Is Genius Born or Made?

Refinements and Complications in the Nature-Nurture Controversy

The Nature-Nurture Controversy with Respect to Outstanding Achievement

- Nature:
  - Galton's (1869) *Hereditary Genius*
  - Galton's (1874) *English Men of Science*

The Nature-Nurture Controversy with Respect to Outstanding Achievement

- Nurture:
  - Behaviorist Learning (e.g., Watson)

“Give me a dozen healthy infants, well formed, and my own specified world to bring them up in, and I’ll guarantee to take any one at random and train him to become any type of specialist I might select – a doctor, lawyer, artist, merchant chief, and yes, even a beggar-man and thief, regardless of his talents, penchants, tendencies, abilities, vocations and race of his ancestors.”

The Nature-Nurture Controversy with Respect to Outstanding Achievement

- Nurture:
  - Behaviorist Learning (e.g., Watson)
  - Expertise Acquisition (e.g., Ericsson)
    - Deliberate Practice
      - The 10-year Rule
      - The Monotonic Function

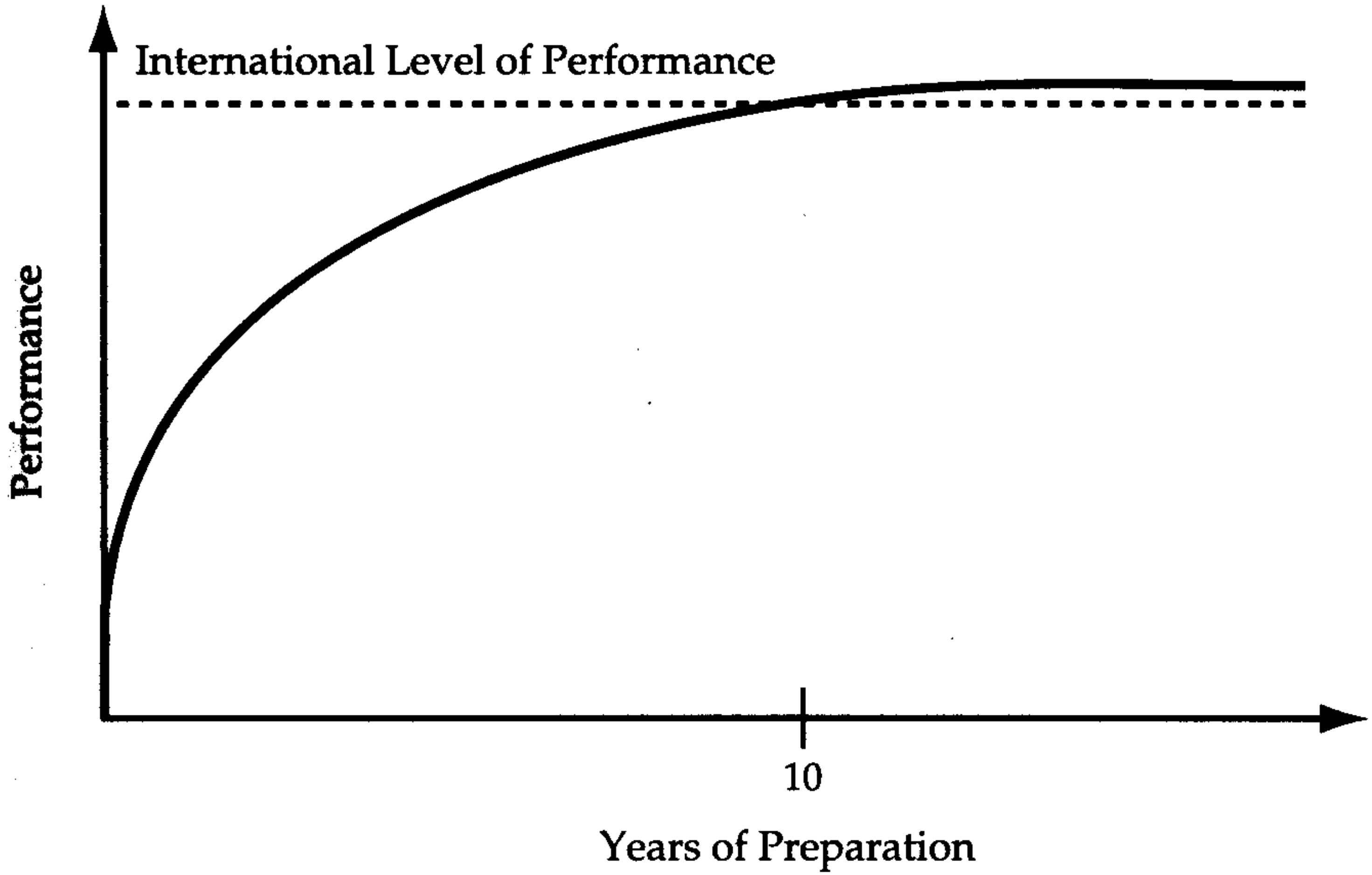
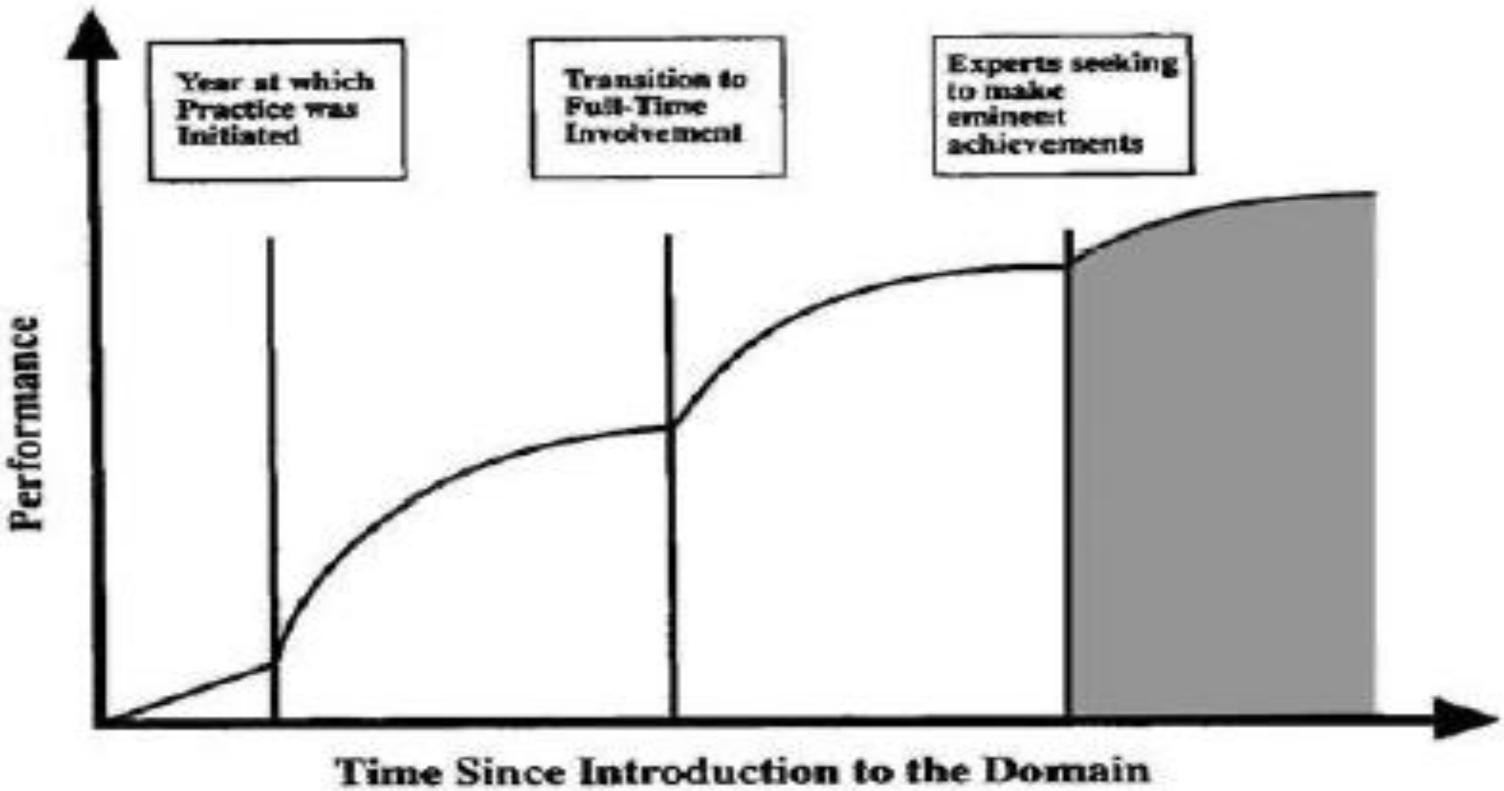


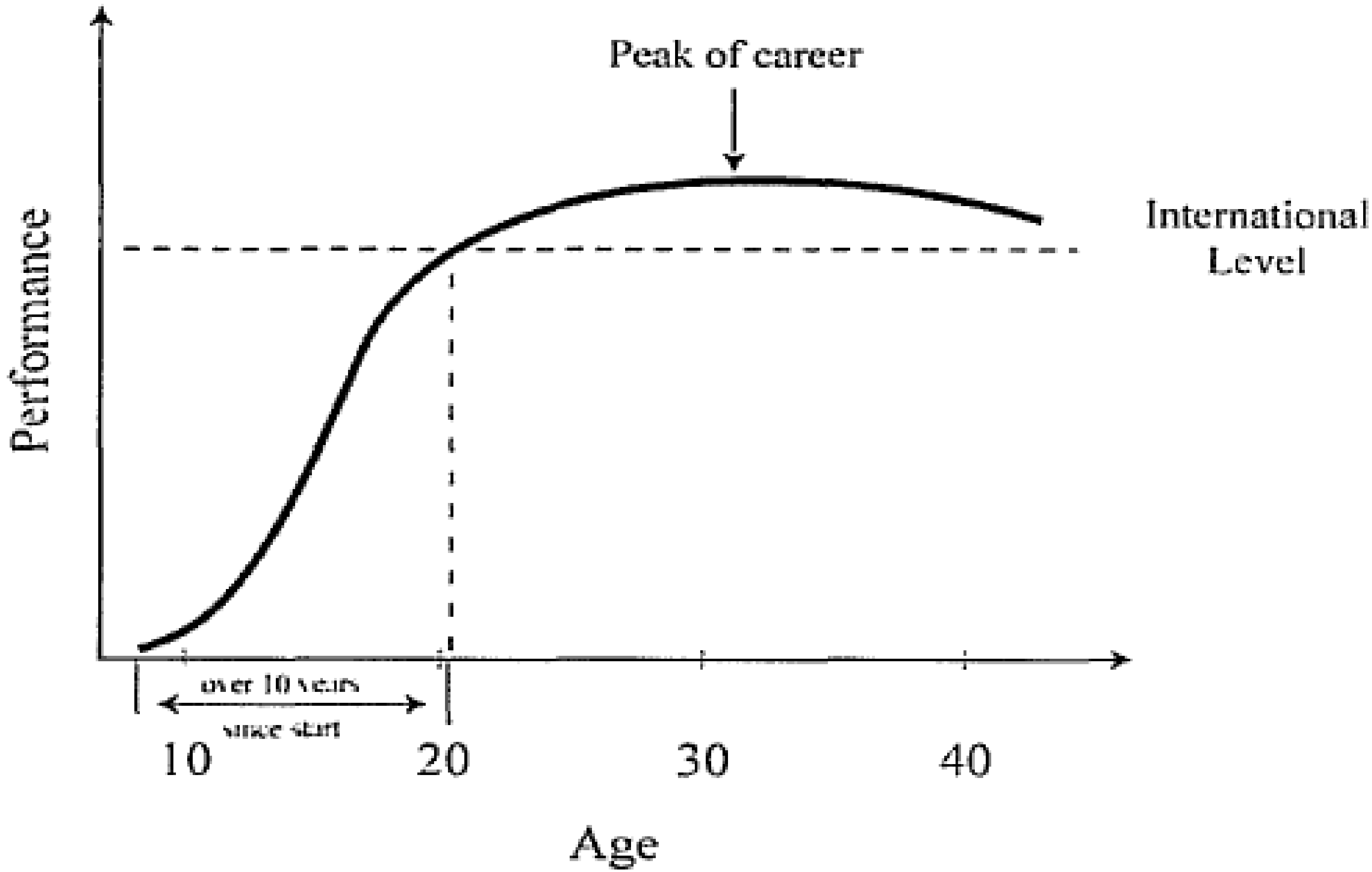
FIG. 1.2. A schematic illustration of the general form of the relation between attained performance as a function of the number of years of serious preparation.

Figure 3

Three Phases of Development of Expert Performance Followed by a Qualitatively Different Phase of Efforts to Attain Eminent Achievements



Note. From "Can We Create Gifted People?" by K. A. Ericsson, R. Th. Krampe, and S. Heizmann in *The Origins and Development of High Ability* (pp. 222–249), 1993, Chichester, England: Wiley. Copyright 1993 by Ciba Foundation. Adapted by permission.


Peak of career
International Level
Performance
over 10 years
since start
10
20
30
40
Age

Nature Revisited: Behavioral Genetics

- Environmental Effects
  - Shared (e.g., parental child-rearing practices)
  - Nonshared (e.g., birth order)
- Genetic Effects
  - Numerous nontrivial heritability coefficients for both cognitive and dispositional correlates of achievement in various achievement domains

Nature Revisited: Behavioral Genetics

- However, two potential complications in biological inheritance that render it less simple than often conceived:
  - Multiplicative rather than additive inheritance (emergenesis)
  - Dynamic rather than static inheritance (epigenesis)
- Hence, a more complex conception of talent and its development, as indicated in the following formal model

Definition: Potential Talent

- Any genetic trait or set of traits that
  - accelerates expertise acquisition and/or
  - enhances expert performance
- in a talent domain (e.g., creativity)
- Traits may be
  - cognitive (e.g. IQ) or dispositional (e.g., introversion),
  - specific (e.g., perfect pitch) or general (e.g., *g*)

Two-Part Genetic Model

- Emergenic Individual Differences
- Epigenetic Development

Emergenic Individual Differences: The Model

$$P_i = \prod_{j=1}^{k} C_{ij}^{\,w_j}$$

Emergenic Individual Differences: The Model

- P_i is the potential talent for the *i*th individual
- C_{ij} is the *i*th individual's score on component trait *j* ($i = 1, 2, 3, \ldots N$)
- w_j is the weight given to the *j*th component trait ($w_j > 0$)
- Π is the multiplication operator (cf. Σ)

Emergenic Individual Differences: The Model

$$P_i = \prod_{j=1}^{k} C_{ij}^{\,w_j}$$

Emergenic Individual Differences: The Implications

- the domain specificity of talent
- the heterogeneity of component profiles within a talent domain
- the skewed frequency distribution of talent magnitude
- the attenuated predictability of talent
- the low familial inheritability of talent
- the variable complexity of talent domains

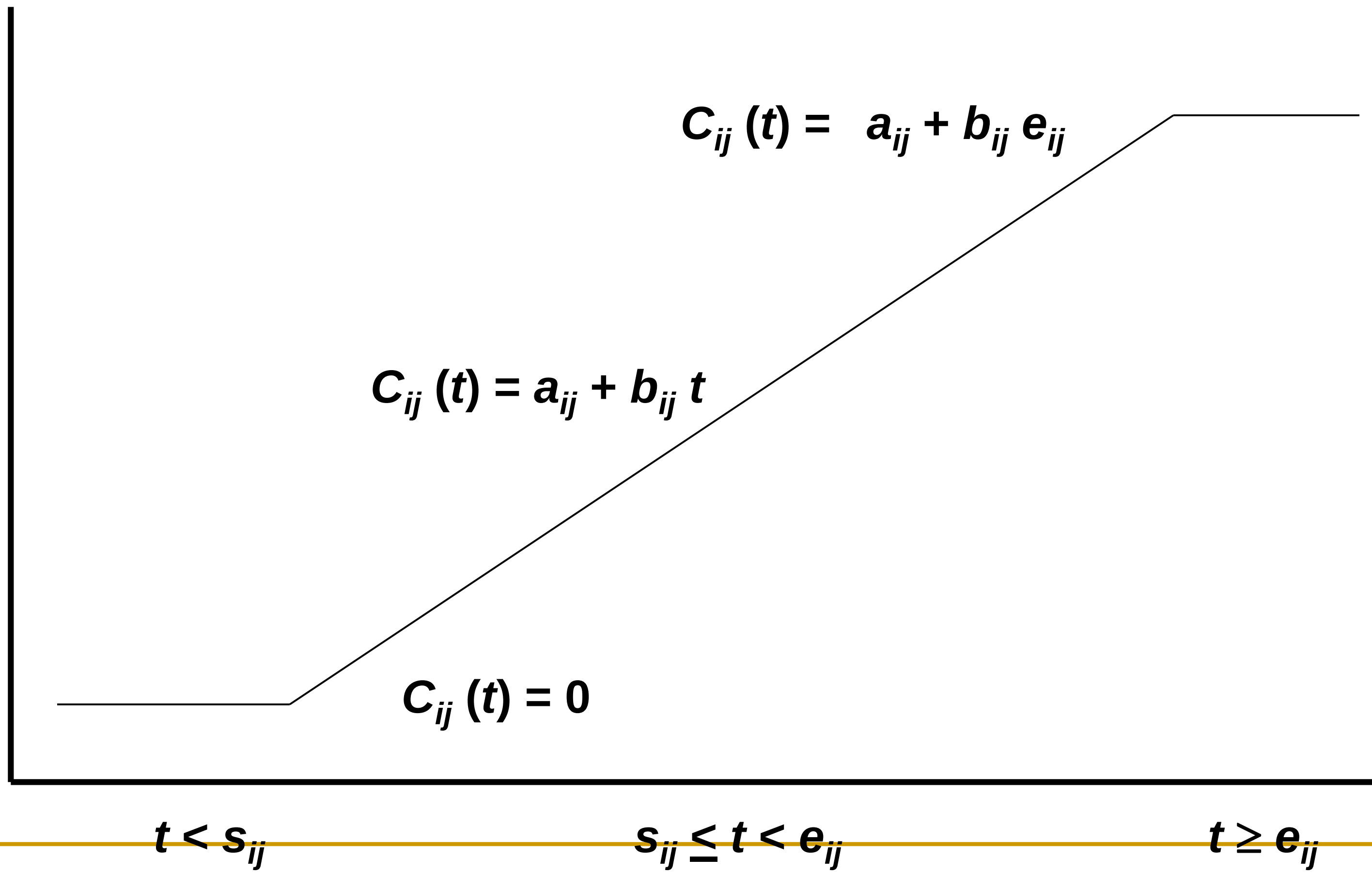
Epigenetic Development: The Model

$$P_i(t) = \prod_{j=1}^{k} C_{ij}(t)^{w_j}$$

e.g.

$$
\begin{aligned}
C_{ij}(t) &= 0, \text{ if } t < s_{ij}, \\
&= a_{ij} + b_{ij}\, t, \text{ if } s_{ij} \leq t < e_{ij}, \text{ and} \\
&= a_{ij} + b_{ij}\, e_{ij}, \text{ if } t \geq e_{ij}.
\end{aligned}
$$

Epigenetic Development: The Model



Epigenetic Development: The Implications

- the occurrence of early- and late-bloomers
- the potential absence of early talent indicators
- the age-dependent cross-sectional distribution of talent
- the possibility of talent loss (absolute vs. relative)
- the possible age-dependence of a youth’s optimal talent domain
- the increased obstacles to the prediction of talent

Conceptual Integration

- Fourfold Typology of Genetic Gifts
- Additive versus Multiplicative Models
- Simple versus Complex Domains

Fourfold Typology of Genetic Gifts

	Additive	***Additive***	***Multiplicative***	***Multiplicative***
Results	***Simple***	***Complex***	***Simple***	***Complex***
Trait profiles	Uniform	Diverse	Uniform	Diverse
Distribution	Normal	Normal	Skewed	Extremely skewed
Proportion ungifted	Small	Extremely small	Large	Extremely large
Familial inheritance	Highest	High	Low	Lowest
Growth trajectories	Few	Numerous	Few	Numerous
Growth onset	Early	Earliest	Later	Latest
Ease of Identification	Highest	High	Low	Lowest
Instruction / training strategies	Few	Numerous	Few	Numerous

Conclusion

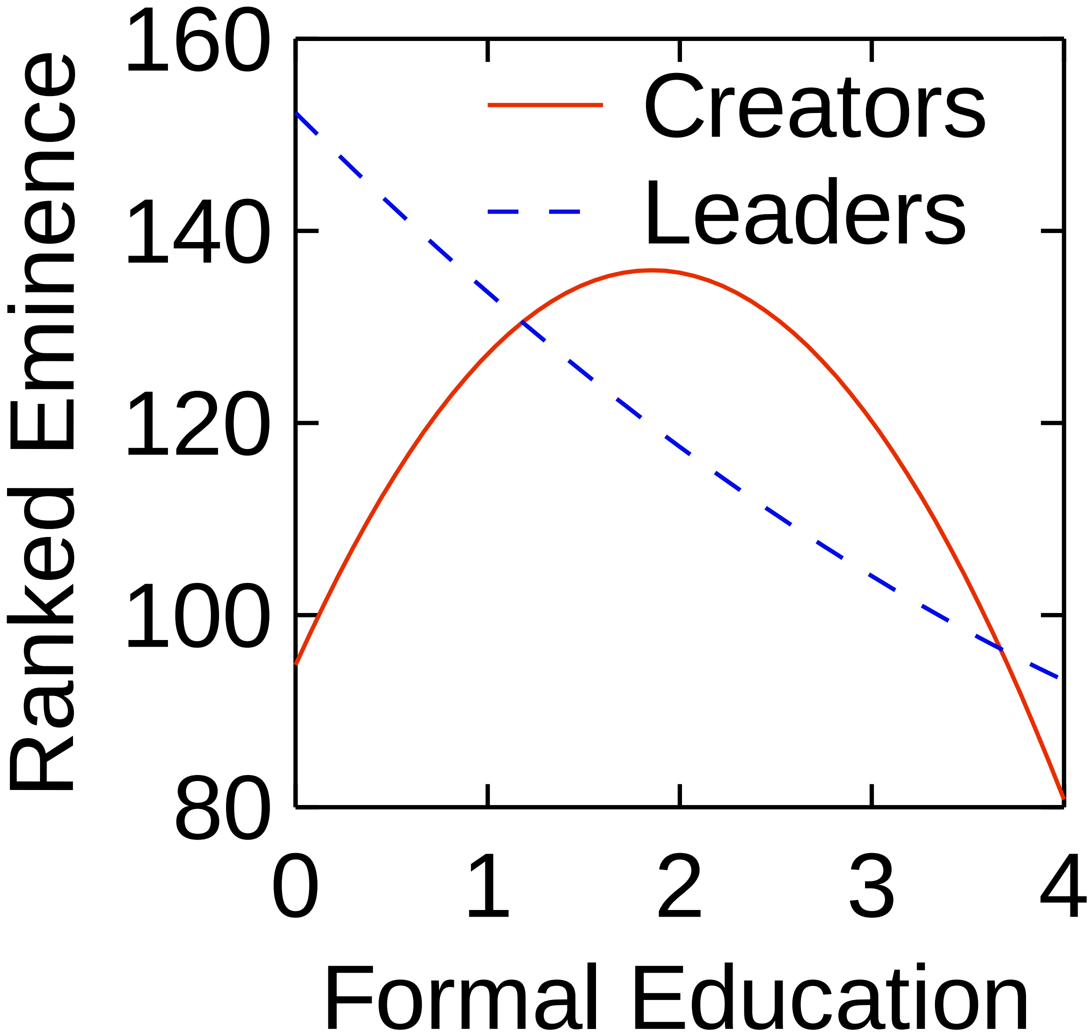
- Some forms of genius may be in part “born” - but not in a simplistic manner,
- because genetic endowment can be multidimensional, multiplicative, and dynamic rather than unidimensional, additive, and static.
- As a consequence, it can be inherited even when familial inheritance is low, in contrast Galton’s assumption in *Hereditary Genius*.

Nurture: Empirical Studies of Exceptional Creators

- There can be little doubt that certain forms of exceptional accomplishments closely fit the expertise-acquisition explanation
- Examples include world-class achievements in individual sports, musical performance, and competitive games (e.g., chess)
- Yet other forms of extraordinary achievement do not seem so compatible with this account
- This is especially true for creative genius

Creative Genius:

- The Originality Paradox:
  - Creativity depends on originality, but originality may be undermined by excessive expertise
  - Anecdotal evidence: Einstein vs. Grossman
  - Experimental evidence: Insightful problem solving (e.g., “functional fixedness”)
  - Historiometric evidence: Cox (1926) data



160
140
120
100
80
0
1
2
3
4
Creators
Leaders
Ranked Eminence
Formal Education

Creative Genius:

- The Originality Paradox:
  - Creativity depends on originality, but originality may be undermined by excessive expertise
  - Anecdotal evidence: Einstein vs. Grossman
  - Experimental evidence: Insightful problem solving (e.g., “functional fixedness”)
  - Historiometric evidence: Cox (1926) data
  - Hence, experts are not creators and vice versa
- In support of this position can be cited several problematic findings regarding individual differences and longitudinal changes

Problematic Findings

- Individual Differences
  - The 10-Year Rule
    - Substantial cross-sectional variation in the actual number of years prior to making a major contribution
    - For example, in a sample of 120 composers two kinds of preparation measures were defined for both unweighted counts of *themes* and weighted counts of *works*:
      - Musical preparation: year of first hit minus year of first formal lessons
      - Compositional preparation: year of first hit minus year of first composition

Table 3
Correlations With Musical and Compositional Preparation Measures

Measure	Musical		Compositional	
	Themes	Works	Themes	Works
[redacted]				
M	17.11	21.59	9.67	14.15
SD	7.33	9.39	7.35	9.06
Range	0–37	4–48	0–35	0–43

* $p < .05$. ** $p < .01$. *** $p < .001$.

Problematic Findings

- Individual Differences
  - The 10-Year Rule
    - Moreover, this variation correlates negatively with
      - maximum annual output,
      - lifetime output, and
      - eminence
    - In other words, the greatest creators require *less* time to acquire domain-specific expertise

Table 3

Correlations With Musical and Compositional Preparation Measures

Measure	Musical		Compositional	
	Themes	Works	Themes	Works
[redacted]				
Maximum annual output				
Themes	−.18*	−.19*	−.15	−.18*
Works	−.30**	−.34***	−.22*	−.29**
Lifetime output				
Themes	−.26**	−.29**	−.20*	−.25**
Works	−.26**	−.37***	−.19*	−.32***
Eminence	−.13	−.21*	−.13	−.22*
[redacted]				

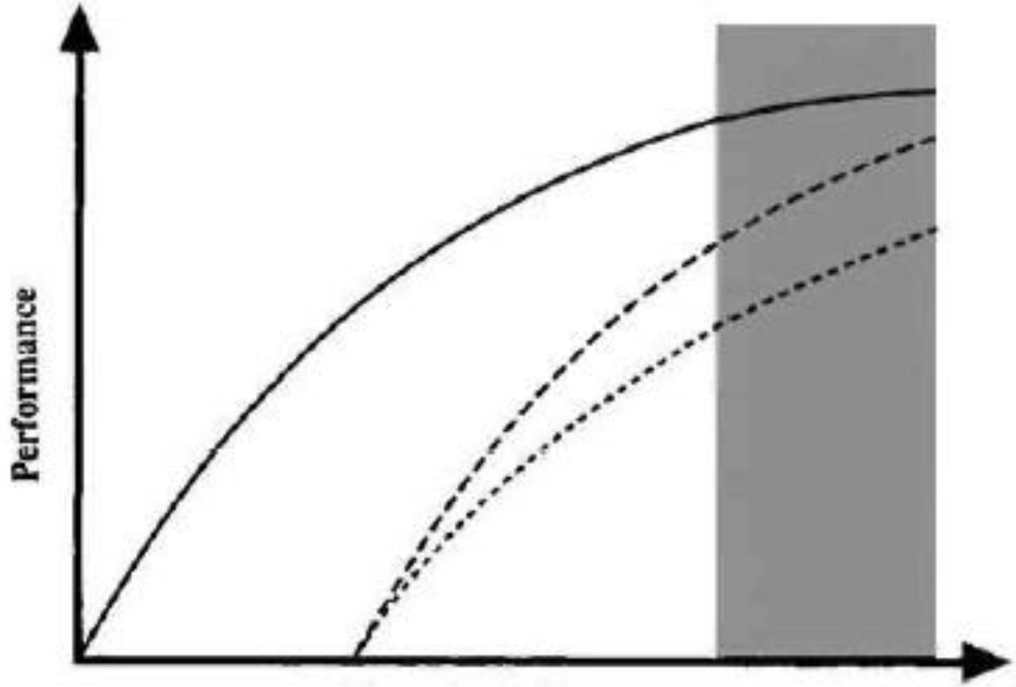
* $p < .05$. ** $p < .01$. *** $p < .001$.

Problematic Findings

- Individual Differences
  - The 10-Year Rule
    - What renders these negative correlations all the more remarkable is that productivity and impact are also negatively correlated with
      - age at first formal lessons and
      - age at first composition
    - That is, those who start earlier take less time: both onset and the rate of expertise acquisition are accelerated
    - This pattern differs from what is normally expected of expertise acquisition (e.g., musical performance)

Figure 4

Relations Between Age and Performance



Note. Late period involving selection to the best music academies has been shaded. Solid line: performance associated with early starting age and high level of practice. Dashed line: performance for equally high level of practice but later starting age. Dotted line: performance associated with the same late starting age but lower level of practice. The slope of the dashed line appears steeper than that of the solid line. However, the horizontal distance between these two curves is constant. From "Can We Create Gifted People?" by K. A. Ericsson, R. Th. Krampe, and S. Heizmann in *The Origins and Development of High Ability* (pp. 222–249), 1993, Chichester, England: Wiley. Copyright 1993 by Ciba Foundation. Adapted by permission.

Problematic Findings

- Individual Differences
  - The 10-Year Rule
    - Similar findings have been found for other samples (e.g., eminent scientists):
      - Those with the highest output and impact begin expertise-acquisition earlier and complete it more rapidly
    - This consistent empirical finding can be interpreted as support for the existence of creative talent
      - That is, those individuals who are able to accelerate the onset and termination of expertise acquisition are also able to generate creative ideas at an accelerated rate

Problematic Findings

- Individual Differences
  - Personal Characteristics
    - Creativity is
      - negatively correlated with latent inhibition (and other cognitive filtering processes) and
      - positively correlated with
        - openness to experience (from the “Big Five”),
        - breadth of interests (number of hobbies, omnivorous reading, etc.),
        - versatility (both intra- and inter-domain)

Problematic Findings

- Individual Differences
  - Personal Characteristics
    - Two difficulties regarding the above list:
    - First, several of the traits appear to have a significant genetic basis (e.g., openness, latent inhibition).
    - Second, these do not seem to be the individual attributes that would be expected if creative genius was made according to a standard expertise-acquisition model

Problematic Findings

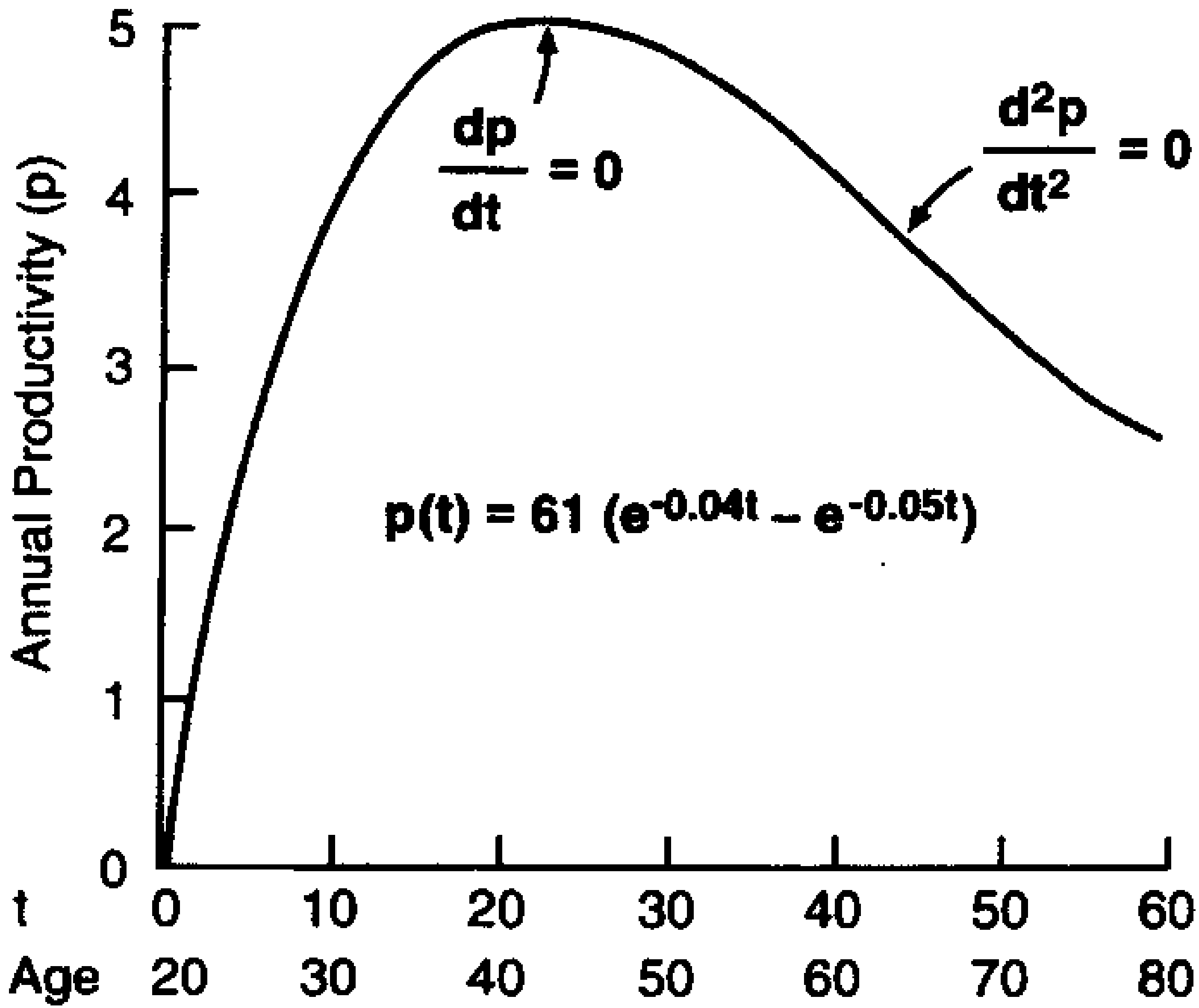
- Individual Differences
  - Personal Characteristics
    - According to the latter framework, expertise acquisition should require specialized concentration on a single domain that filters out all extraneous distractions
    - It is especially difficult to explain how exceptional creativity in one domain would be positively correlated with expertise acquisition in multiple domains (particularly given that creativity is not positively correlated with sleep deprivation)
    - However, these individual traits do make sense if originality is dependent on a breadth of knowledge and skills and on a receptiveness to serendipitous stimuli

Problematic Findings

- Longitudinal Changes

Problematic Findings

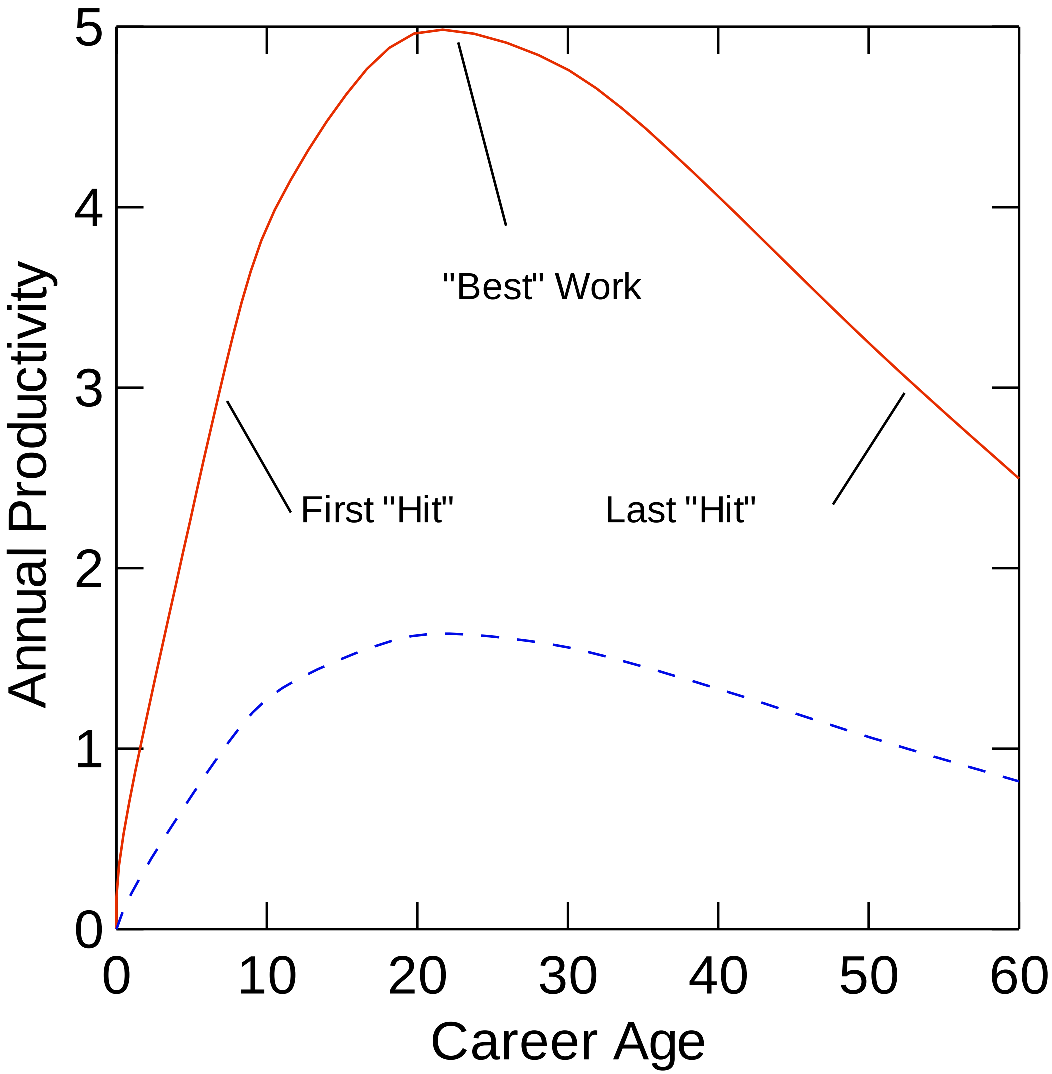
- Longitudinal Changes
  - Total Productivity: A Non-Monotonic Function



Annual Productivity (p)
5
4
3
2
1
0
$\frac{dp}{dt} = 0$
$\frac{d^2p}{dt^2} = 0$
$p(t) = 61\,(e^{-0.04t} - e^{-0.05t})$
t
0
10
20
30
40
50
60
Age
20
30
40
50
60
70
80

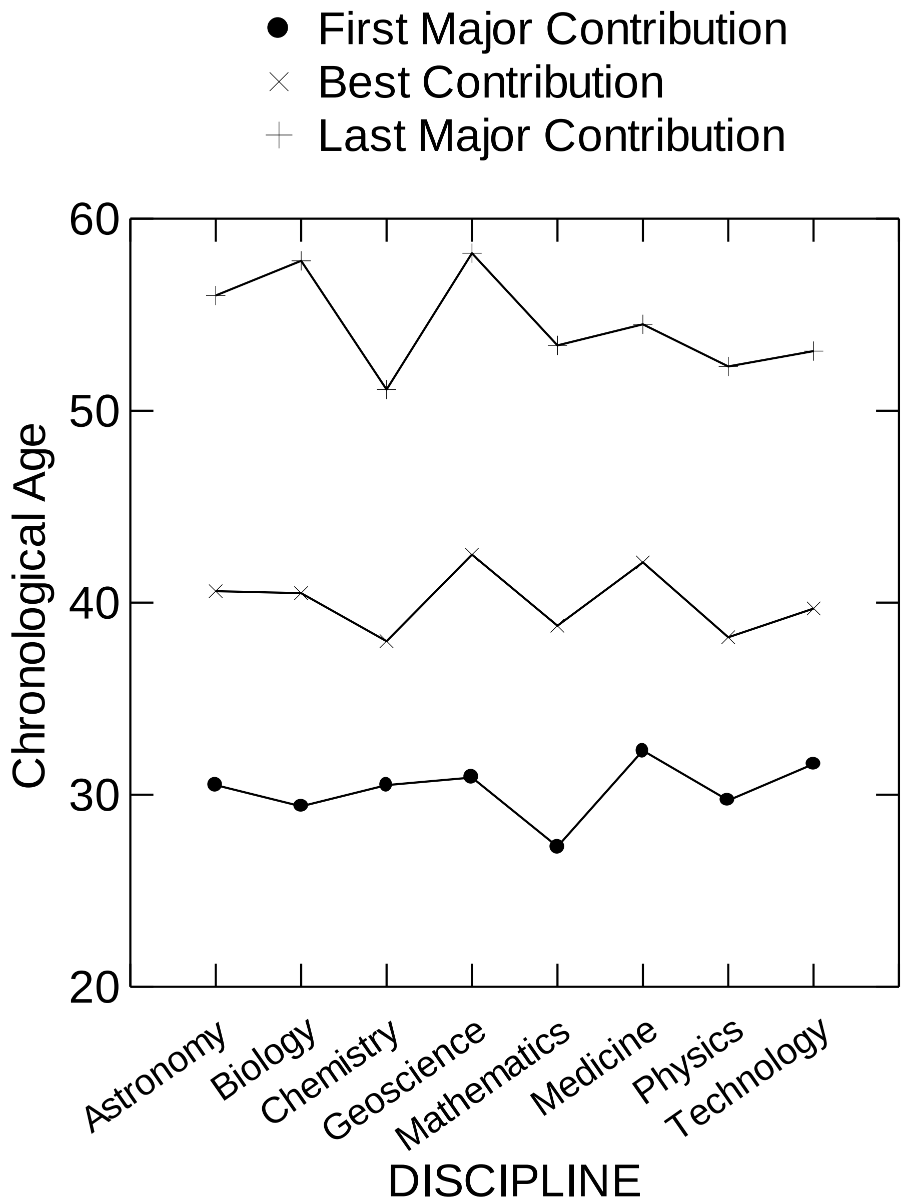
Problematic Findings

- Longitudinal Changes
  - Total Productivity
  - Quantity-Quality Relation: The Equal-Odds Rule


5
4
3
2
1
0
"Best" Work
First "Hit"
Last "Hit"
Annual Productivity
0
10
20
30
40
50
60
Career Age

Problematic Findings

- Longitudinal Changes
  - Total Productivity
  - Quantity-Quality Relation
  - Career Landmarks: Best Work < Last Work


First Major Contribution
Best Contribution
Last Major Contribution
Chronological Age
60
50
40
30
20
Astronomy
Biology
Chemistry
Geoscience
Mathematics
Medicine
Physics
Technology
DISCIPLINE

Problematic Findings

- Longitudinal Changes
  - Total Productivity
  - Quantity-Quality Relation
  - Career Landmarks
  - Overtraining and Cross-training Effects
    - Former: Within-domain expertise acquisition can eventually undermine creativity
    - Latter: Cross-domain expertise acquisition can enhance creativity

Problematic Findings

- Longitudinal Changes
  - Total Productivity
  - Quantity-Quality Relation
  - Career Landmarks
  - Overtraining and Cross-training Effects
    - First example: Highly popular opera compositions
    - Second example: High-impact research programs
      - e.g., Charles Darwin when working on the *Origin*

Chronology of Darwin’s Work on Evolution

1837 He opens notebook on the “transmutation of species.”

1842 He produces a pencil sketch of his theory

1844 He enlarges the sketch

1854 Begins collating notes for *Origins*

1856 Begins writing in earnest

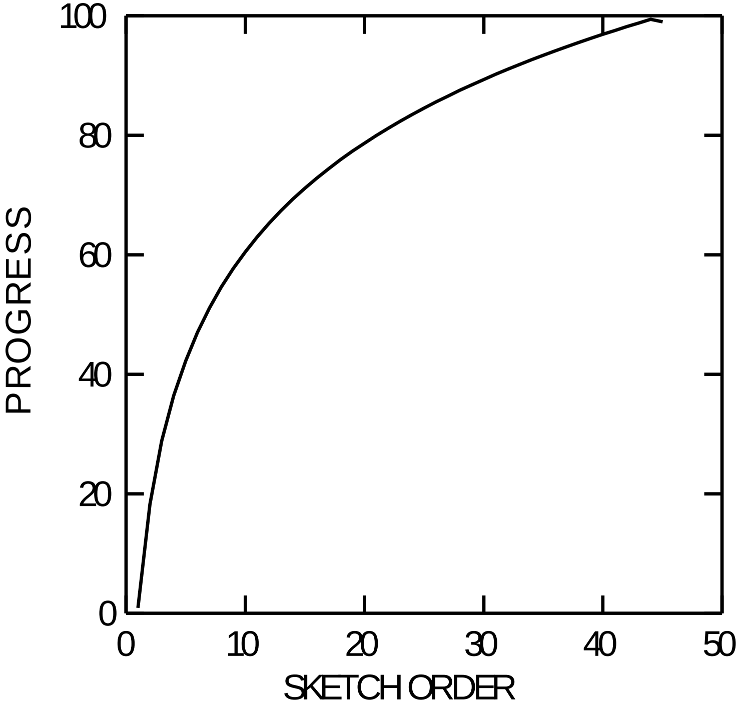
1859 He publishes *Origin of Species*

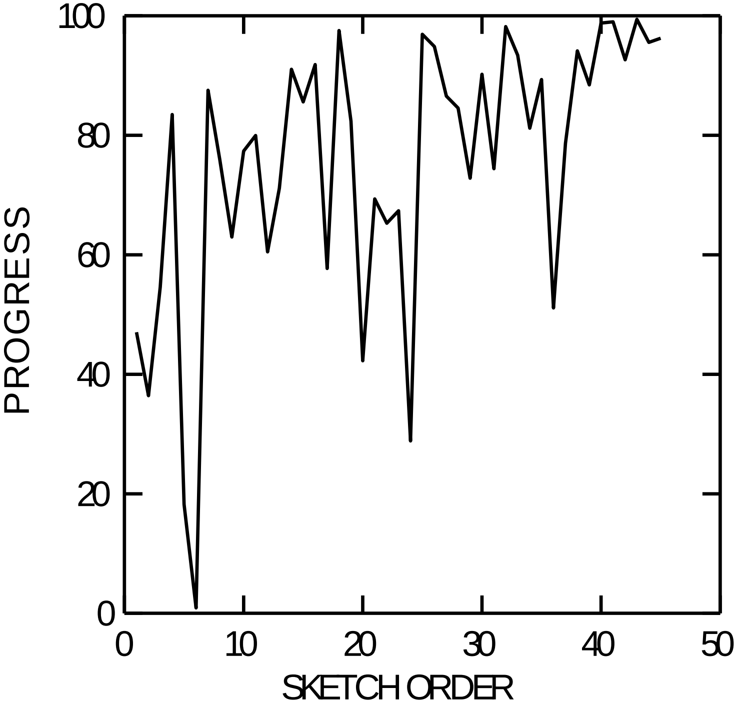
Meanwhile ...

1837-46	He studies the geology of South America
1837-42	He studies coral formation
1838-44	He studies volcanic islands and mountain chains
1838-42	He studies geological formations in Scotland and Wales
1837-45	He prepares the volumes reporting the zoological findings of the *Beagle* voyage (5 volumes on fossil mammals, mammals, birds, fish, and reptiles)
1847-54	He publishes extensive monographs on both fossil and modern cirripedes
1837-58	He publishes miscellaneous papers, notes, and reviews on topics as diverse as earthworms, mold, glacial action, erratic boulders, volcanic rocks, a rock seen on an iceberg, dust falling on ships in the Atlantic, the effects of salt water on seeds, seed vitality, the role of bees in the fertilization of Papilionaceous flowers, Waterhouse's *Natural History of the Mammalia*, and on *Rhea americana*, *Sagitta*, *Planaria*, and *Arthrobalanus*

Nature-Nurture Integration

- Environmental Effects on Phenotype
  - e.g., contingency of heritability estimates on environmental variance
- Genotypic Effects on Environment
  - e.g., deliberate practice
- Genetic-Environmental Multiplicative Effects
  - e.g., practice effects moderated by genetic profile
- Dynamic Longitudinal Interactions
  - e.g., general intelligence


100
80
60
40
20
0
0
10
20
30
40
50
PROGRESS
SKETCH ORDER


100
80
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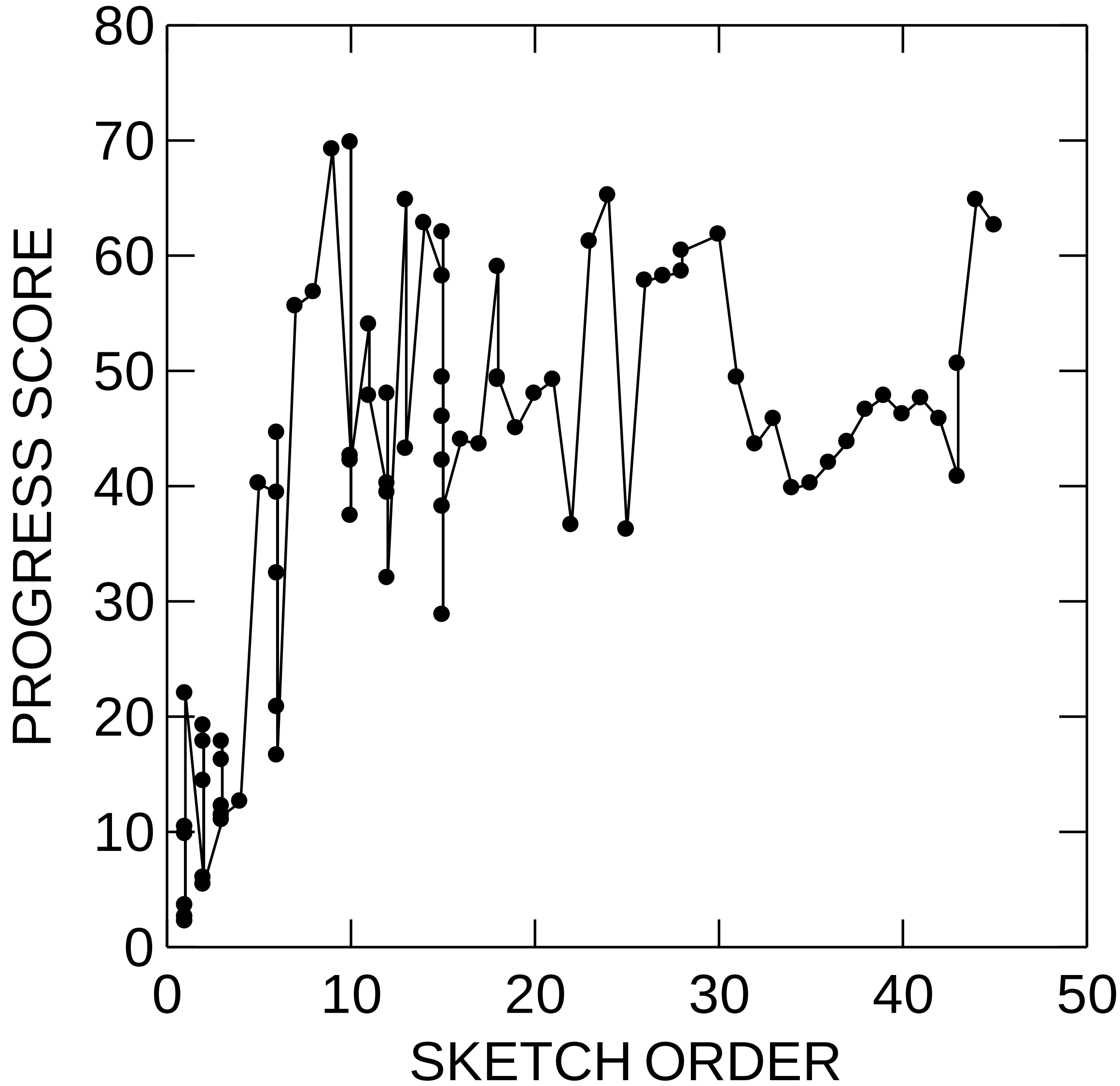
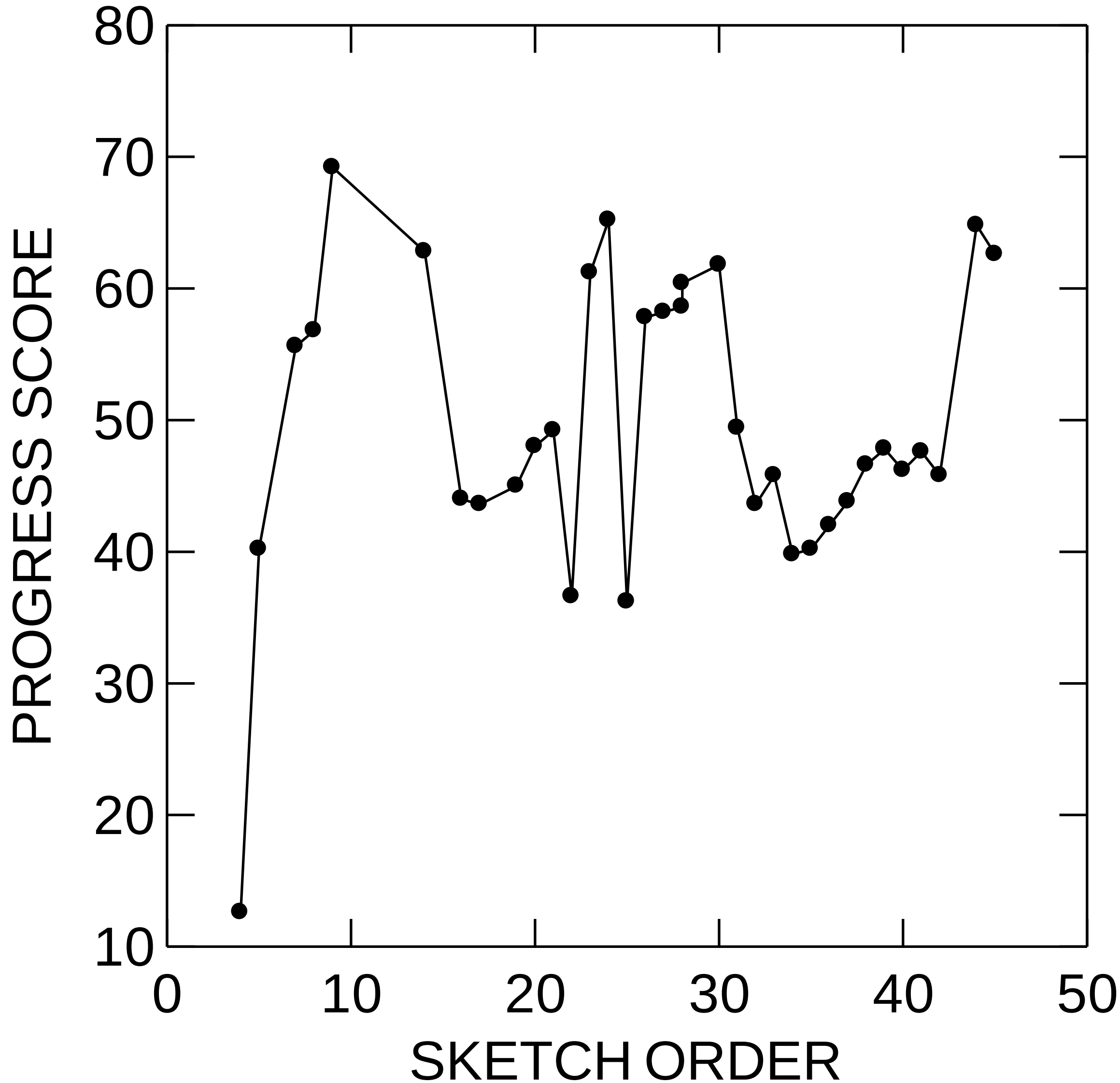
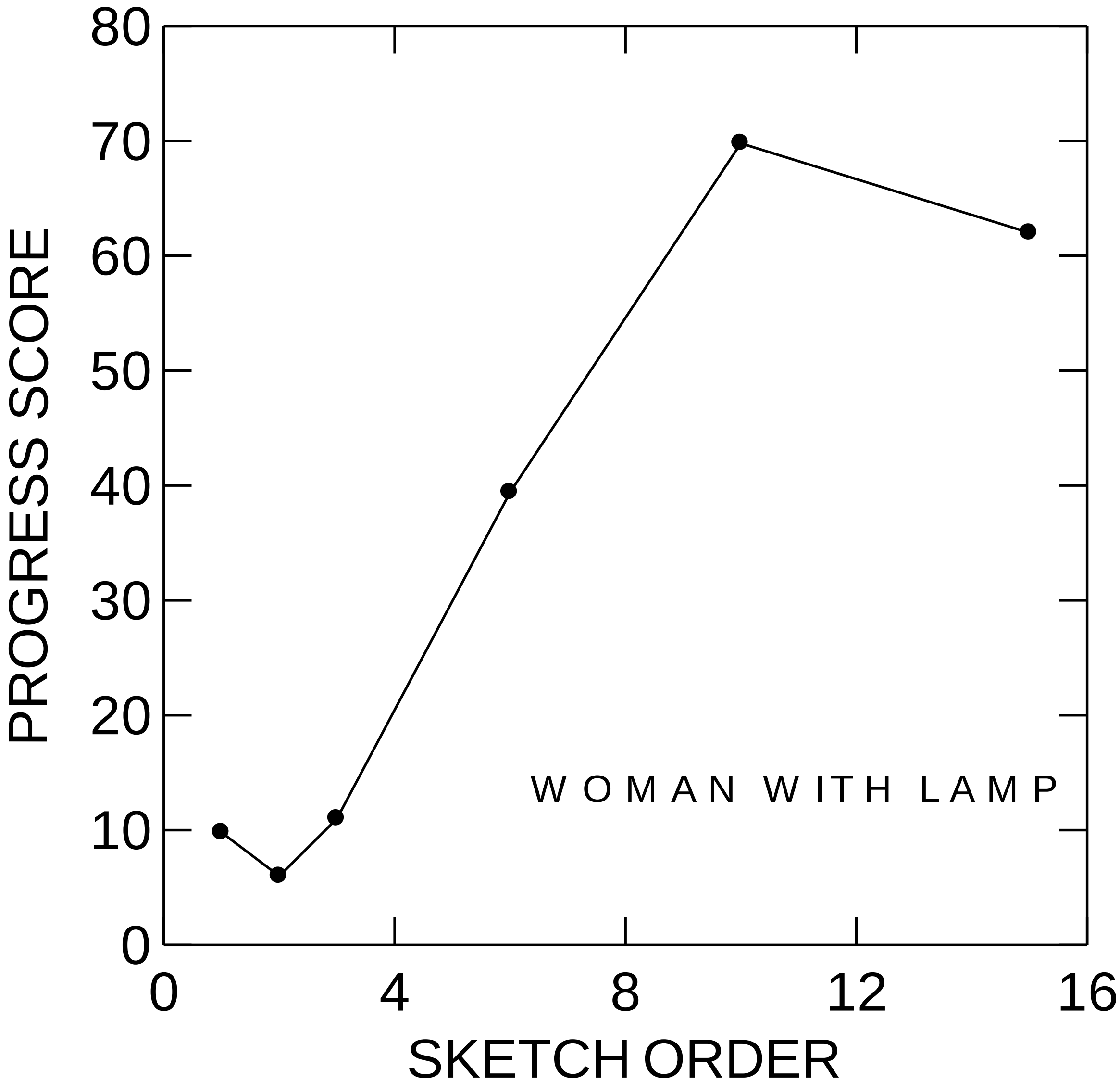
PROGRESS
SKETCH ORDER



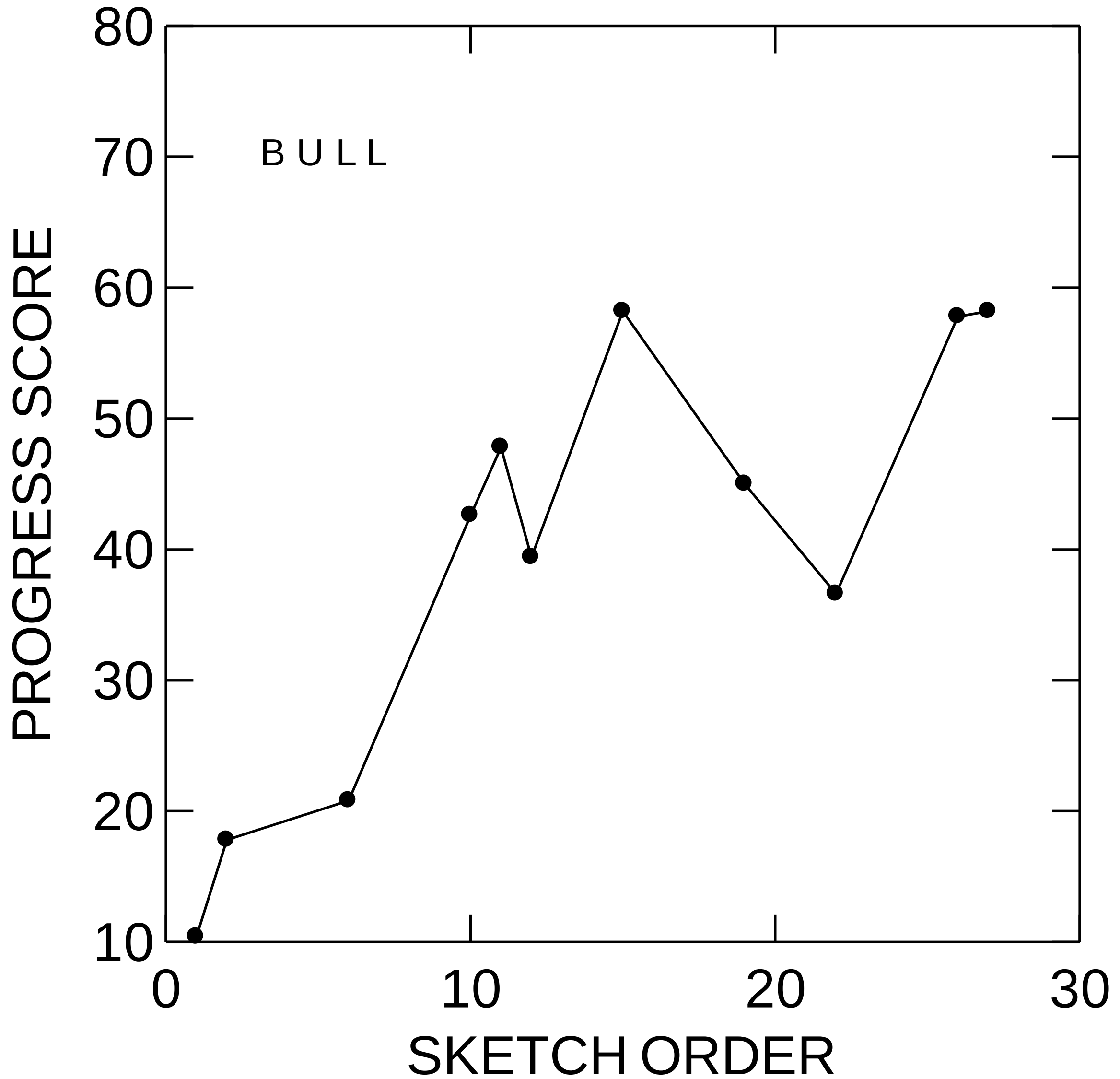
PROGRESS SCORE
SKETCH ORDER
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50



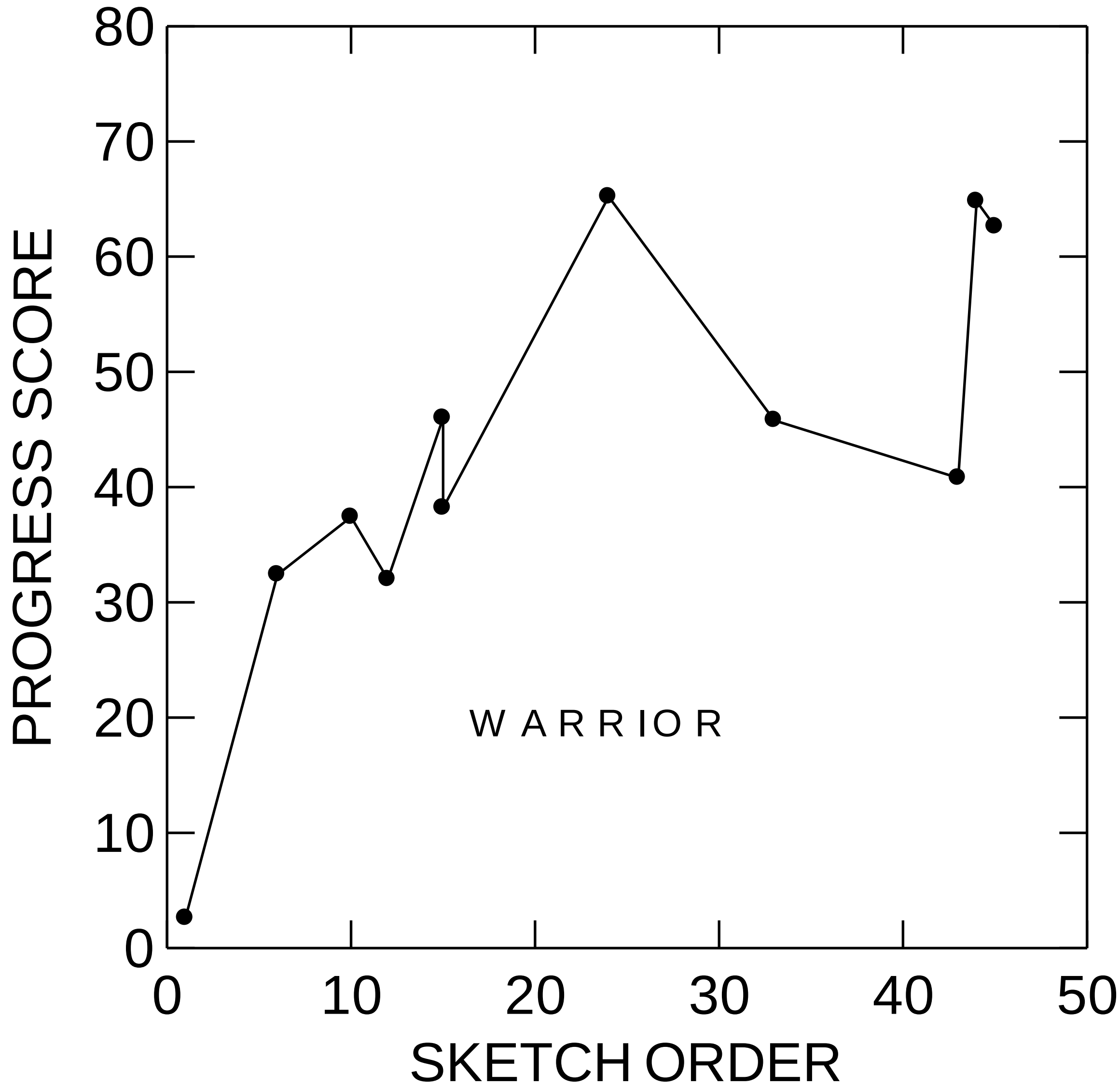
80
70
60
50
40
30
20
10
PROGRESS SCORE
0
10
20
30
40
50
SKETCH ORDER



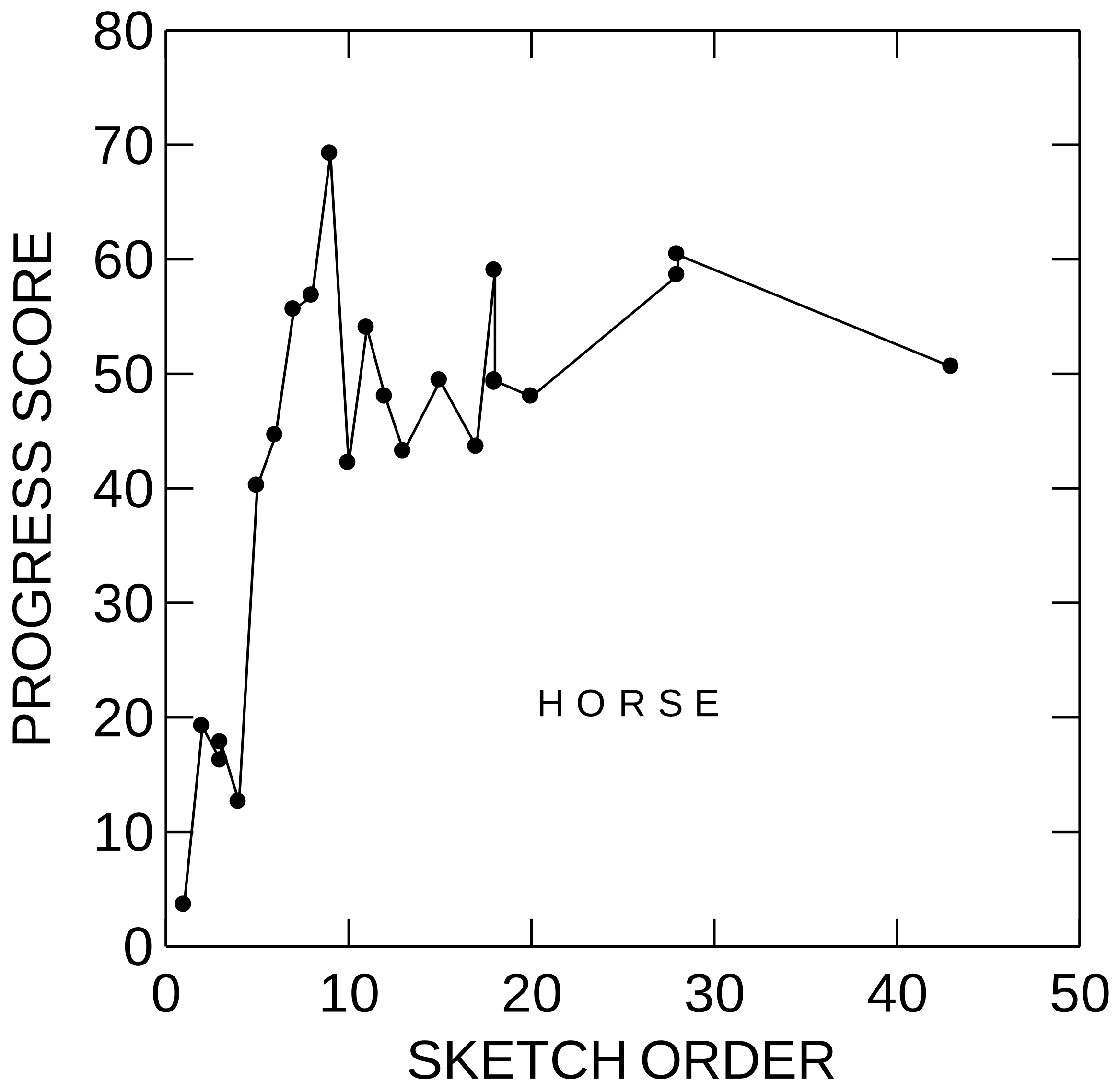
80
70
60
50
40
30
20
10
0
PROGRESS SCORE
WOMAN WITH LAMP
0
4
8
12
16
SKETCH ORDER

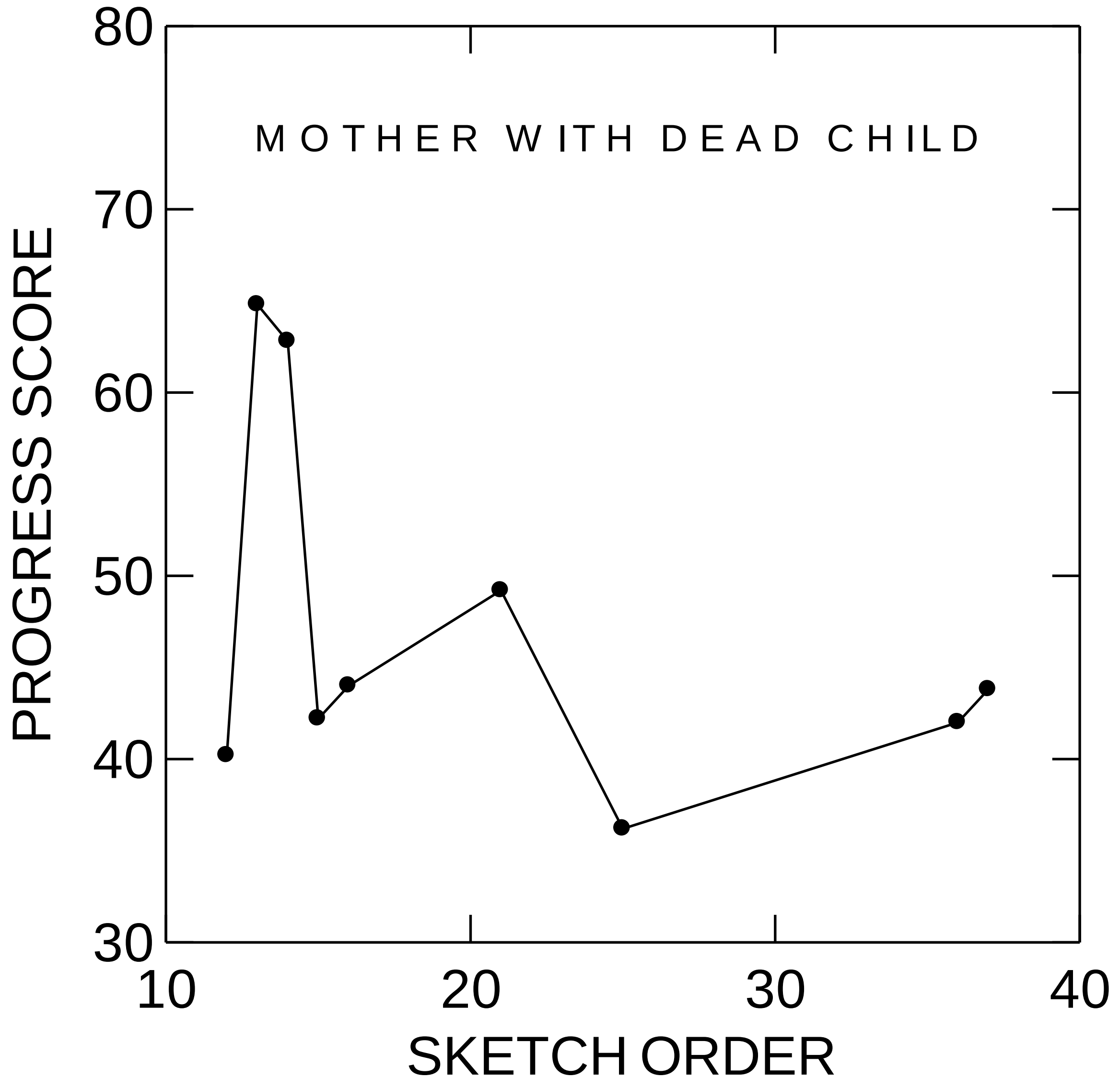


BULL
PROGRESS SCORE
80
70
60
50
40
30
20
10
0
10
20
30
SKETCH ORDER



80
70
60
50
40
30
20
10
0
PROGRESS SCORE
WARRIOR
0
10
20
30
40
50
SKETCH ORDER


PROGRESS SCORE
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
SKETCH ORDER
HORSE



MOTHER WITH DEAD CHILD
PROGRESS SCORE
SKETCH ORDER
80
70
60
50
40
30
10
20
30
40

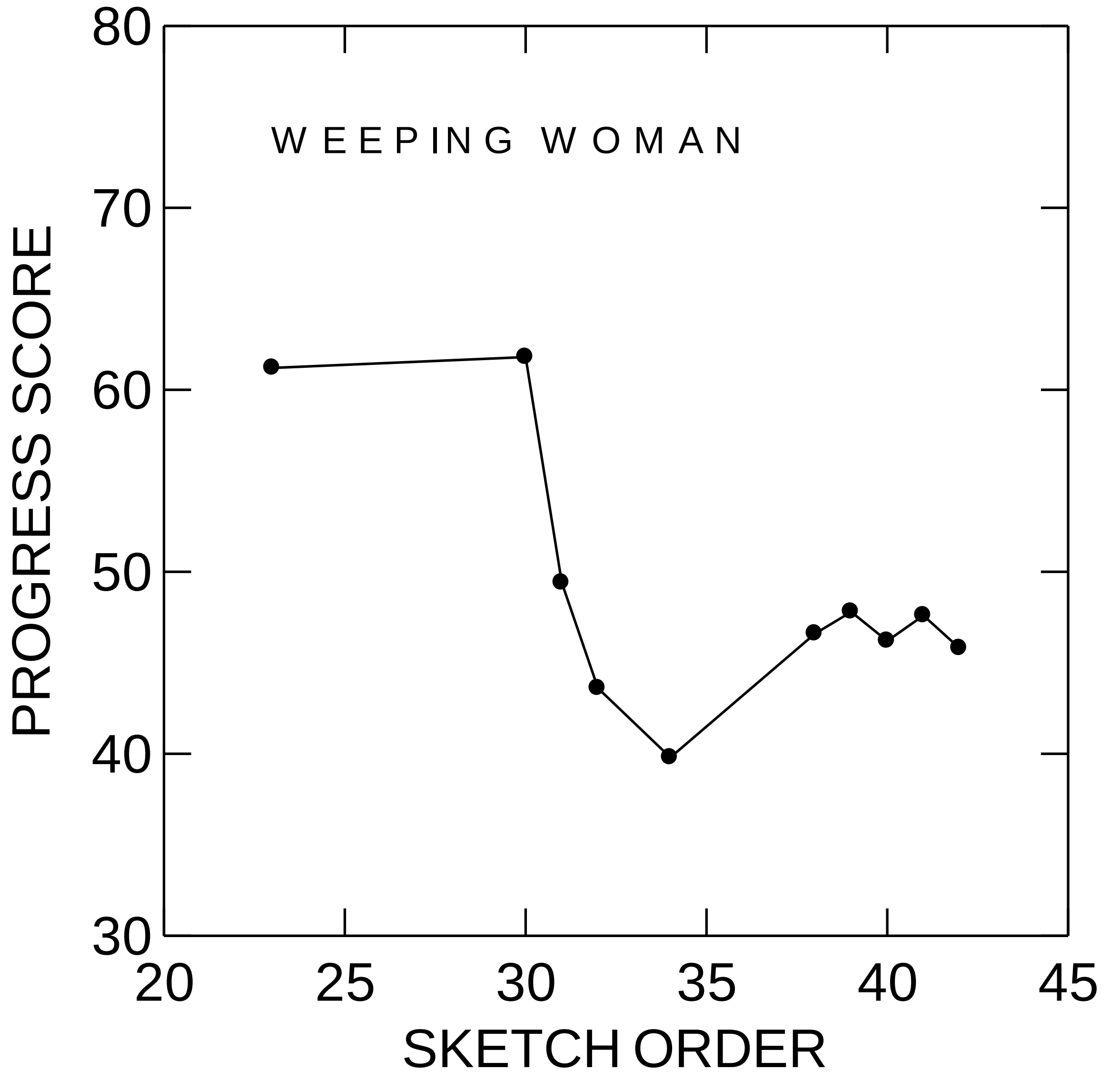

WEEPING WOMAN
PROGRESS SCORE
SKETCH ORDER
80
70
60
50
40
30
20
25
30
35
40
45

Table 1
Basic Statistics and Correlations for Career Measures

Measure	1	2	3	4	5	6	*M*	*SD*	Range
1. Age at first hit	.61***	.49***	.12	.48***	−.39***	−.46***	30.76	10.06	8–60
2. Age at best hit	.44***	.54***	.59***	.42***	−.02	−.01	40.78	12.55	16–80
3. Age at last hit	.26**	.62***	.68***	.38***	.14	.22*	50.99	15.02	18–86
4. Age at maximum output	.44***	.75***	.60***	.53***	−.14	−.15	37.46	12.48	16–84
5. Maximum annual output	−.30**	.02	.15	−.02	.54***	.72***	3.67	3.17	1–21
6. Lifetime output	−.39***	.09	.20*	.01	.84***	.79***	12.32	19.76	1–135
M	26.28	39.68	51.74	39.58	20.18	102.60			
SD	7.86	10.83	13.72	11.59	18.38	141.72			
Range	5–47	18–76	18–80	11–76	1–104	1–812			

Note. Correlations on the diagonal are between themes and works measures, those below the diagonal among themes measures only, and those above the diagonal among works measures only.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 2
Correlations Between Career Measures and Other Individual Differences

Measure	Birth year	Age at Lessons	Age at Composition	Age at Death	Eminence
Age at first hit					
Themes	−.21*	.37***	.46***	.36***	−.25**
Works	−.10	.36***	.45***	.23*	−.30**
Age at best hit					
Themes	−.30**	.04	.14	.21*	.22*
Works	−.12	.03	.24**	.32***	.14
Age at last hit					
Themes	−.33***	−.02	.08	.47***	.38***
Works	−.09	−.06	.05	.46***	.31**
Age at maximum output					
Themes	−.29**	.15	.13	.22*	.15
Works	−.06	.15	.19*	.28**	−.10
Maximum annual output					
Themes	−.23*	−.31**	−.21*	−.22*	.59***
Works	−.06	−.19*	−.21*	−.15	.38***
Lifetime output					
Themes	−.20	−.33***	−.28**	−.18	.69***
Works	−.06	−.34***	−.30**	−.13	.53***
M	1823.22	9.17	16.61	65.51	3.70
SD	76.46	3.58	5.86	14.62	3.79
Range	1524–1913	2–19	4–32	26–92	0.20–11.49

* $p < .05$. ** $p < .01$. *** $p < .001$.

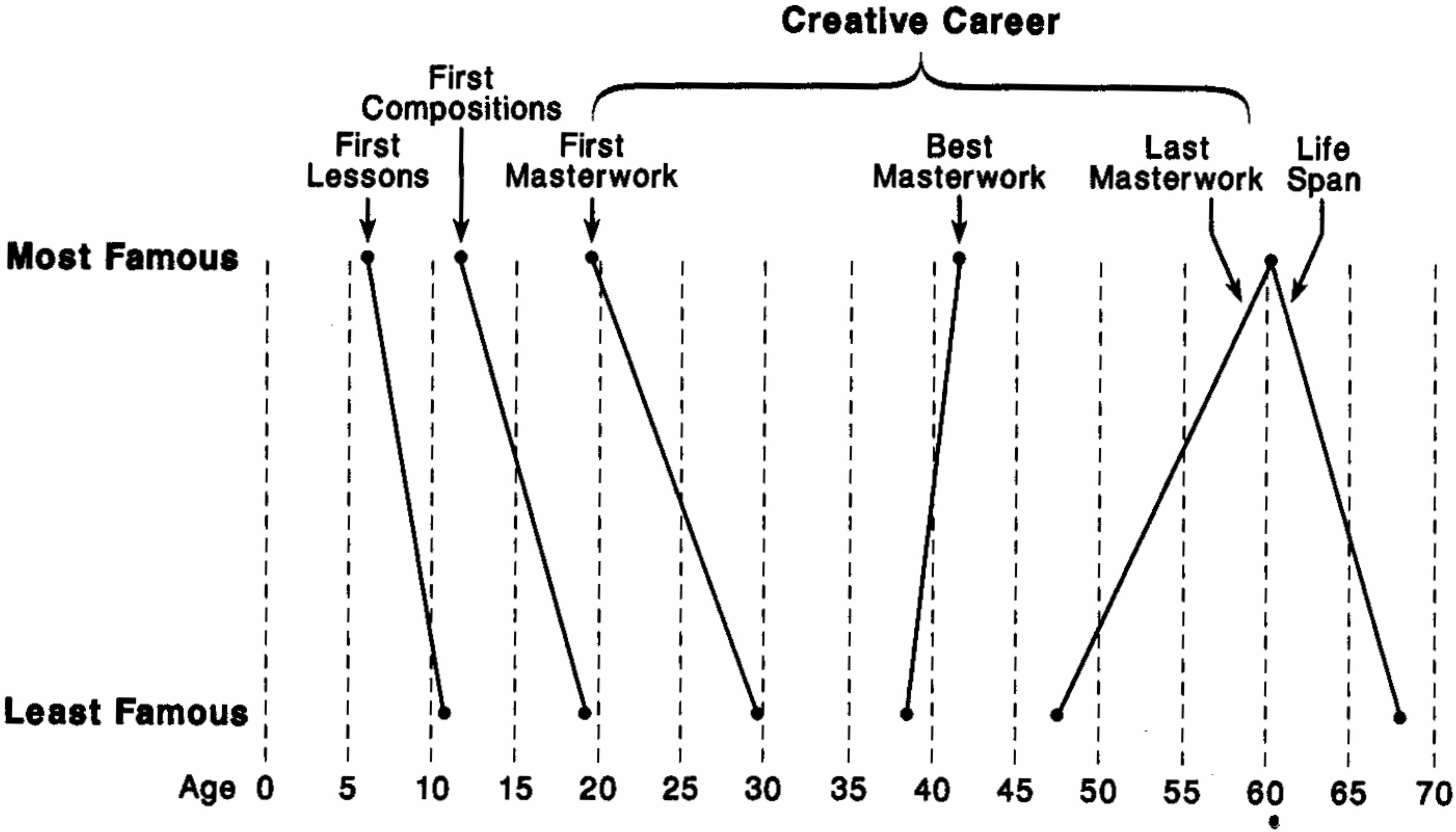


FIGURE 8.5. Typical career paths for the most and least famous of 120 classical composers.

TABLE 2
Correlations between Aesthetic Success (Log-Transformed and Residualized) and Cumulative Expertise (Linear and Logarithmic Functions)

	Log-transformed		Residualized	
Type of expertise acquisition	Linear	Logarithmic	Linear	Logarithmic
Years accumulated since				
First operas	.07*	.07*	.06	.05
First compositions	.11**	.17***	.06	.12***
First lessions	.10**	.12***	.05	.06
Cumulative number of				
Opears: Specific genre	−.18***	−.19***	−.11**	−.13***
Operas: All genre	−.18***	−.16***	−.06	−.06
All vocal compositions	−.13***	−.08*	−.02	−.00
All compositions	.10**	.08*	.17***	.13***

Note. $N = 911$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

TABLE 4
Predictors of Log-Transformed and Residualized Measures of Aesthetic Success: Statistically Significant Logarithmic Developmental Functions

Type of expertise acquisition	Log-transformed		Residualized		
	b	β	*b*	β	Tolerance
Years accumulated since					
First operas	0.61***	.25	0.30*	.14	.24
First compositions	0.63**	.20	0.56*	.20	.12
First lessions	−0.77*	−.17	−0.94**	−.23	.13
Cumulative number of					
Operas: Specific genre	−0.30***	−.14	−0.23**	−.12	.72
Operas: All genre	−1.20***	−.58	−0.75***	−.40	.24
All compositions	0.85***	.39	0.79***	.41	.31

Note. For the log-transformed measure of aesthetic success $R^2 = .18$, whereas for the residualized measure $R^2 = .11$. For both measures $N = 911$. Because the two regression equations contain the exact same independent variables, the tolerances are unchanged across the two analyses.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

TABLE 3

Predictors of Log-Transformed and Residualized Measures of Aesthetic Success: Statistically Significant Linear and Quadratic Development Functions

	Log-transformed			Residualized		
Type of expertise acquisition	*b*	β	Tolerance	*b*	β	Tolerance
Cumulative years since first operas						
Linear	0.02442*	.14	.18	0.02751***	.17	.58
Cumulative years since first compositions						
Quadratic	−0.00350***	−.45	.14	−0.00331	−.48	.15
Cumulative years since first lessons						
Linear	0.02039*	.13	.21	—	—	—
Quadratic	0.00184**	.22	.14	0.00237***	.31	.15
Cumulative operas: Specific genre						
Linear	−0.09841***	−.28	.22	−0.08522**	−.27	.23
Quadratic	0.00329**	.16	.26	0.00334**	.18	.27
Cumulative operas: All genre						
Linear	−0.07383***	−.64	.14	−0.04254***	−.41	.19
Quadratic	0.00048***	.20	.25	0.00036**	.16	.28
Cumulative total compositions						
Linear	0.03713***	.46	.16	0.02297***	.32	.59
Quadratic	−0.00011**	−.15	.25	—	—	—

Note. For the log-transformed measure of aesthetic success $R^2 = .20$, whereas for the residualized measure $R^2 = .14$. For both measures $N = 911$. Because the second regression equation contains a subset of the independent variables contained in the first regression equation, the tolerances are not identical across the two analyses.

* $p < .05$.
** $p < .01$.
*** $p < .001$.