
FRANK & ERNEST by Bob Thaves
TONIGHT'S DEBATE
NATURE VERSUS NURTURE
YOU BELIEVE IN HEREDITY OVER ENVIRONMENT?
YEP --- I WAS JUST BORN THAT WAY.
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THAVES

Scientific Talent, Training, and Performance:

Intellect, Personality, and Genetic Endowment

The Problem

- In general: How to establish scientific talent as an empirical phenomenon
- In specific:
  - How to estimate the magnitude of the genetic contribution to scientific training and performance,
  - including the particular correspondences between intellect and personality, on the one hand, and training and performance, on the other

Background

- Historical
  - The Nature Position:
    - Francis Galton’s 1869 *Hereditary Genius*
      - The family pedigree method

Darwin family

- Charles Darwin
  - Grandfather: Erasmus Darwin
  - Sons:
    - Francis Darwin, the botanist,
    - Leonard Darwin, the eugenist, and
    - Sir George Darwin, the physicist
    - Grandson: Sir Charles Galton Darwin, physicist
  - Cousin: Francis Galton

Background

- Historical origins
  - The Nature Position:
    - Francis Galton (1869): *Hereditary Genius*
      - The family pedigree method
    - Follow-up investigations
      - Bramwell (1948)
      - Brimhall (1922, 1923, 1923)
    - Modern Examples

Nobel Laureates in the Sciences

- 7 parent-child pairs (e.g., Arthur Kornberg 1959 and Roger D. Kornberg 2006)
- 1 brother-brother pair (Jan Tinbergen 1969 and Nikolaas Tinbergen 1973)
- 1 uncle-nephew pair (C V Raman 1930 and S Chandrasekhar 1983)
- 0nly once for the same achievement (viz., the father and son Braggs 1915)

Background

- Historical origins
  - The Nurture Position
    - Alphonse de Candolle (1873): *Histoire des sciences et des savants depuis deux siècles*
  - The Nature-Nurture Issue
    - Francis Galton (1874): *English Men of Science: Their Nature and Nurture*

Background

- Contemporary emergence
  - Nature: Behavioral Genetics
    - Twin and adoption studies
    - Substantial h^2 (hereditability coefficients) for most intellectual and personality variables
    - Including those identified in the psychology of science as predictors of scientific training and performance
    - Some examples …

Trait	Heritability
Personality (adult samples)	
Big Five	
Extraversion	.54
Agreeableness (aggression)	.42
Conscientiousness	.49
Neuroticism	.48
Openness	.57

Psychological interests	
Realistic	.36
Investigative	.36
Artistic	.39
Social	.37
Enterprising	.31
Conventional	.38

Intelligence

By age in Dutch cross-sectional twin data	
Age 5	.22
Age 7	.40
Age 10	.54
Age 12	.85
Age 16	.62
Age 18	.82
Age 26	.88
Age 50	.85
In old age (> 75 years old)	.54–.62

Background

- Contemporary emergence
  - Nurture: Cognitive Science
    - Expertise acquisition
    - Deliberate practice
    - 10-year rule

Participants at the conference on "The Acquisition of Expert Performance" at Wakulla Springs Conference Center, Florida, April 27–30, 1995. Front row: John Shea, Anders Ericsson, Vimla Patel, John Sloboda, Ellen Winner, Robert Glaser, Robert Sternberg, and Lawrence Holmes. Back row: Richard Shiffrin, Herbert Simon, Neil Charness, Dean Simonton, Keith Stanovich, Richard Wagner, and Michael Howe.

Resolution?

- Define scientific talent so as to include expertise in the definition
- In particular …

Talent Definition

- Any natural endowment that enhances
  - Training
    - Facilitates concentrated engagement in domain-specific practice and learning (e.g., doing problem sets in mathematical science courses)
    - Accelerates practice and learning; less time to master domain-specific expertise (e.g. individual differences in 10-year rule)
  - Performance
    - Increases achievement from a given level of expertise
    - e.g. Openness to experience in creators vs. experts

Talent Definition

- Three specifications:
  - The endowment consists of a weighted composite of intellectual abilities and personality traits (domain-specific profiles)
  - The training and performance composites do not have to be identical, nor even consistent (e.g., Openness to experience)
  - The endowment can be genetic or nongenetic (e.g., intrauterine environment)

Quantitative Measures

- Here we focus on genetic endowment because we can take direct advantage of estimated heritabilities
- In particular, suppose that
  - That for a given training or performance criterion research has identified *k* predictor traits, and
  - for each *j*th trait we possess corresponding (a) validity coefficients and (b) heritability coefficients
- Then we can specify three estimators

Equation 1

- $h_{c1}^2 = \Sigma\, r_{cj}^2\, h_j^2$, where
  - h_{c1}^2 = the *criterion heritability*,
  - r_{c1}^2 = the squared criterion-trait correlation for the *j*th (i.e., the squared validity coefficient),
  - h_j^2 = the heritability coefficient for trait *j*, and
  - the summation is across *k* traits (i.e., *j* = 1, 2, 3, ... *k*).
- Assumption: *k* traits uncorrelated
  - If correlated, then estimate biased upwards

Equation 1

- However, if inter-trait correlation matrix also known, two less biased estimators can be calculated using the multiple regression “beta” coefficients, i.e.
- $\boldsymbol{\beta} = \mathbf{r}_{cp}' \, \mathbf{R}_{pp}^{-1}$, where
  - $\boldsymbol{\beta}$ is the vector of standardized partial regression coefficients**,**
  - $\mathbf{r}_{cp}'$ is the transpose of the vector of criterion-trait correlations, and
  - $\mathbf{R}_{pp}^{-1}$ is the inverse of the correlation matrix for the *k* traits that predict the criterion

Equation 2

- $h_{c2}^2 = \Sigma\, \beta_{cj}^2\, h_j^2$ (Ilies, Gerhardt, & Le, 2004),
  - where β_{cj} is the standardized partial regression coefficient obtained by regressing criterion *c* on the *k* predictor traits (taken from vector **β**)
  - Under the assumption of redundancy $\beta_{cj}^2 < r_{cj}^2$, $h_{c2}^2 < h_{c1}^2$, and hence, it will less likely have a positive bias

Equation 2

- However, h_{c2}^2 has one disadvantage: it lacks an upper bound
- To overcome this drawback, we derive a similar estimator from the formula for the squared multiple correlation $R_c^2 = \Sigma\, r_{cj}\, \beta_{cj}$,
  - where R_c^2 = the proportion of the total variance in the training or performance criterion that can be explained given the *k* predictor traits
  - This provides the upper bound for criterion heritability for the …

Equation 3

- $h_{c3}^2 = \Sigma\, r_{cj}\, \beta_{cj}\, h_j^2$,
  - which must obey the following inequality
    - $h_{c3}^2 \leq R_c^2$ and hence
    - h_{c3}^2/R_c^2 provides an estimate of the proportion of the *explained* variance that can be potentially attributed to genetic endowment
  - and which under the redundancy assumption will obey the following relation
    - $h_{c2}^2 < h_{c3}^2 < h_{c1}^2$

The Redundancy Assumption

- What if redundancy assumption is invalid?
- i.e., what if there are suppression effects?
  - Then it's no longer true that $|\beta_{cj}| < |r_{cj}|$ or even that $|\beta_{cj}| < 1$, and
  - some of the terms in the third estimator may be negative, i.e., $r_{cj}\,\beta_{cj}\,h_j^2 < 0$ for some j
- Hence, suppression should be removed by progressive trait deletion,
  - a solution that can be justified on both methodological and theoretical grounds

Formal Family Resemblance

- $h_{c1}^2 = \mathbf{r}_{cp}' \mathbf{D}_h^2 \mathbf{r}_{cp}$
- $h_{c2}^2 = \boldsymbol{\beta}' \mathbf{D}_h^2 \boldsymbol{\beta}$
- $h_{c3}^2 = \mathbf{r}_{cp}' \mathbf{D}_h^2 \boldsymbol{\beta}$
- $\mathbf{D}_h^2$ is a diagonal matrix with the heritabilities along the diagonal and zero elements off the diagonal
- Whenever $\mathbf{R}_{pp} = \mathbf{I}$, then $\mathbf{r}_{cp} = \boldsymbol{\beta}$, and the three expressions become identical

Data Specifications

- Highly specific criteria variable(s) (training vs. performance; discipline)
- Both intellectual and personality traits
- Comparable samples for all statistics
- Corrections for measurement error
- Corrections for range restriction
- Broad- rather just narrow-sense heritabilities (i.e., both additive and nonadditive variance)

Meta-Analytic Illustrations

- Personality Traits
  - Source: Feist (1998)
    - Scientists versus nonscientists (SvNS; 26 samples of 4,852 participants) and
    - Creative versus less creative scientists (CvLCS; 30 samples of 3,918 participants)
    - Validity and heritability coefficients available for the
      - California Psychological Inventory (CPI) and the
      - Eysenck Personality Questionnaire (EPQ)
    - Selected all traits $d_j \geq 0.49$ (i.e., “medium” or better)
    - Validity coefficients from $r_{cj} = d_j / (d_j^2 + 4)^{-1/2}$
  - Results

Meta-Analytic Illustrations

- Personality Traits
  - CPI

Table 1

California Psychological Inventory Scale Heritabilities, Criterion-Trait Correlations, and Standardized Partial Regression Coefficients for Two Criteria

		SvNS		CvLCS	
Scale	h_j^2	r_{cj}	β_{cj}	r_{cj}	β_{cj}
Dominance	.56			.256	
Sociability	.66	.238	.079	.287	.096
Self-Acceptance	.56			.326	.146
Tolerance	.40			.359	.217
Achievement via Conformance	.30	.279	.098		
Achievement via Independence	.32	.335	.244	.243	
Intellectual Efficiency	.32			.252	
Psychological Mindedness	.44	.247		.243	
Flexibility	.40			.265	.146

Note. SvNS = scientists versus nonscientists and CvLCS = creative scientists versus less creative scientists.

Table 2

California Psychological Inventory Criterion Heritability Estimation for Two Criteria

Estimator		SvNS	CvLCS
Equation 1:	k	4	8
	Minimum product ($r_{cj}^2 h_j^2$)	.0233	.0188
	Maximum product ($r_{cj}^2 h_j^2$)	.0374	.0596
	M ($1/k \, \Sigma \, r_{cj}^2 h_j^2$)	.0308	.0369
	Sum ($\Sigma \, r_{cj}^2 h_j^2$) = h_{c1}^2	.1233	.2955
Equation 2:	k	3	4
	Minimum product ($\beta_{cj}^2 h_j^2$)	.0029	.0061
	Maximum product ($\beta_{cj}^2 h_j^2$)	.0191	.0187
	M ($1/k \, \Sigma \, \beta_{cj}^2 h_j^2$)	.0087	.0113
	Sum ($\Sigma \, \beta_{cj}^2 h_j^2$) = h_{c2}^2	.0260	.0454
Equation 3:	k	3	4
	Minimum product ($r_{cj} \beta_{cj} h_j^2$)	.0081	.0155
	Maximum product ($r_{cj} \beta_{cj} h_j^2$)	.0262	.0311
	M ($1/k \, \Sigma \, r_{cj} \beta_{cj} h_j^2$)	.0156	.0229
	Sum ($\Sigma \, r_{cj} \beta_{cj} h_j^2$) = h_{c3}^2	.0467	.0915
	h_{c3}^2 / R_c^2	.3659	.4770

Note. SvNS = scientists versus nonscientists and CvLCS = creative scientists versus less creative scientists.

Meta-Analytic Illustrations

- Personality Traits
  - EPQ

Table 3

Eysenck Personality Questionnaire Heritabilities, Criterion-Trait Correlations and Standardized Partial Regression Coefficients for SvNS Criterion

Scale	h_j^2	r_{cj}	β_{cj}
Psychoticism	.43	.220	.202
Extraversion	.57	.163	.137

Note. SvNS = scientists versus nonscientists.

Meta-Analytic Illustrations

- Personality Traits
  - EPQ
    - SvNS: h_{c1}^2 = .036, h_{c2}^2 = .028, and h_{c3}^2 = .032
    - Because R_c^2 = .067, about 47% of the variance explained by the EPQ might be credited to genetic influences
  - CPI + EPQ = .079 or about 8%

Meta-Analytic Illustrations

- Intellectual Traits
  - Source: Kuncel, Hezlett, & Ones (2004)
    - MAT (Miller Analogies Test)
    - 15 studies of 1,753 participants yields a true-score correlation of .75 with general intelligence
  - Results

Table 4

Criterion-MAT Correlations and Lower- and Upper-Bound Criterion Heritability Estimates

Criterion (c)	r_{cM}	r_{cM}^2	h_{cL}^2	h_{cU}^2
First-year graduate grade point average	.41[a]	.168	.118	.134
Graduate grade point average	.39[a]	.152	.106	.122
Faculty ratings	.37[a]	.137	.096	.110
Comprehensive examination scores	.58	.336	.235	.269
Degree attainment	.21[b]	.044	.031	.035
Time to finish degree	.35[b]	.123	.086	.098
Research productivity	.19[b]	.036	.025	.029

Note. The column of criterion-MAT correlations (r_{cM}) are taken from the column of ρ's given in Table 2 in Kuncel, Hezlett, and Ones (2004). The criterion of "Number of courses/credits completed" was omitted because its magnitude was too small to yield a nontrivial criterion heritability. The lower-bound estimate assumes that $h_L^2 = .70$ and the upper-bound estimate that $h_U^2 = .80$

[a] Criterion corrected for attenuation due to measurement error. [b] Corrected for range restriction in the intellectual trait (MAT scores).

Discussion

- Best conservative estimate
  - $.10 \leq h_c^2 \leq .20$
  - or, using $d_c = 2h_c(1 - h_c^2)^{-1/2}$,
  - $0.67 \leq d_c \leq 1.0$ ("medium" to "large" effect size)
  - i.e., roughly between the relation between
    - psychotherapy and subsequent well-being
    - height and weight among US adults

Discussion

- Estimate may be conservative because
  - Many criteria and predictor variables omitted (e.g., vocational interests and spatial intelligence)
  - Inheritance may be multiplicative rather than additive (i.e., emergenesis)
- Hence, future research should
  - expand the variables used in estimating the criterion heritabilities, and
  - expand the sophistication of the genetic process

Discussion

- As scientific talent becomes established as a phenomenon, researchers can increasingly focus on the specific causal processes by which the inheritable trait profiles enhance scientific training and performance
- These results can also be combined with research on environmental effects to develop completely integrated nature-nurture models that move beyond either-or explanations

The Beginning