g?

Cognitive Ability is Important

- If you want to know one thing about a 16 year old in the National Longitudinal Survey of Youth to predict later income or education it is that person's AFQT or IQ score.
- Correlation higher still for performance in school (.6 or greater)
- If we can improve people's cognitive ability we can substantially affect their ability to learn and their life outcomes.
- Despite evidence that the white-black test score gap has shrunk (Dickens and Flynn 2006 *Psychological Science*) there is little hope for equality if we can't shrink it further.

How Malleable is Cognitive Ability?

- Pre-school programs and adoption both produce large gains in cognitive ability for most participants
- But gains in cognitive ability from preschool are mostly gone a few years after programs end
- No evidence of statistically significant effects of adoption on cognitive ability in late adolescence or adulthood

In Contrast…

- Large secular gains affect people at all points in life (The Flynn Effect)
- Gains of 1SD or more a generation have been documented
- Almost certainly environmental in origin
- But several researchers have suggested that secular gains are not “g” gains *and therefore aren’t meaningful changes in cognitive ability*

What is g?

- Scores on a wide range of tests of mental ability are correlated
- Spearman postulated the existence of a single, largely genetically determined, mental ability that was the source of this correlation.
- Today we know that there are multiple dimensions to cognitive ability, but they too are correlated suggesting something like Spearman's g underlies all abilities.
- Tests that are more highly correlated with this general ability factor are said to be more g loaded.

About g

- More highly g loaded sub-tests
  - have scores that are more highly heritable
  - have stronger correlation with physiological correlates of cognitive ability
  - show the largest black-white gap
- These facts have been interpreted by some to indicate a large role for genetic endowment in individual as well as black-white differences in g
- Some argue that nearly all the ability of IQ tests to explain life outcomes is due to g

Secular Gains and g

- But in most data sets more g loaded tests are not the ones that show the largest secular gains.
  - Somewhat positive correlation between secular gains and g loadings
  - But there is considerably more to secular gains than g gains
  - Unlike black-white differences which correlate highly with g loadings
- Thus it has been argued that secular gains are not g gains and therefore don't reflect real changes in cognitive ability
- *Thus it is argued they provide no evidence for malleability of true cognitive ability*

An Alternative View

- Is laid out in my new paper “What is g?”
- That new paper presents an extension of the mathematical model from my 2001 paper with Flynn to multiple abilities.
- The paper shows that all of the important facts about g can be generated by a model in which environment is quite powerful.
- I don’t have time to do the math here
  - Instead I will present intuition and
  - The results of a simulation

An Alternative View (A Basketball Analogy)

- Suppose there was no correlation between physical attributes that made one a good basketball player (height, speed, agility, coordination, etc.)
- Scores of very young children who had never played basketball or other sports on tests of basketball skills (shooting, dribbling, passing, etc.) would show little or no correlation across skills
- *But the skills of older children would…*

An Alternative View (continued)

- Those who are taller (or quicker, or have better hand-eye coordination) will be more likely to be good at basketball and more likely to play it more.
- Those who play basketball more will improve *all* skills.
- They will become particularly good at the skills that are used most and most important to success at basketball.
  - These will be the most g loaded skills
  - They are the most correlated with the underlying cause of correlation – *practice*
- This can give rise to all the g phenomena described above

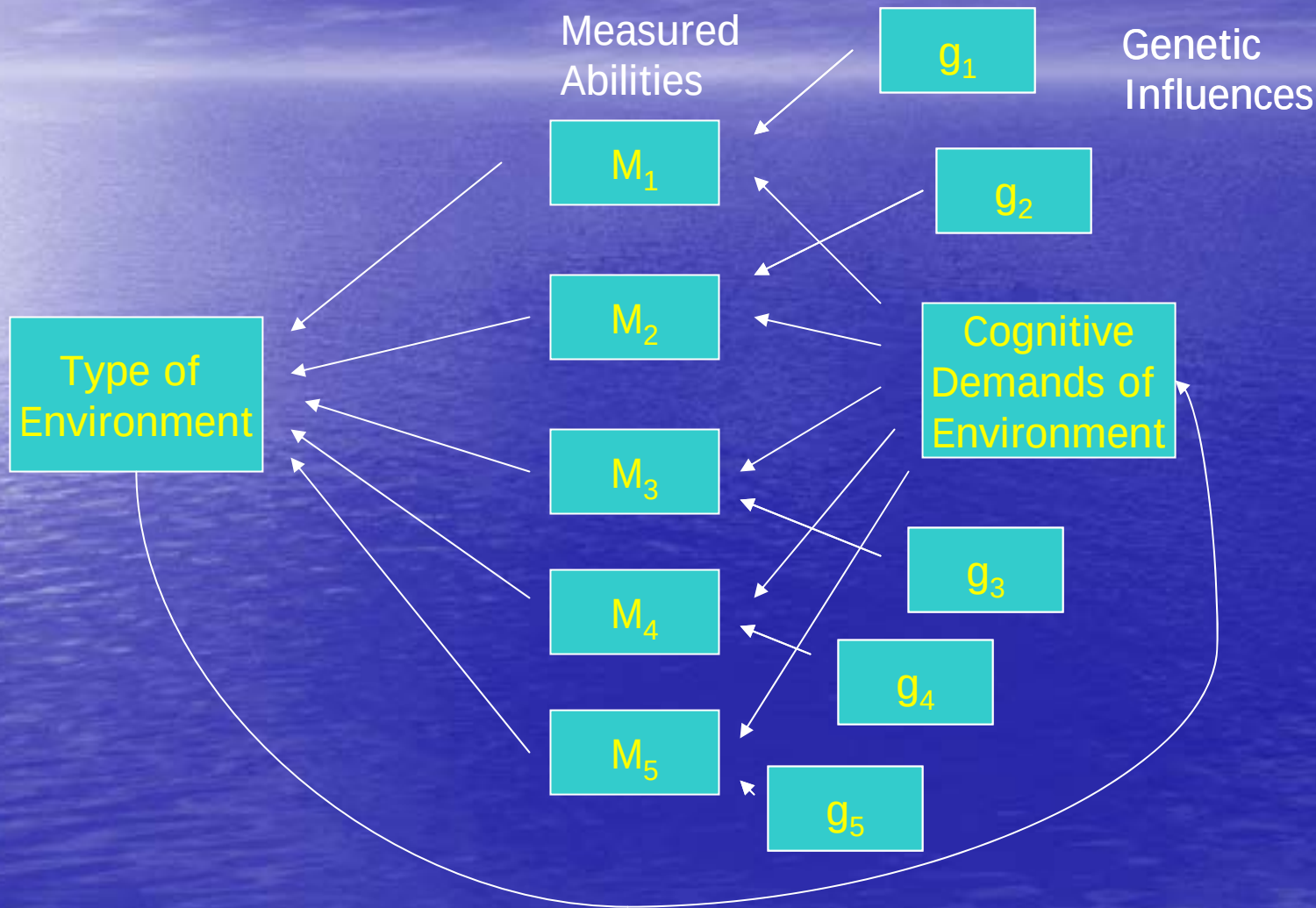
Explaining Facts About g

- Basketball g would be a very good predictor of success at basketball
- Any physiological advantage that made you good at basketball would lead to you practicing more improving all your skills, but particularly those most used and most important to basketball (the most g loaded).
- If a group was discriminated against in access to basketball teams or pick-up games all their skills would suffer, but particularly the skills most used and most important to success.

Secular Gains in the Alternative Model

- Now suppose that a decision was made to make all basketball games last twice as long and to make it illegal for players to return to the court after being take off for any reason (like soccer).
- All skills might improve if people play more because of the longer games
- But players endurance would improve disproportionately so their scores on test of endurance would be out of proportion to other gains
- *Thus no reason for gains to be biggest for most g loaded abilities, but they would be substantive – particularly in the new environment.*

Schematic of the Alternative View Reciprocal Effects



Reciprocal Effects Means...

- Environment more important than many g theorists would allow
  - Dickens and Flynn (2001)
  - Heritability estimates that show cognitive ability is largely genetically determined mask the fact that environment is the proximate cause of much “genetic” influence
- Reciprocal effects mean multiplier effects.
  - Small persistent advantage (environmental or genetic) gives rise to greater ability and then to better environment
  - Ultimate effect is much larger than initial impetus
  - Most environmental effects that are not correlated with genetic endowment is transient so it doesn’t get full effect
  - But differences between generations or groups subject to discrimination are not transient and so get full effect

Equations for a Simulation Model

$$(1)\quad \begin{bmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \end{bmatrix} = \begin{bmatrix} g_1 \\ g_2 \\ g_3 \\ g_4 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix}$$

Abilities = *Genetic Influences* + *Environ Influences*

$$(2)\quad \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix} = \begin{bmatrix} D_{1,1} & D_{1,2} & D_{1,3} & D_{1,4} & D_{1,5} & D_{1,6} & D_{1,7} \\ D_{2,1} & D_{2,2} & D_{2,3} & D_{2,4} & D_{2,5} & D_{2,6} & D_{2,7} \\ D_{3,1} & D_{3,2} & D_{3,3} & D_{3,4} & D_{3,5} & D_{3,6} & D_{3,7} \\ D_{4,1} & D_{4,2} & D_{4,3} & D_{4,4} & D_{4,5} & D_{4,6} & D_{4,7} \end{bmatrix} \begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \\ f_6 \\ f_7 \end{bmatrix} + \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{bmatrix}$$

Cognitive Demands of Environ. *Fraction of Time in Environ.* *Random Environ.*

Simulation Equations (continued)

- Fraction of time spent in each environment is function of individual ability times weights plus a constant
- Logit model for fraction to guarantee that they add to 1.

$$(3) \qquad f_i = \frac{e^{c_i + \sum_{j=1}^{4} W_{i,j} m_j}}{\sum_{j=1}^{7} e^{c_j + \sum_{k=1}^{4} W_{j,k} m_k}}$$

Simulation Procedure

1. Generate genetic influences shared by pairs of identical twins
2. Draw initial random environmental influences (uncorrelated for twins)
3. Compute initial abilities (standardize)
4. Draw new random environment
5. Compute environment (standardize)
6. Compute new abilities (standardize)
7. Repeat 4 to 6 till population statistics stabilize (less than 20 iterations)

Matrix of Cognitive Demands

B Matrix for Equation 2
Also W Matrix for Equation 3 (after rescaling)

	Technical /Prof Tasks	Managerial /Prof Tasks	Clerical Tasks	Routine Technical Tasks	Skilled Manual Tasks	Unskilled Tasks	Inactive
Quantitative	.70	.50	.20	.30	.10	.01	.05
Spatial	.60	.50	.15	.20	.10	.05	.10
Verbal	.50	.60	.30	.20	.10	.10	.30
Memory	.40	.40	.30	.30	.10	.10	.20

Two Simulation Exercises

- Simulate two different populations – one is as described above, the other is minority that experiences discrimination in access to more cognitively demanding jobs (their *c* s are lower for those jobs)
- Simulate two different populations – one is as described above, the other has larger *c* s for cognitively demanding jobs (therefore more people are in them) and the demands of those jobs shift (secular gains)

Results of Simulation

Simulated Correlation of Abilities

	Quantitative	Spatial	Verbal	Memory
Quantitative	1	0.58	0.48	0.37
Spatial	0.58	1	0.47	0.33
Verbal	0.48	0.47	1	0.34
Memory	0.37	0.33	0.34	1

More Simulation Results

- Heritability of “IQ” is .70 while heritability of “g” is .71
- Those with g scores greater than 1SD spend nearly all their time in Technical and Managerial Activities while those with g scores less than -1SD spend less than 15% of their time in such activities

Results of Simulation (continued)

Table 4
Results for Simulation Model with Multiple Environments

	Correlation with First Principal Component	Correlation with Physical Trait Corr. with g2	h^2	Majority-Minority Gap (in majority SDs)	Secular Gains
Quantitative	.82	.12	.67	.48	.52
Spatial	.81	.28	.63	.45	.40
Verbal	.76	.10	.57	.40	.50
Memory	.64	.07	.42	.32	.51

Conclusions

- All the important facts about g can be replicated in a model where environment plays a major role
  - g is good predictor of life outcomes
  - g loadings are correlated with physiological traits
  - g loadings are correlated with heritabilities
  - g loadings are correlated with black-white differences
  - g loadings are not correlated with secular gains
- In such a model, persistent exogenous improvements in environment produce large improvements in cognitive ability (and persistent disadvantages produce large losses)