

Scott E Page

University of Michigan

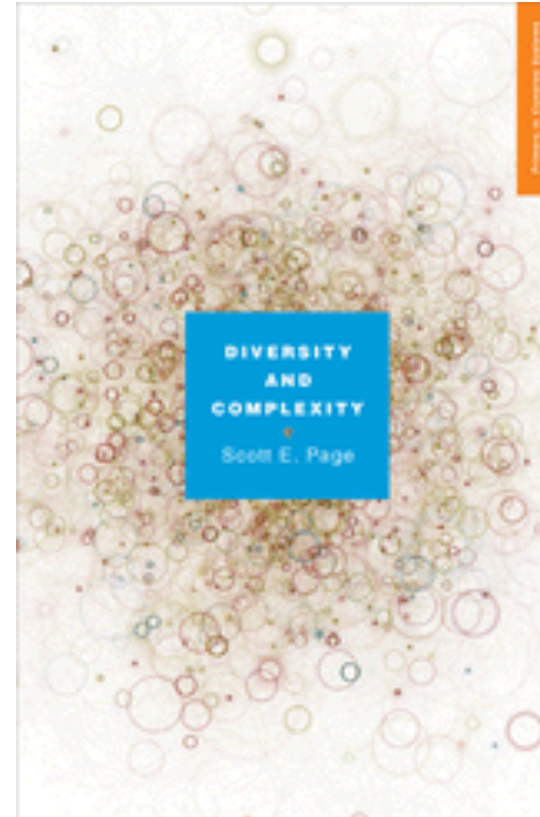
Santa Fe Institute

Leveraging Diversity

Scott E. Page

**THE
DIFFERENCE**

HOW THE POWER OF DIVERSITY
CREATES BETTER GROUPS, FIRMS,
SCHOOLS, AND SOCIETIES



Outline

Background: Two Inescapable Trends

Identity and Cognitive Diversity

Prediction

Case: Netflix Prize

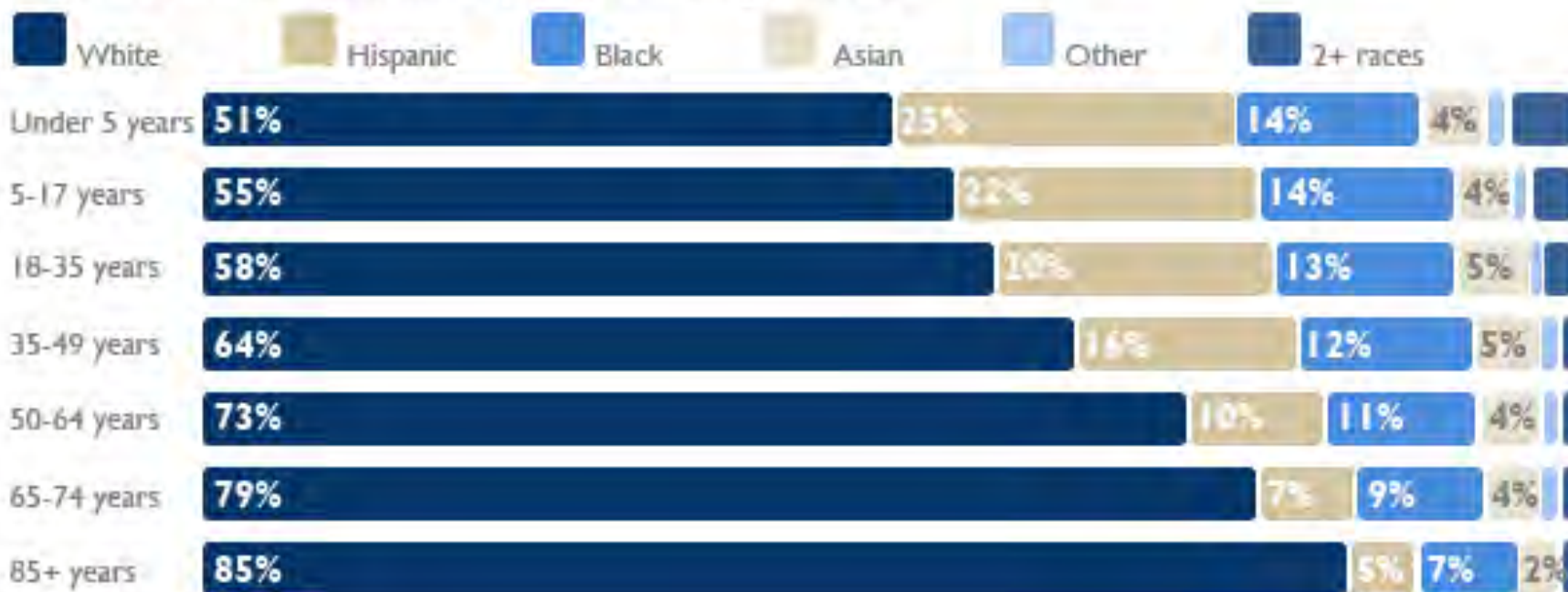
Problem Solving

Takeaways

Trend 1

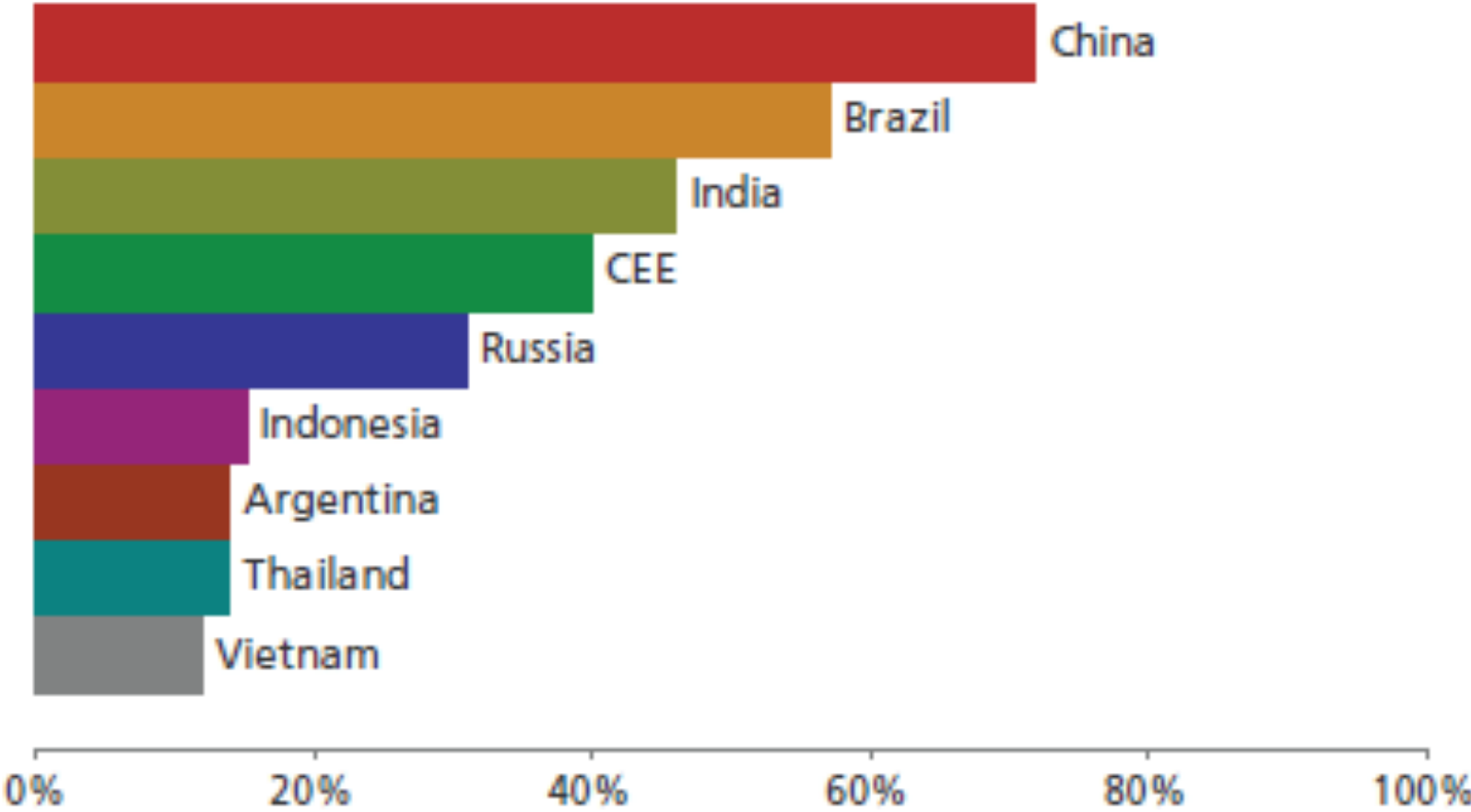
Increasing Diversity

Race-Ethnic Profiles by Age Group, 2010

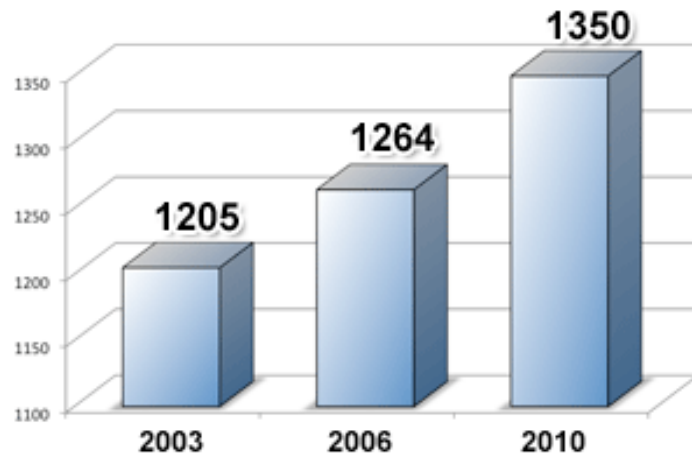


Source: Author's analysis of 2010 census data

Countries/Regions Where Multinationals are Growing

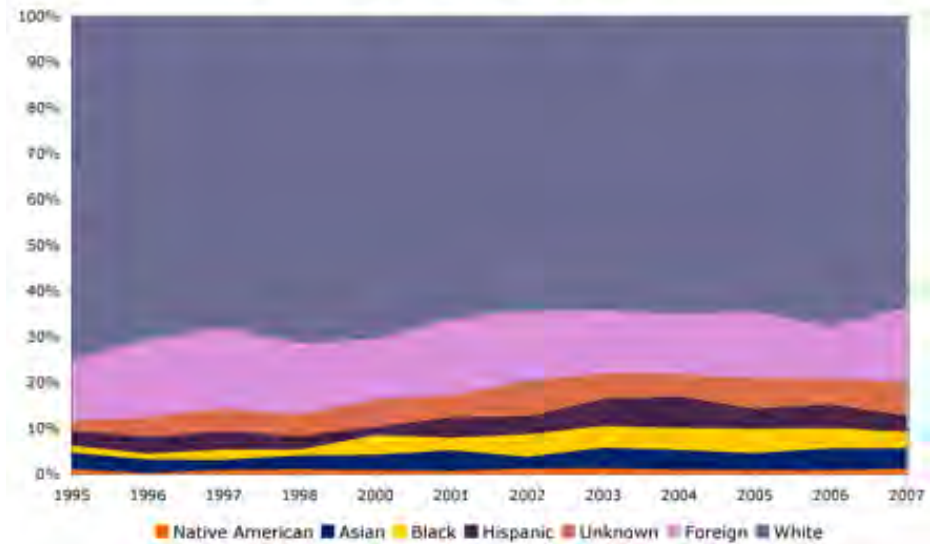


Black First-Year Enrollments in U.S. Medical Schools



Source: Association of American Medical Colleges.

Overall racial distribution in anthropology doctorate production, 1995-2007



A TAXONOMY OF TRANSITIONS

racial / ethnic
self-identification
in chicago
in the year 2000

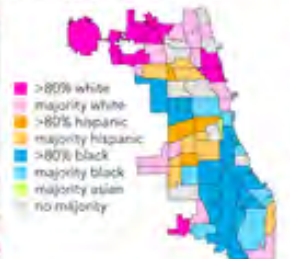
white ■
black ■
asian ■
hispanic ■
other ■

the black lines show
chicago's official
community areas.

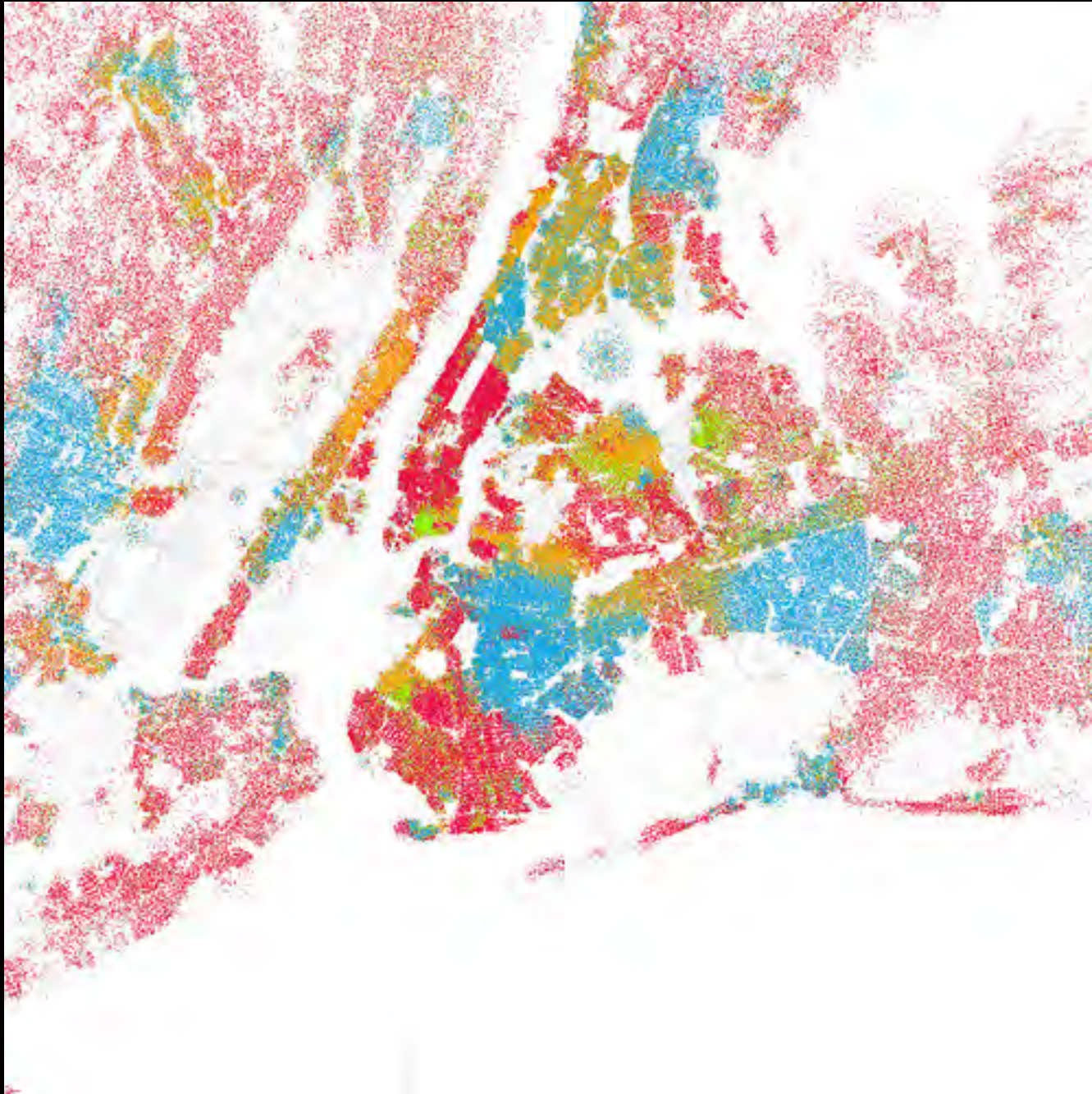
each dot represents
twenty-five people.
here, hispanic is
exclusive of other
categories.

block-level data
from the U.S. census.
scale 1:200,000

The same data, aggregated by community
area and shown with solid colors.



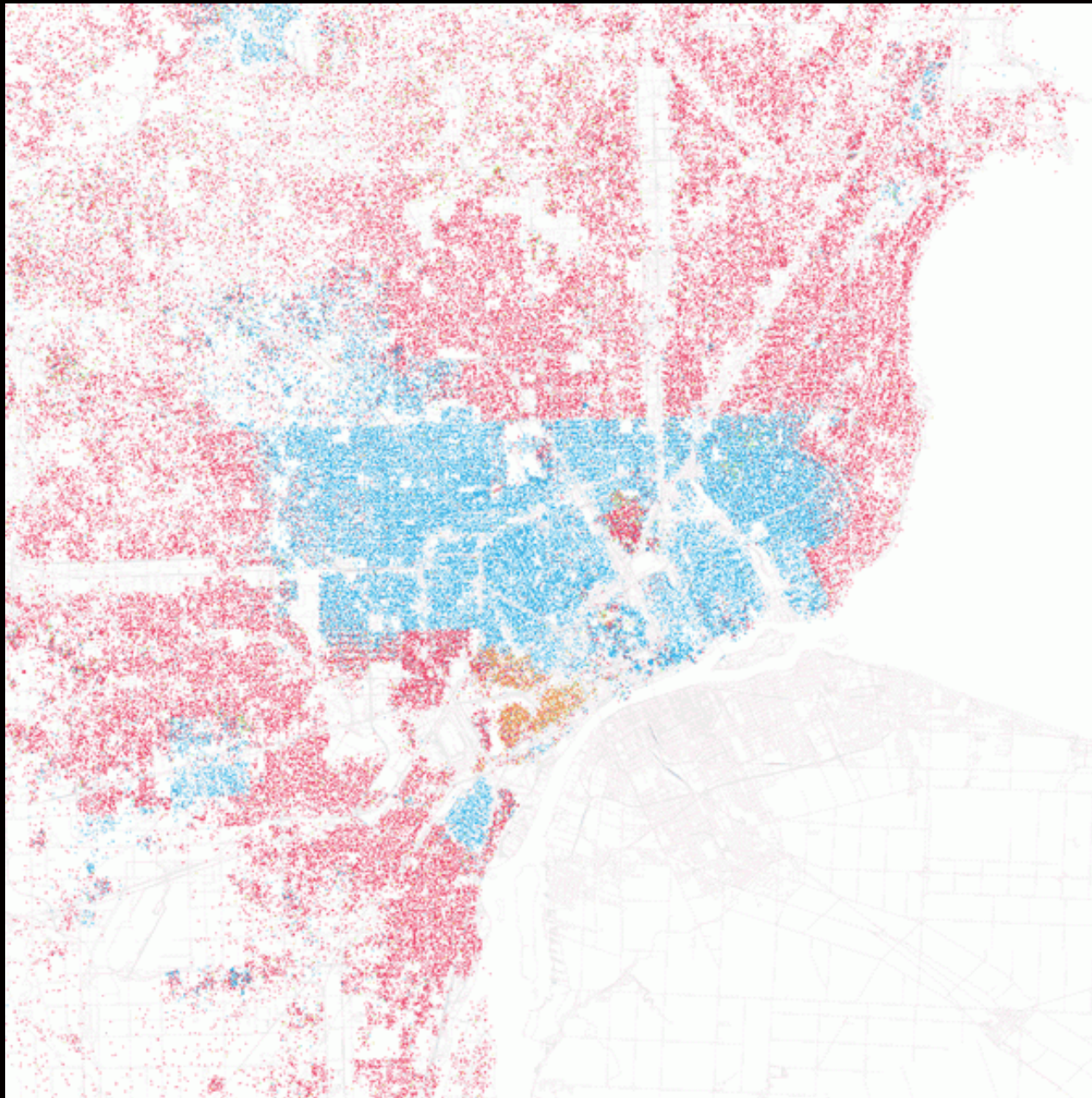
Chicago



New York



LA



The D

Normative Argument

Equalizing Opportunity.

Addressing past disadvantages.

Pragmatic Advantages

Promoting diversity enlarges the pool.

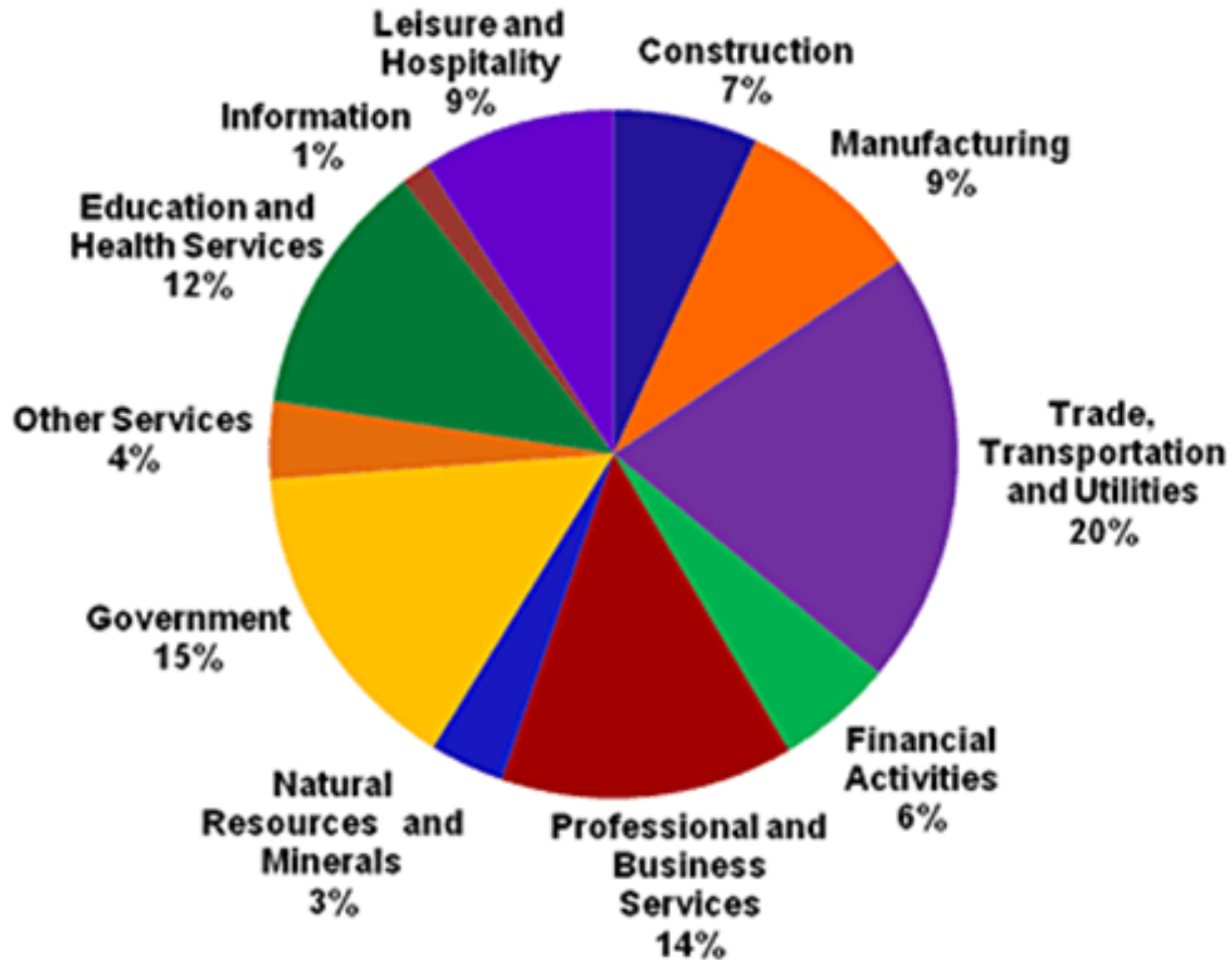
Diversity

Ability

Trend 2

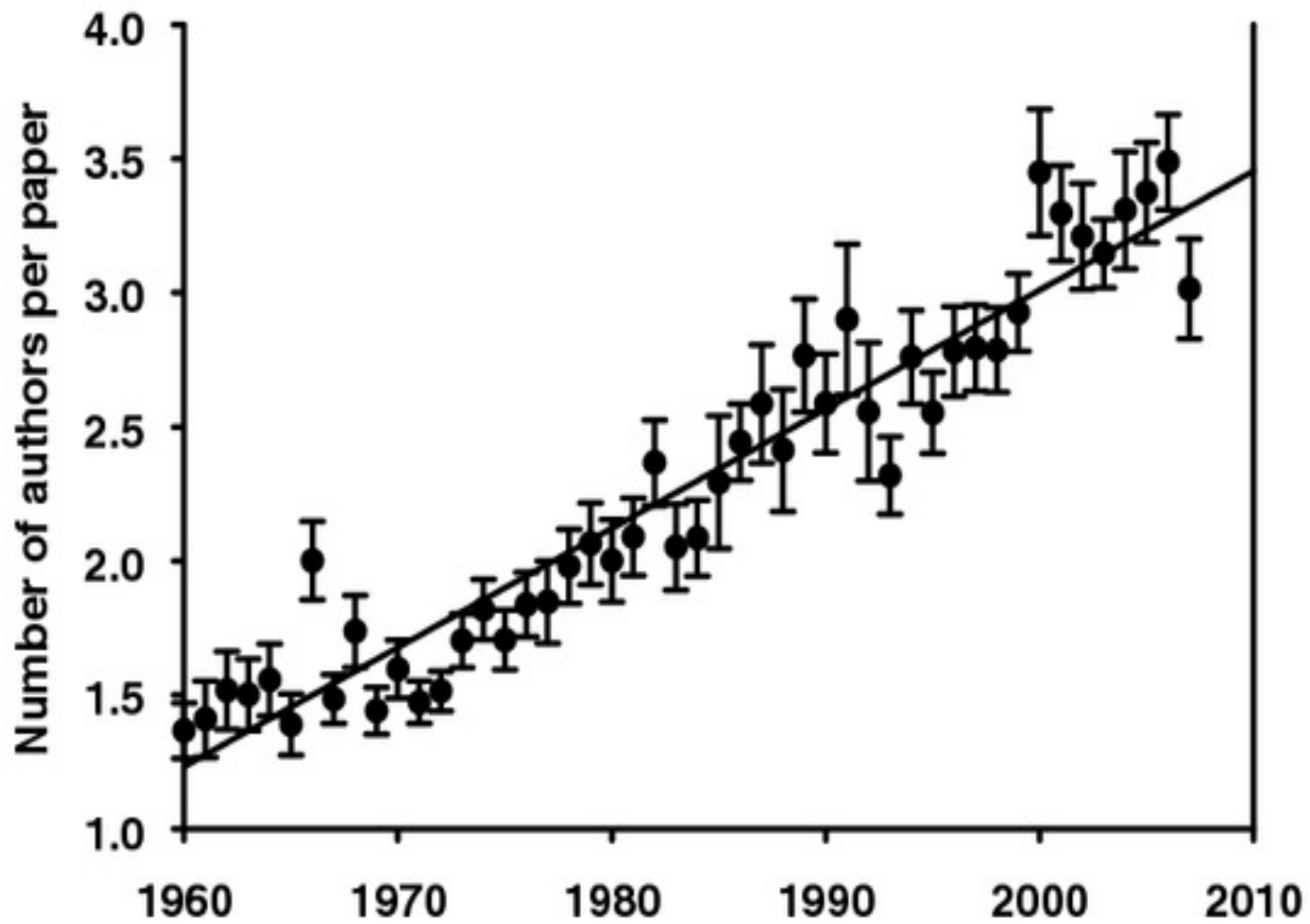
Changing Nature of Work

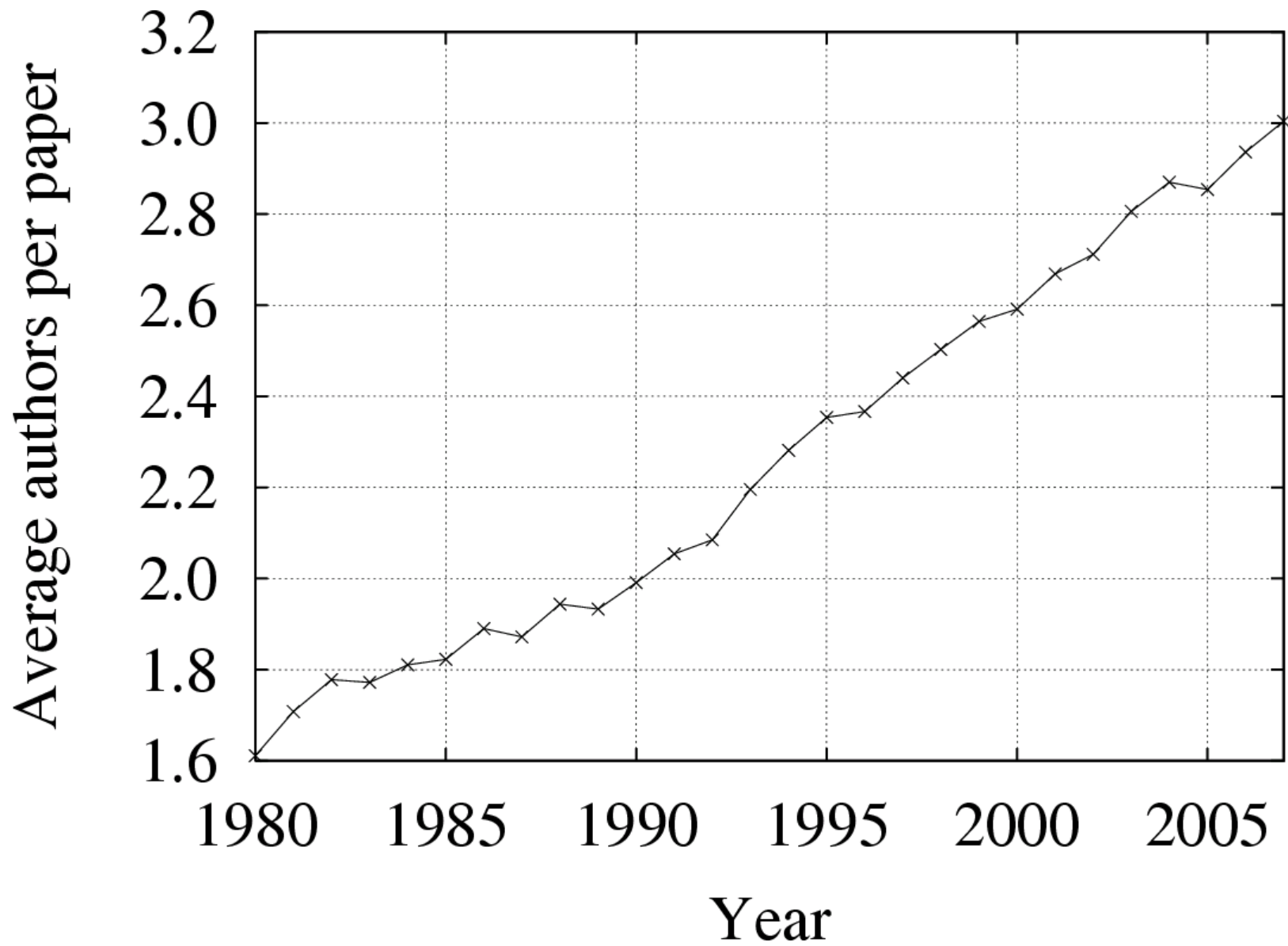
Employment by Industry - Percent of Total Workforce









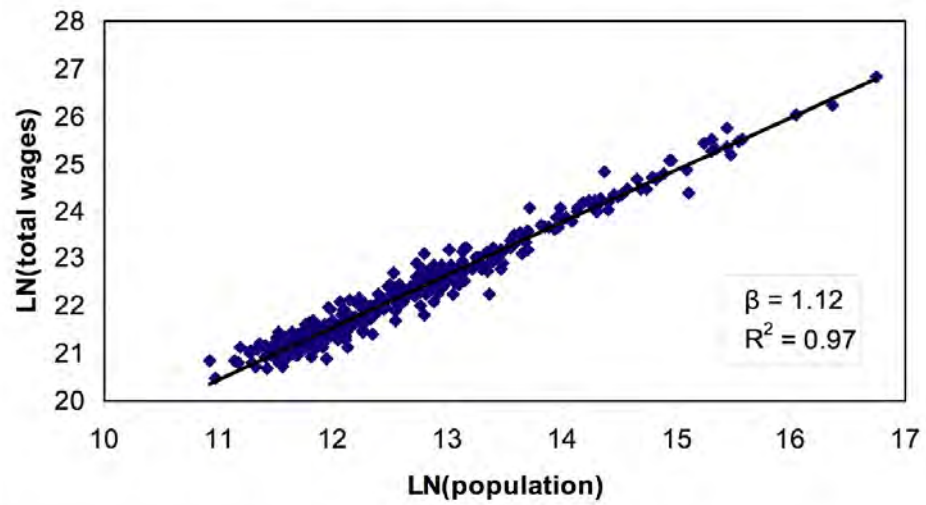


First 15 Nobels in Physics: 19 Winners

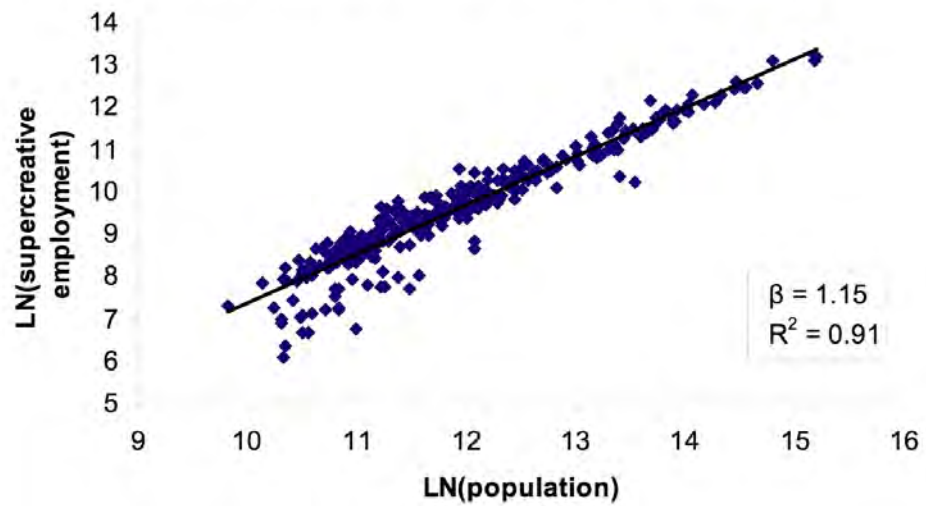
| | |
|------|--|
| 1901 | Wilhelm C. Röntgen |
| 1902 | Hendrik A. Lorentz, Pieter Zeeman |
| 1903 | Antoine Henri Becquerel, Pierre Curie, Marie Curie |
| 1904 | John W. Strutt |
| 1905 | Philipp E. A. von Lenard |
| 1906 | Sir Joseph J. Thomson |
| 1907 | Albert A. Michelson |
| 1908 | Gabriel Lippmann |
| 1909 | Carl F. Braun, Guglielmo Marconi |
| 1910 | Johannes D. van der Waals |
| 1911 | Wilhelm Wien |
| 1912 | Nils G. Dalen |
| 1913 | Heike Kamerlingh Onnes |
| 1914 | Max von Laue |
| 1915 | William Bragg |

42

Total Wages: 361 U.S. MSAs 2003



Supercreative Employment: 331 U.S. MSAs 2003



Diverse

+

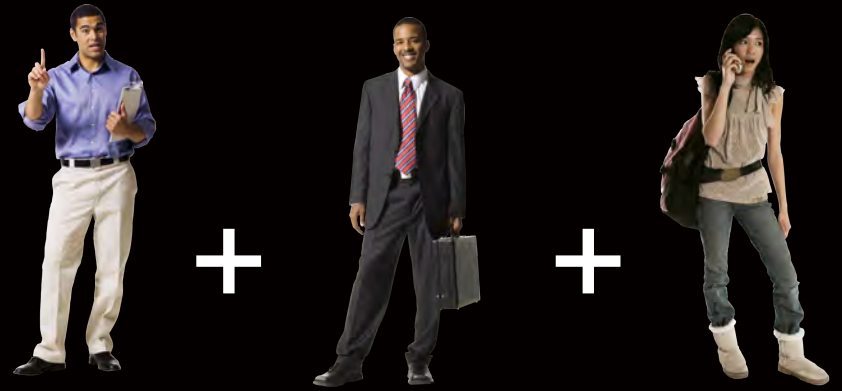
Group

Rethinking

4



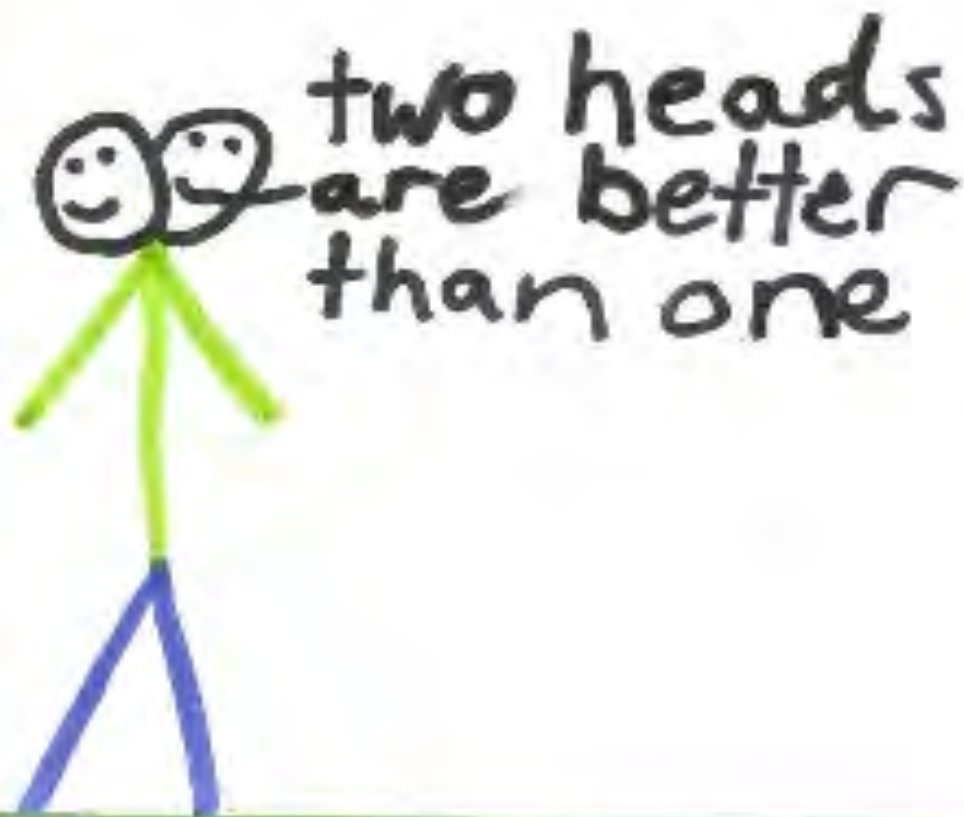
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Want to understand how diversity affects
group performance

Diversity

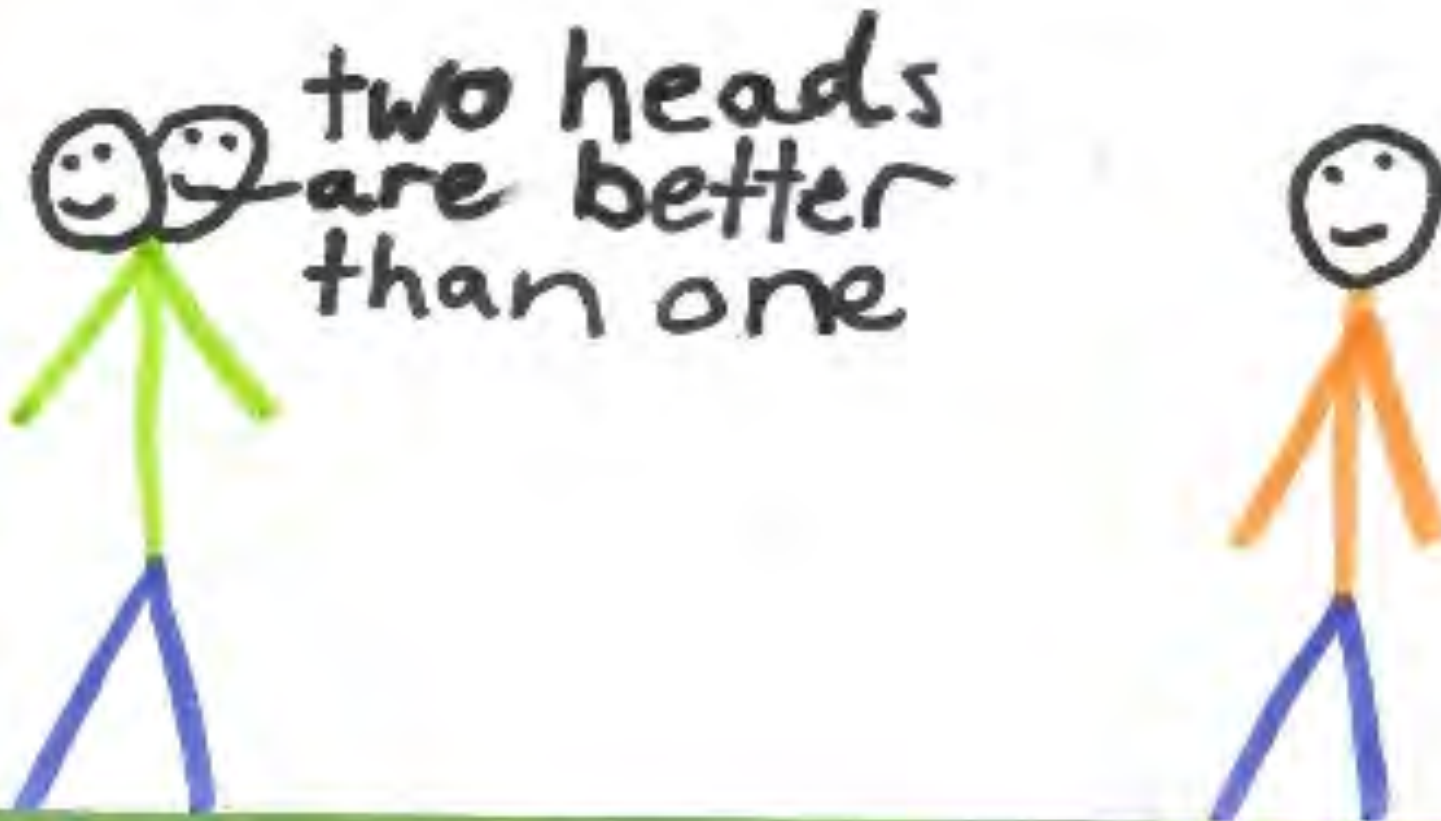
Ability



two heads
are better
than one



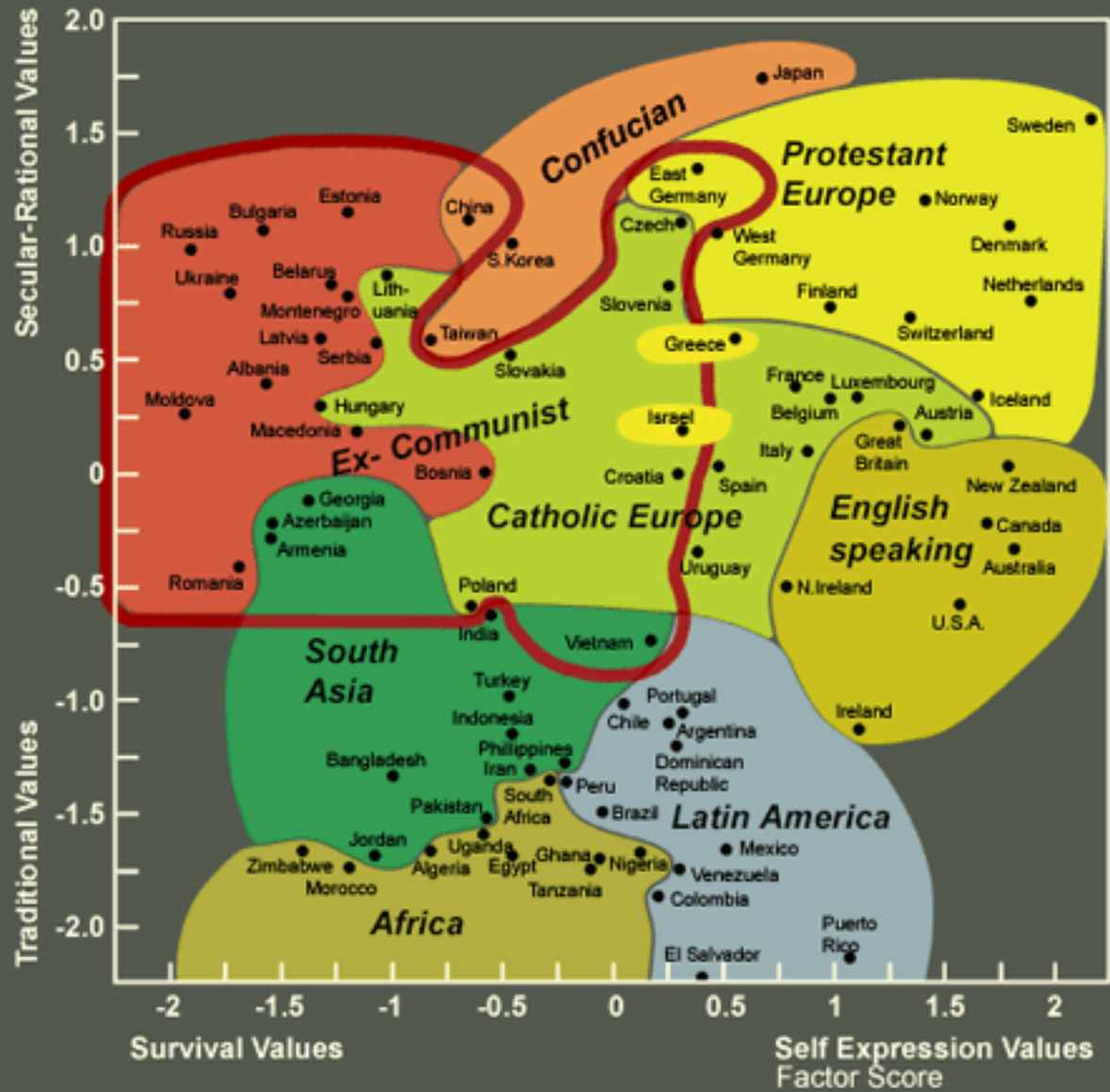
$$E[\text{SqE}(\mathbf{c})] = B^2 + \frac{1}{n} \text{Var} + \frac{n-1}{n} \text{Cov}$$



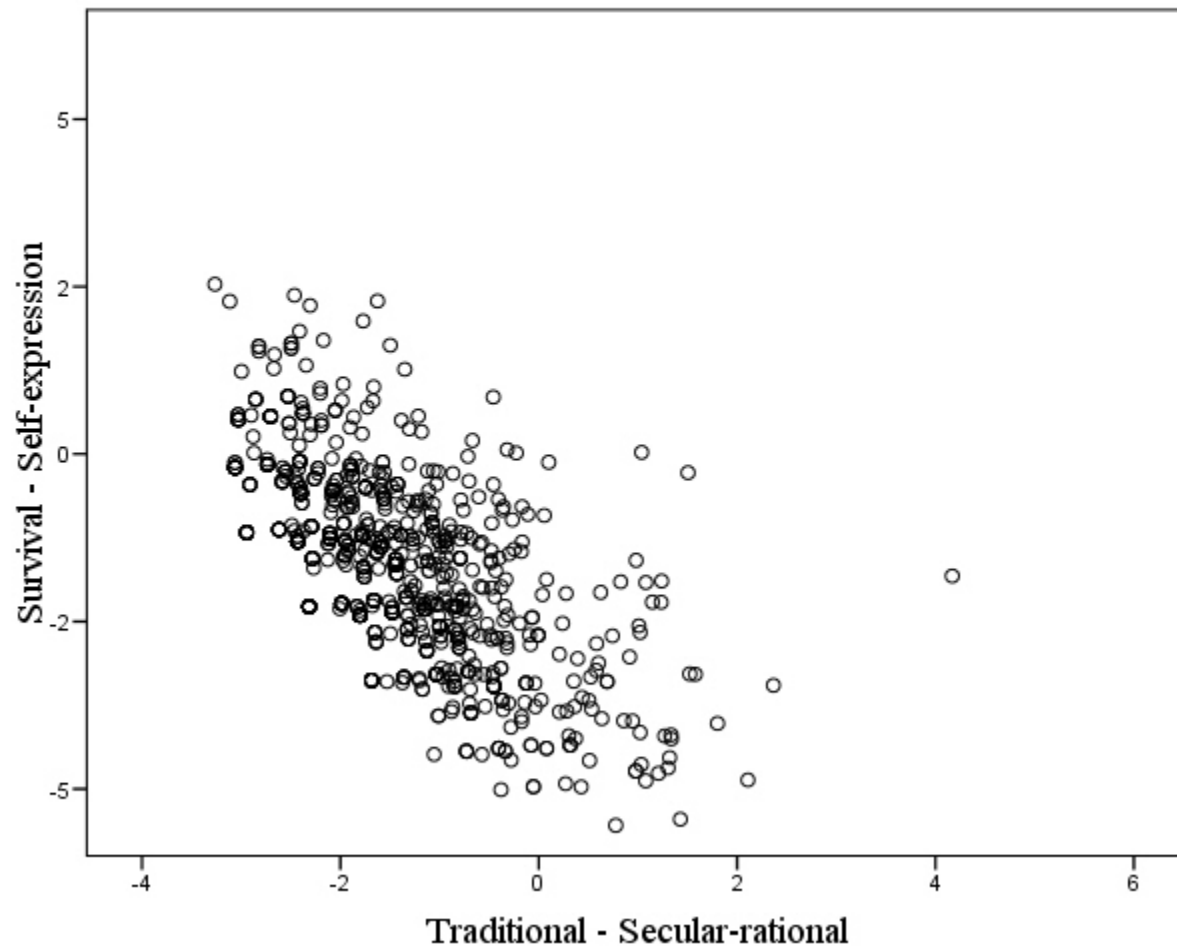




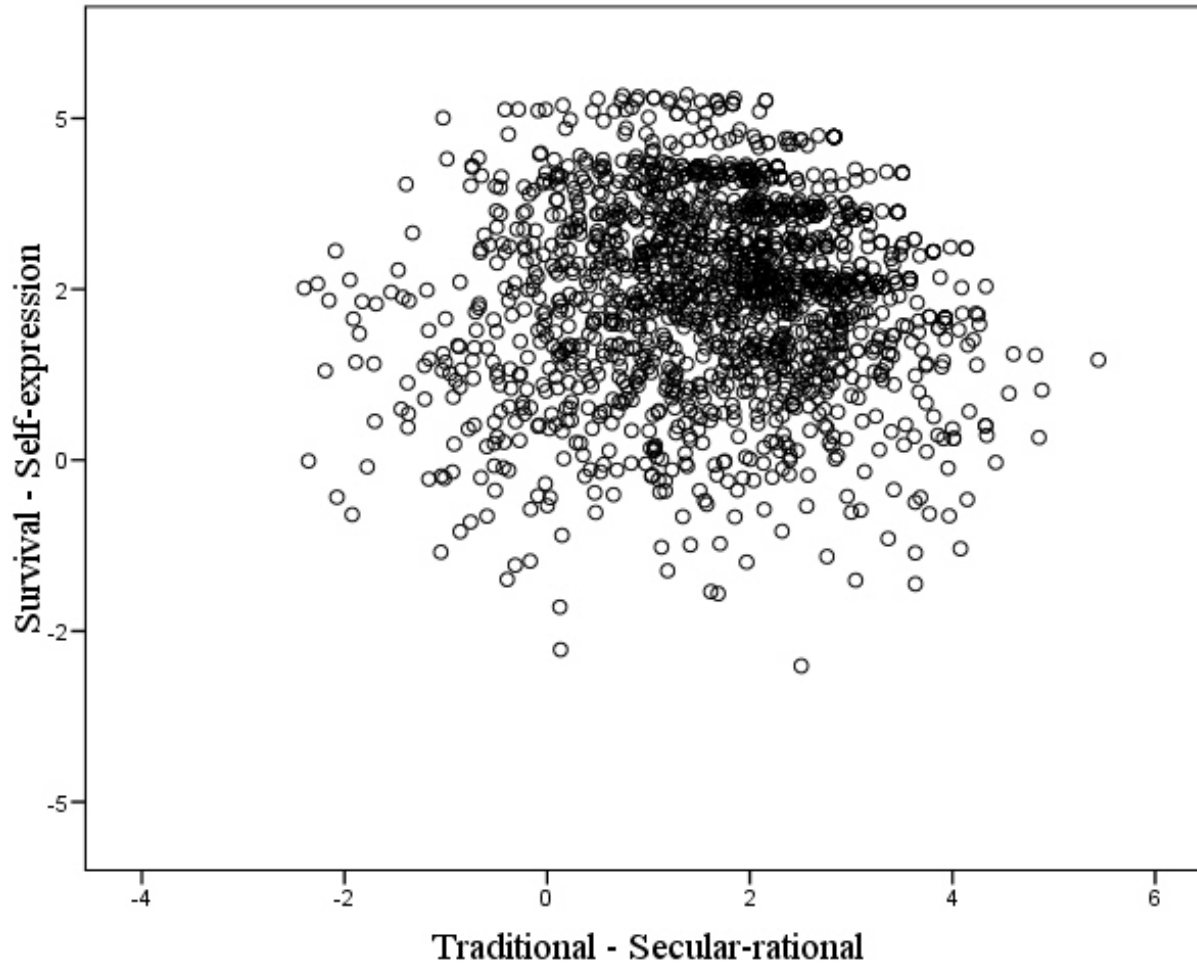
Identity and Cognitive Diversity



Zimbabwe



Sweden





THE GEOGRAPHY OF THOUGHT

Why We Think The Way We Do

RICHARD E. HERRITT PH.D.

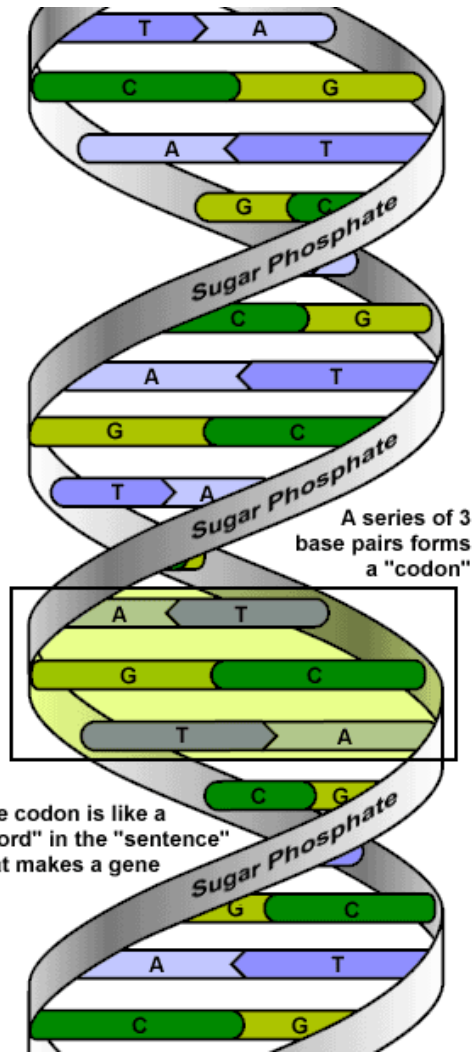
**WESTERNERS AND EAST ASIANS DESCRIBE
THIS SCENE IN DIFFERENT WAYS**

(SOURCE: THE UNIVERSITY OF MICHIGAN INSTITUTE FOR SOCIAL RESEARCH)

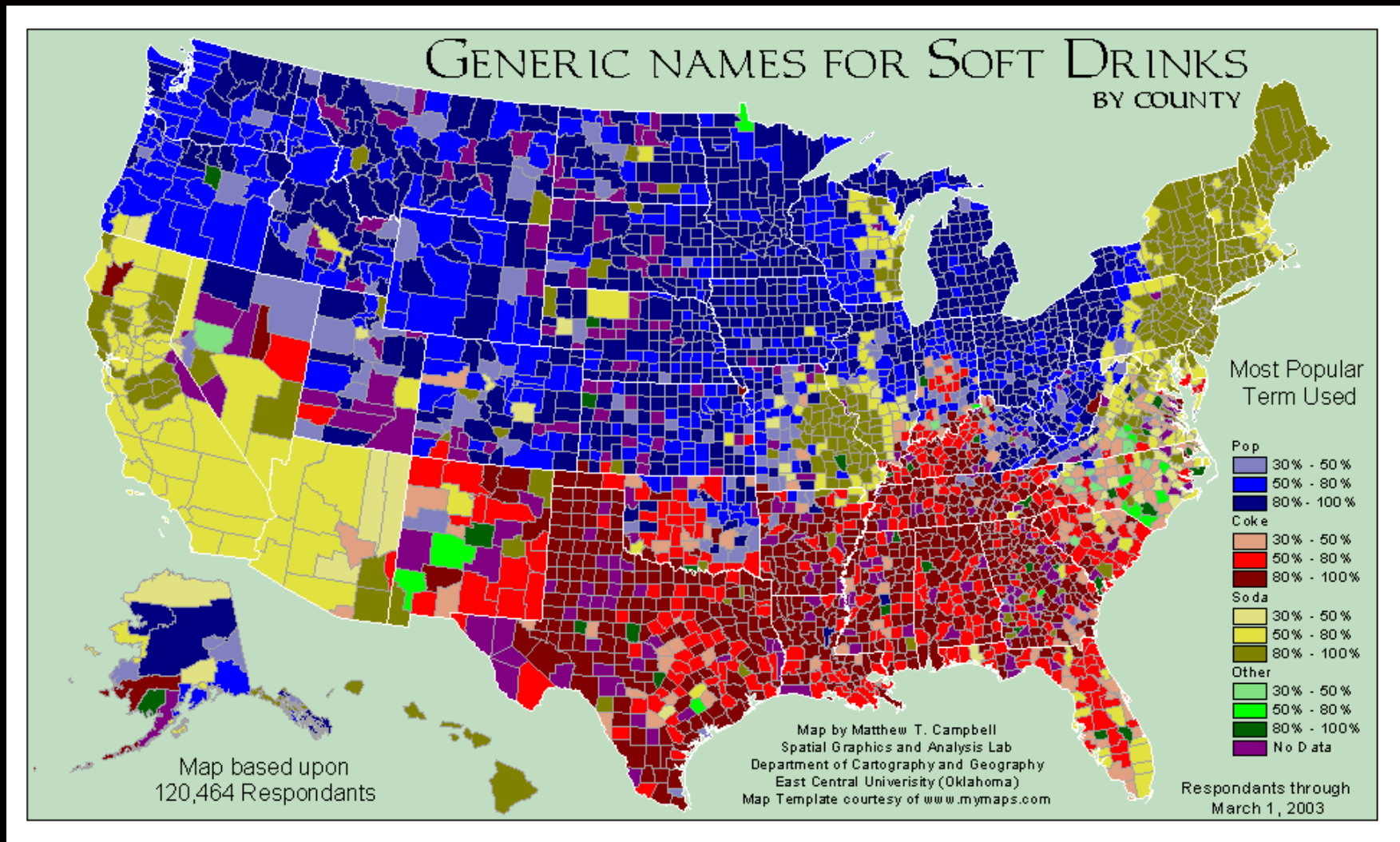


The Ketchup Question





Soda, Pop, or Coke By Region



Cultural Blinders



Poison Rats

Se pa manje rat

Pwazon Rat



\$ 5.00



Coumadin.

Prediction



X lb?

Stars and Planets (astrology)

Lightning

Rolling Dice

Smoke and Fire

Tarot Cards

Flight of Birds

Palm Reading

Methods of

Neighing of Horses

Crystal Balls

Divination

Tea Leaves and Coffee Grounds

Head Shape (Phrenology)

Passages of Sacred Texts

Atmospheric Conditions

Numbers

Dreams

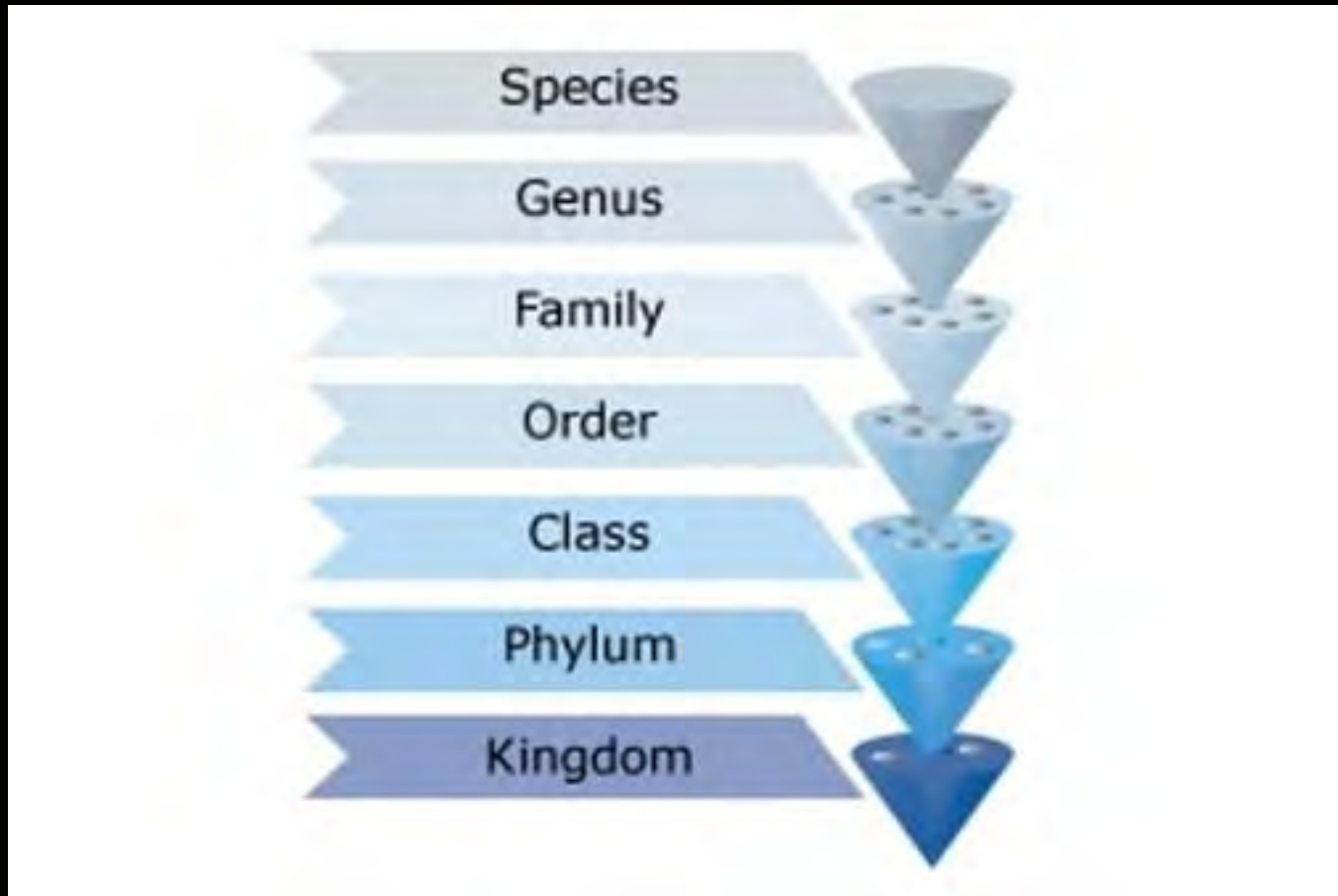
Guessing

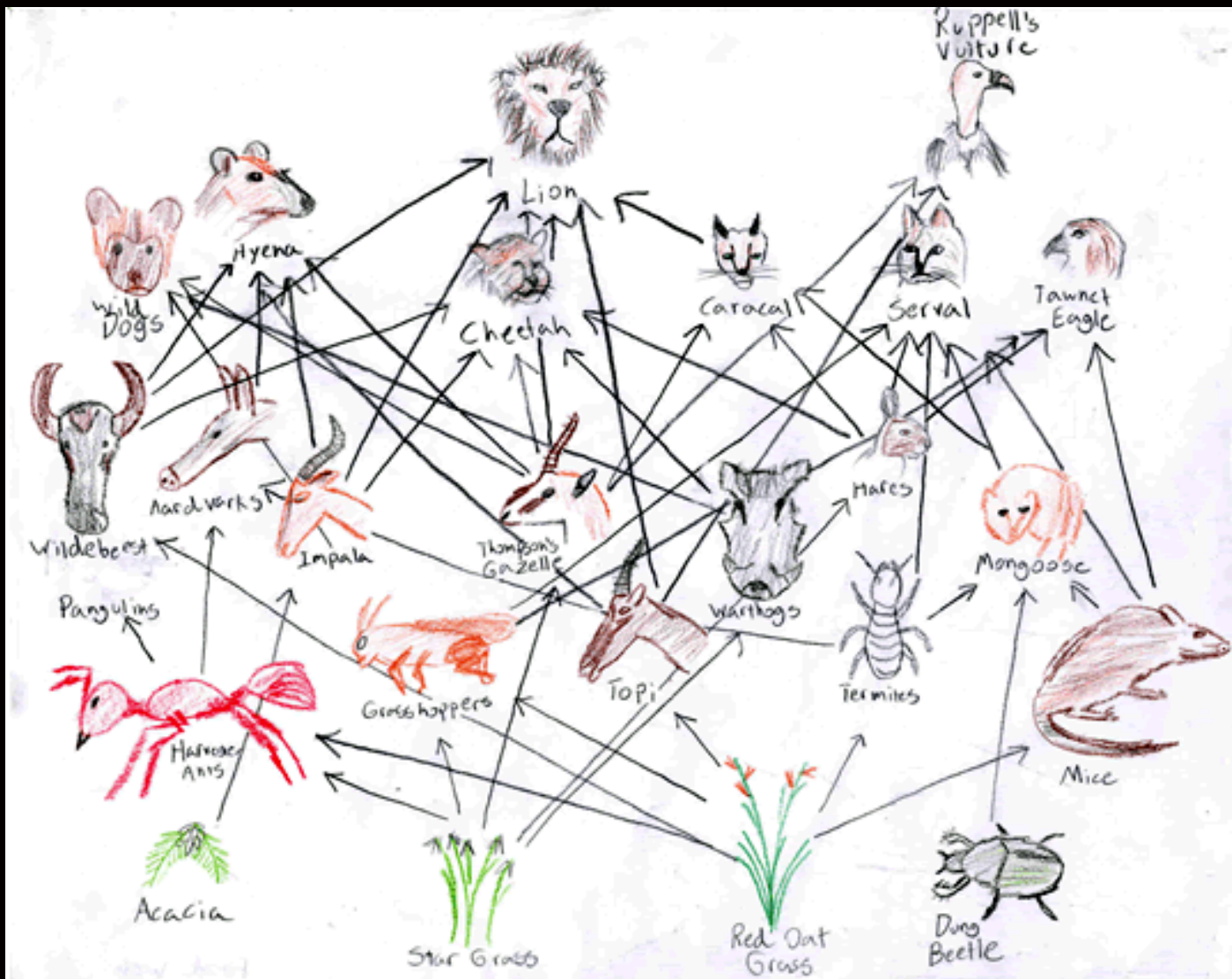
Animal Entrails

Model

Diverse Categorizations

Linnean Classification Sort





Source: www.promotega.org

Pile Sort



BOBO Sort



Airstream Sort

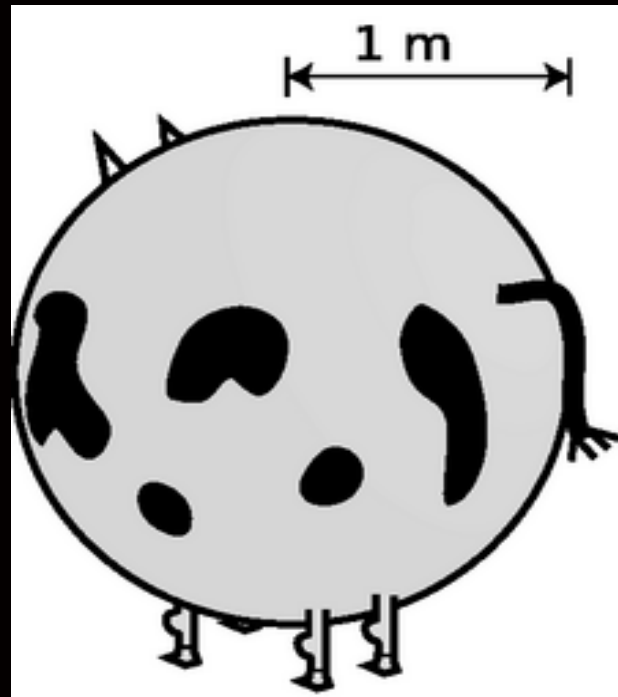


Diversity Prediction Theorem

Crowd Error = Average Error - Diversity

$$(c - \theta)^2 = \frac{1}{n} \sum_{i=1}^n (s_i - \theta)^2 - \frac{1}{n} \sum_{i=1}^n (s_i - c)^2$$

The Spherical Cow



The Gateway Cow



Galton's Steer

Crowd Error = Average Error - Diversity

$$0.6 = 2,956.0 - 2955.4$$



Case: Netflix Prize

Outline

Netflix Prize: Background

Predictive Models

Factor Models

Ensembles of Models

Ensembles of Teams

The Value of Diversity

Netflix Prize

November 2006, Netflix offers a prize of \$1 million to anyone who can defeat their Cinematch recommender system by 10% or more.

Some Details

Netflix users rank movies from 1 to 5



Six years of data

Half million users

17,700 movies

Data divided into (training, testing)

Testing Data dived into (probe, quiz, test)

Interesting Asides

Lost in Translation and *The Royal Tenenbaums* had the highest variance

Shawshank Redemption had the highest rating

Miss Congeniality had the most ratings.

Singular Value Decomposition

Each movie represented by a vector:

$$(p_1, p_2, p_3, p_4 \dots p_n)$$

Each person represented by a vector:

$$(q_1, q_2, q_3, q_4 \dots q_n)$$

$$\text{Rating: } r_{ij} = m_i + a_j + p \cdot q$$

Training: choose p, q to minimize

$$(\text{actual}_{ij} - r_{ij})^2 + c(\|p\|^2 + \|q\|^2)$$

BellKor's Initial Models

Approximately 50 dimensions, 107 Models

Best Model: 6.8% improvement

Combination of Models: 8.4% improvement

Why Do More Work Better?

$$\text{SqE}(c) = \text{SqE}(s) - \text{PDiv}(s)$$

$$(c - \theta)^2 = \frac{1}{n} \sum_{i=1}^n (s_i - \theta)^2 - \frac{1}{n} \sum_{i=1}^n (s_i - c)^2$$

BellKor's Pragmatic Chaos

More is Better: Seven person team

Functional Diversity: statisticians, machine learning experts and computer scientists

Identity Diversity: United States, Australia, Canada and Israel.

Difficult to build a “grand” model (800 variables) but possible to build lots of “huge” models

Ensemble Effects

Best Model 8.4%

Ensemble: 10.1%

Rules: Once someone breaks 10%, then the contest ends in 30 days.

Enter ``The Ensemble''

23 teams from 30 countries who blended their predictive models
who tried in the last moments to defeat BellKor's Pragmatic
Chaos

The Ensemble

“The contest was almost a race to agglomerate as many teams as possible,” said David Weiss, a Ph.D. candidate in computer science at the University of Pennsylvania and a member of the Ensemble.

“The surprise was that the collaborative approach works so well, that trying all the algorithms, coding them up and putting them together far exceeded our expectations.”

New York Times 6/27/09

And The Winner is...

RMSE for The Ensemble: 0.856714

RMSE for Bellkor's Pragmatic Chaos: 0.856704

By the rules of the competition the scores are rounded to four decimal places so it was a tie.

However, BellKor's Pragmatic Chaos submitted 20 minutes earlier so they won. (and they had the lower error)

Oh, by the way..

BellKor's Pragmatic Chaos 10.06%

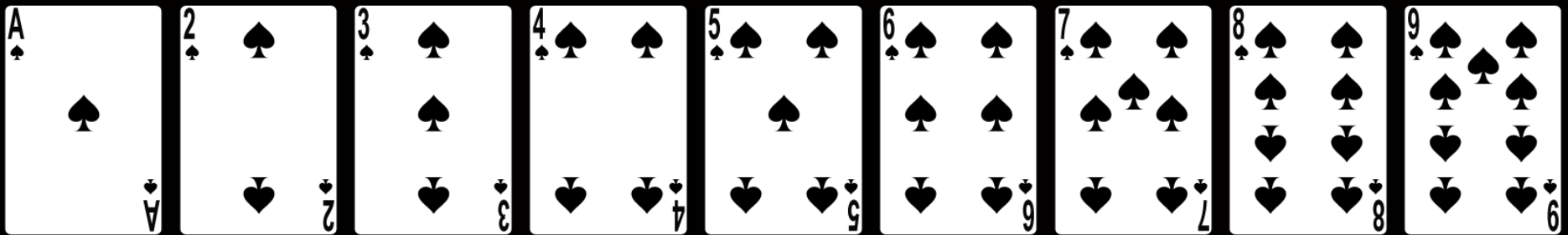
The Ensemble 10.06%

50/50 Blend 10.19%

Problem Solving

Diverse Perspectives

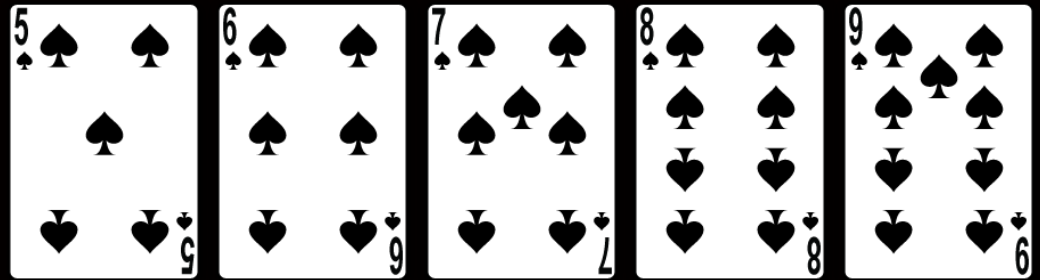
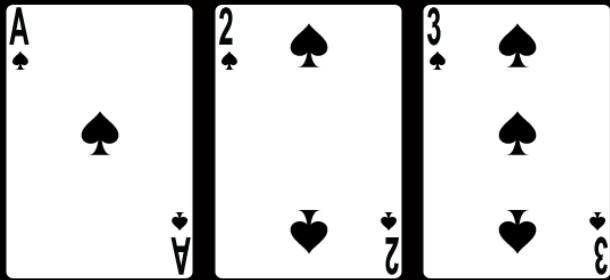
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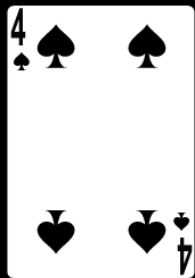
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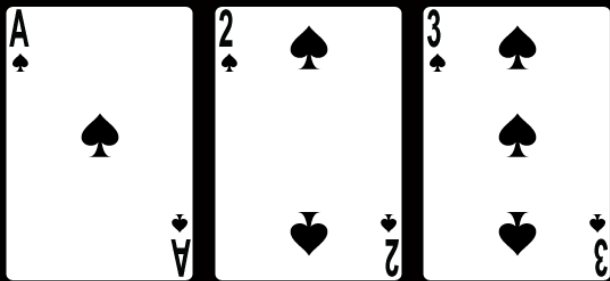


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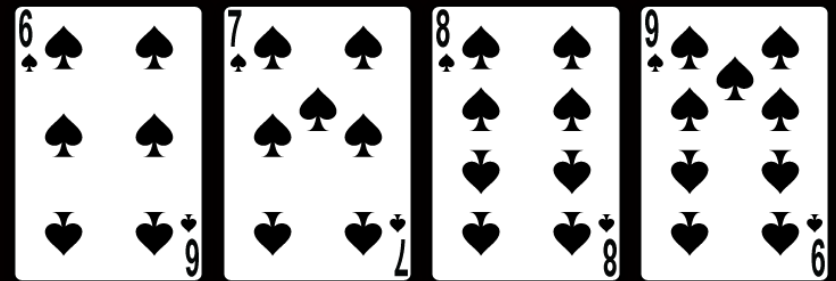
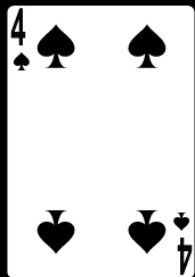
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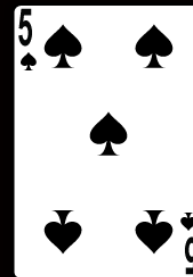
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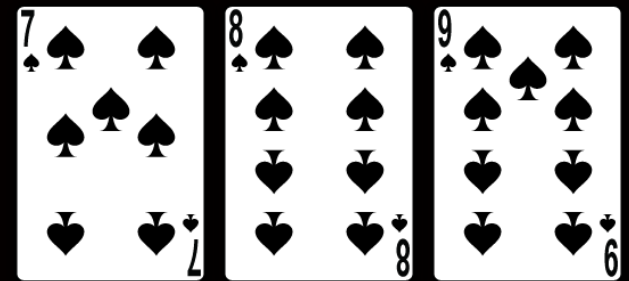
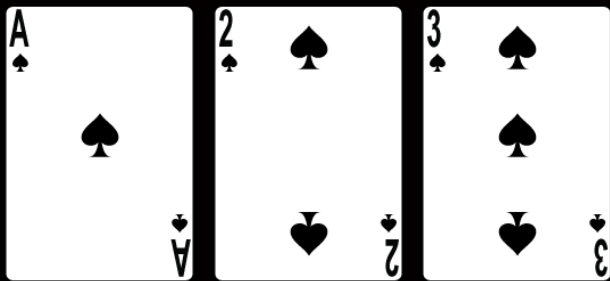
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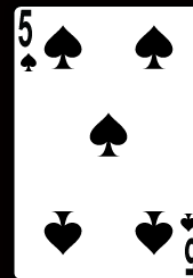
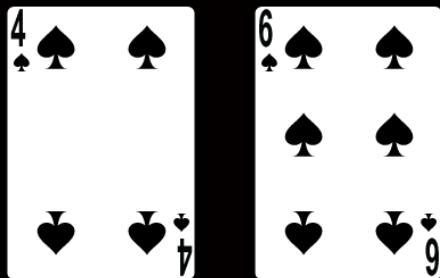


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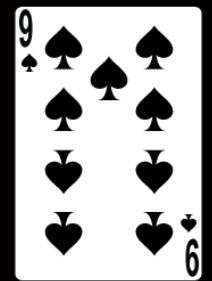
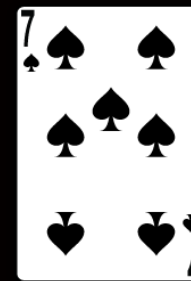
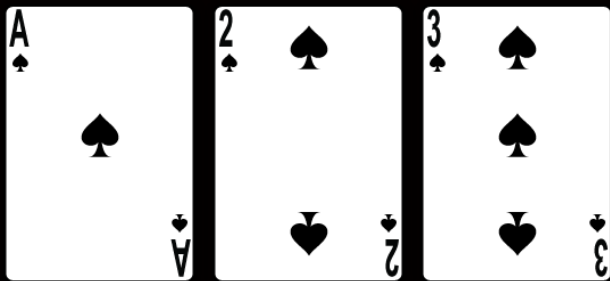


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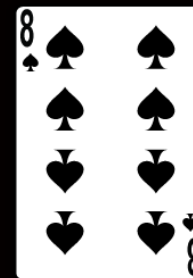
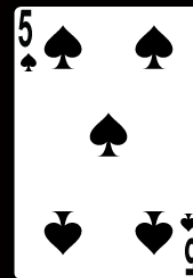
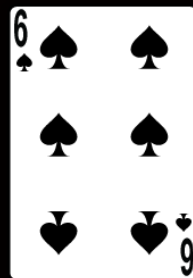
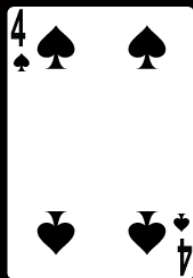


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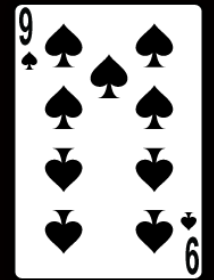
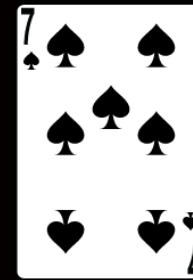
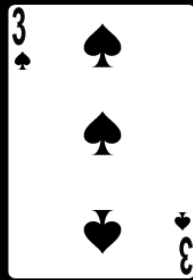


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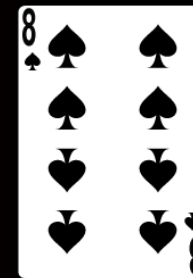
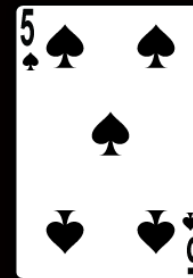
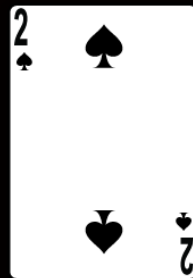
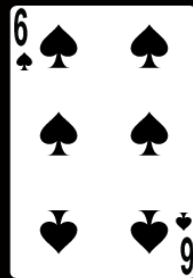
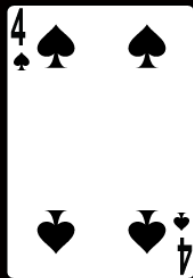


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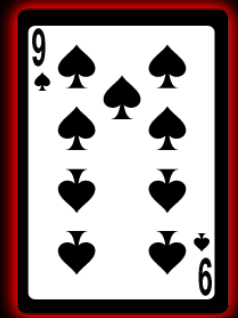
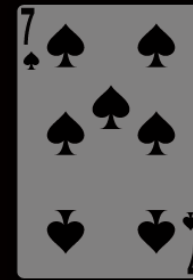
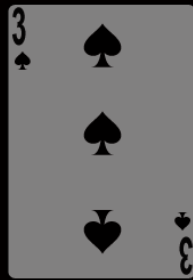
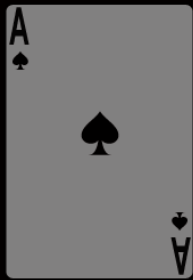


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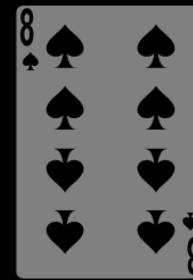
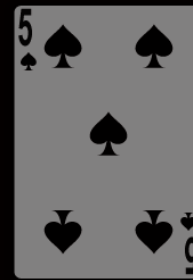
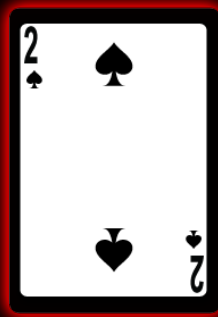
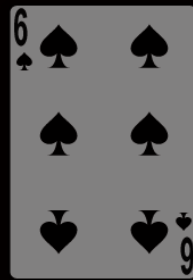
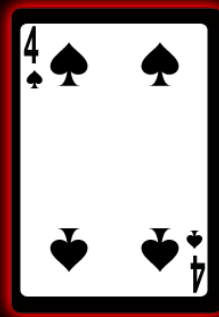


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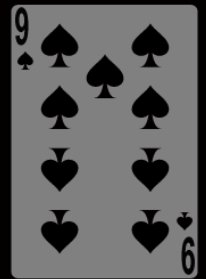
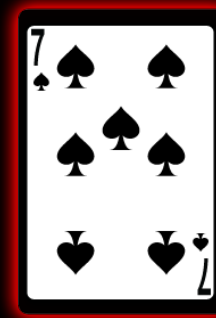
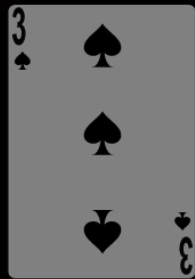


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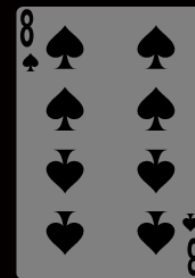
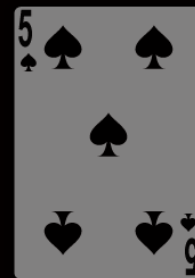
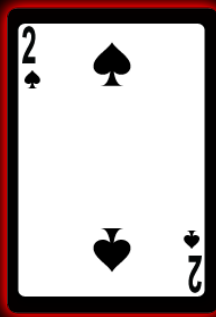
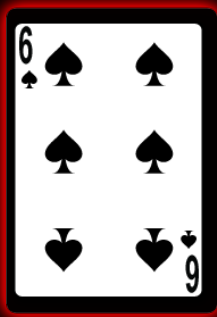
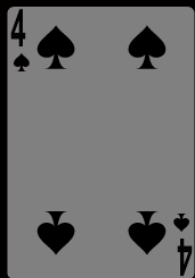


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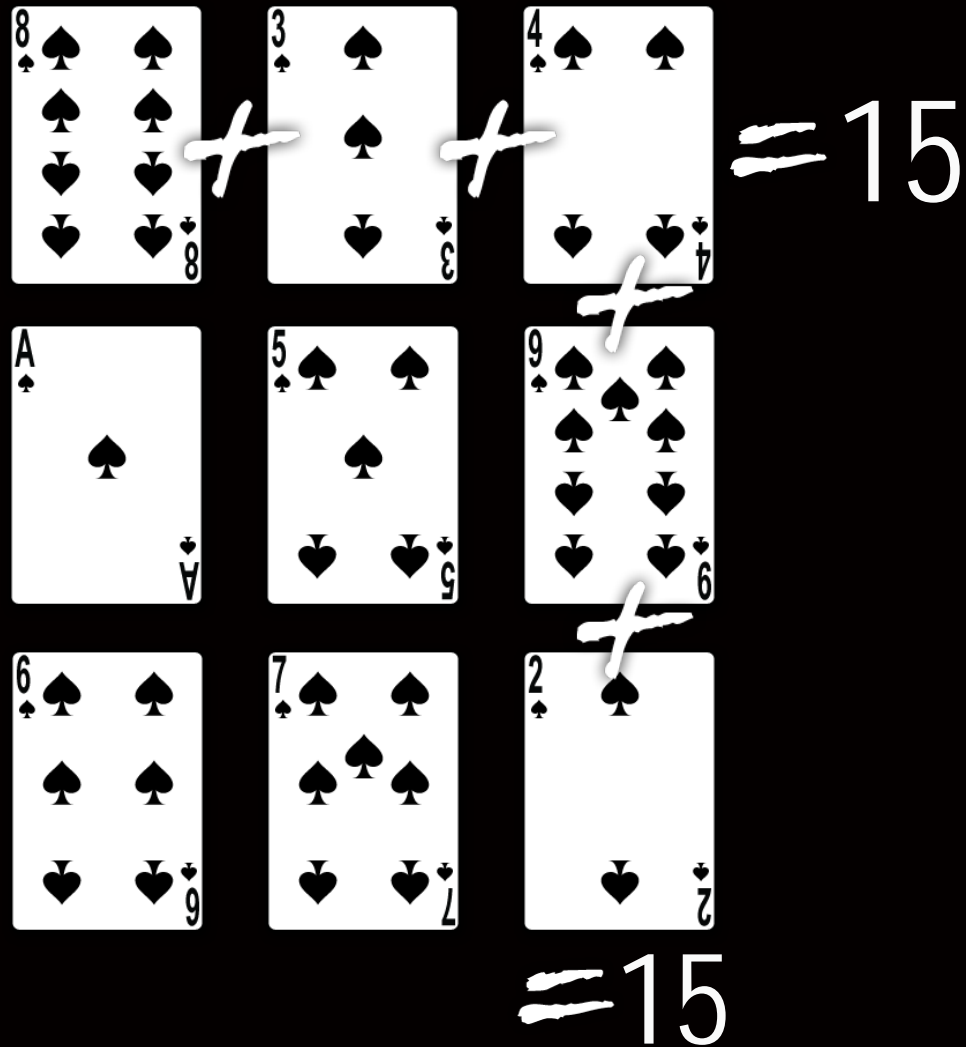


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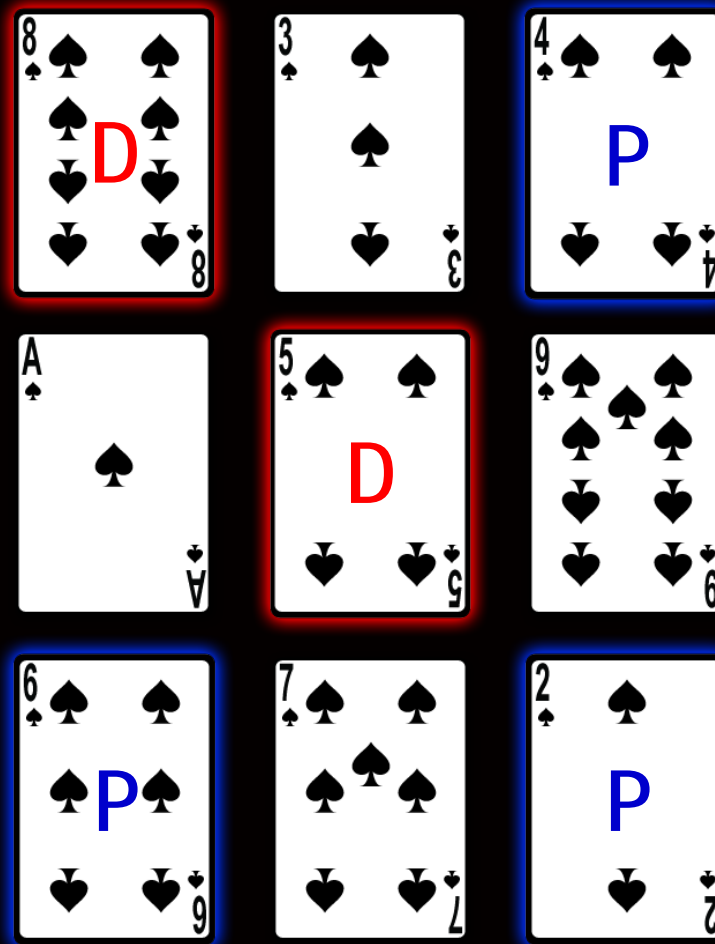
de Marchi



A Magic Square



Play it Again



Diverse Cognitive Models/Heuristics

A Test

- Create a bunch of agents with diverse perspectives and heuristics
- Rank them by their performance on a problem.
- Note: all of the agents must be “smart”

Experiment

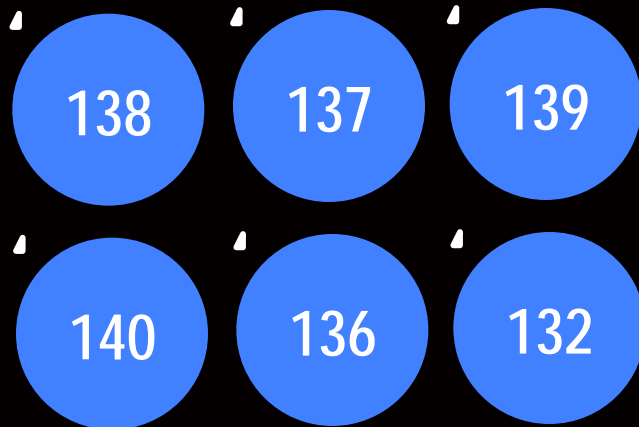
Group 1: Best 20 agents

Group 2: Random 20 agents

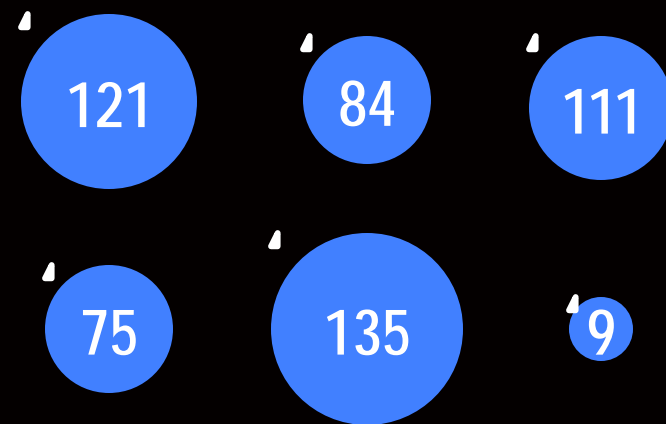
Have each group work collectively - when one agent gets stuck at a point, another agent tries to find a further improvement. Group stops when no one can find a better solution.

The IQ View

Alpha Group



Diverse Group



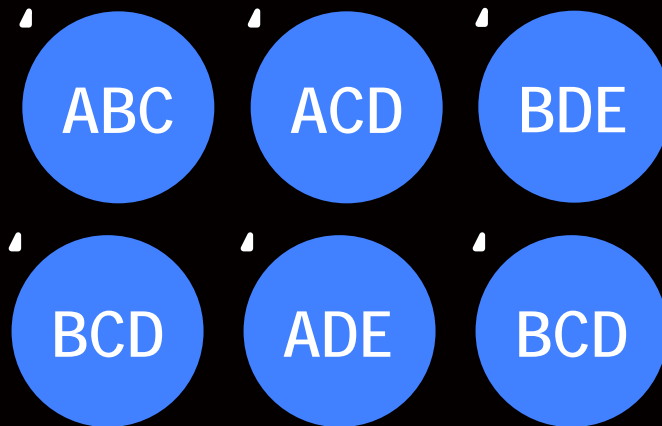
The diverse group almost always outperforms
the group of the best by a substantial margin.

See Lu Hong and Scott Page

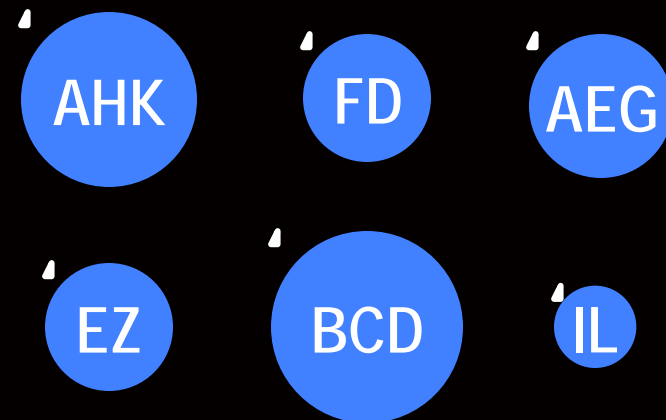
Proceedings of the National Academy of Sciences (2002)

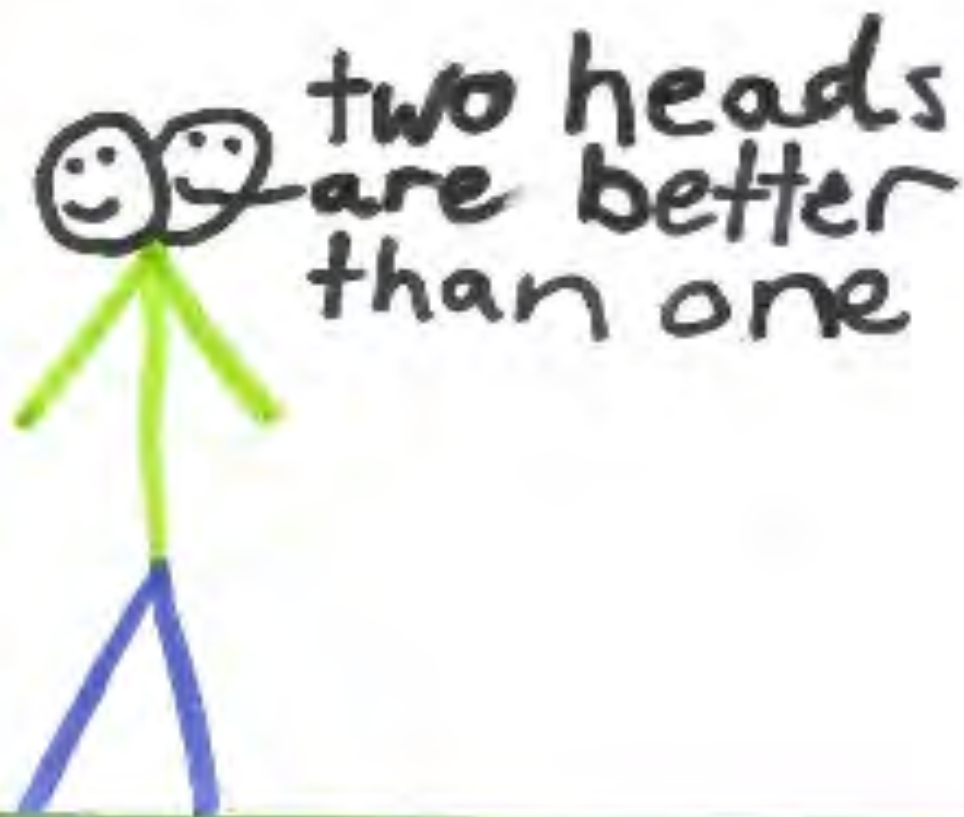
The Toolbox View

Alpha Group



Diverse Group





two heads
are better
than one



What Must be True?

Calculus Condition: *Problem solvers must all be smart-
-we must be able to list their local optima*

Diversity Condition: *Problem solvers must have
diverse heuristics and perspectives*

Hard Problem Condition: *Problem itself must be difficult*

Realizing Diversity's Benefits

Eureka!

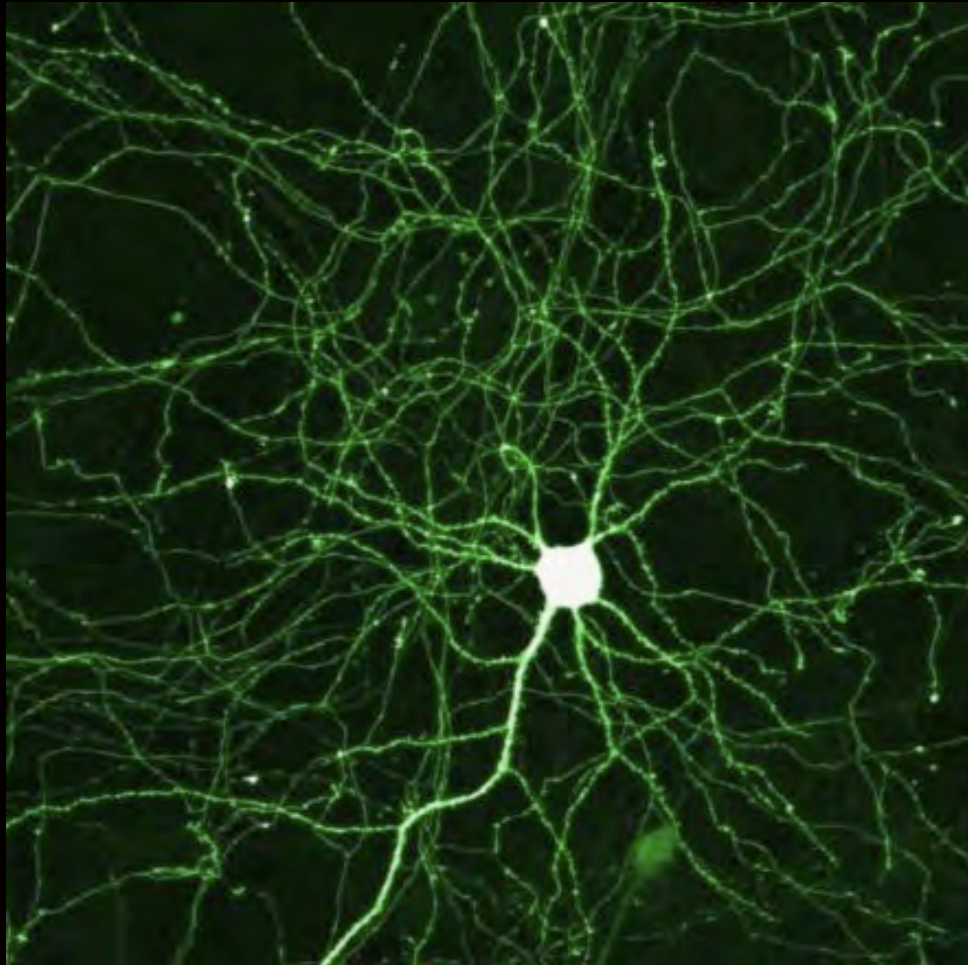


Out of the Bathtub and In the Group



Kevin Dunbar

GRE:???

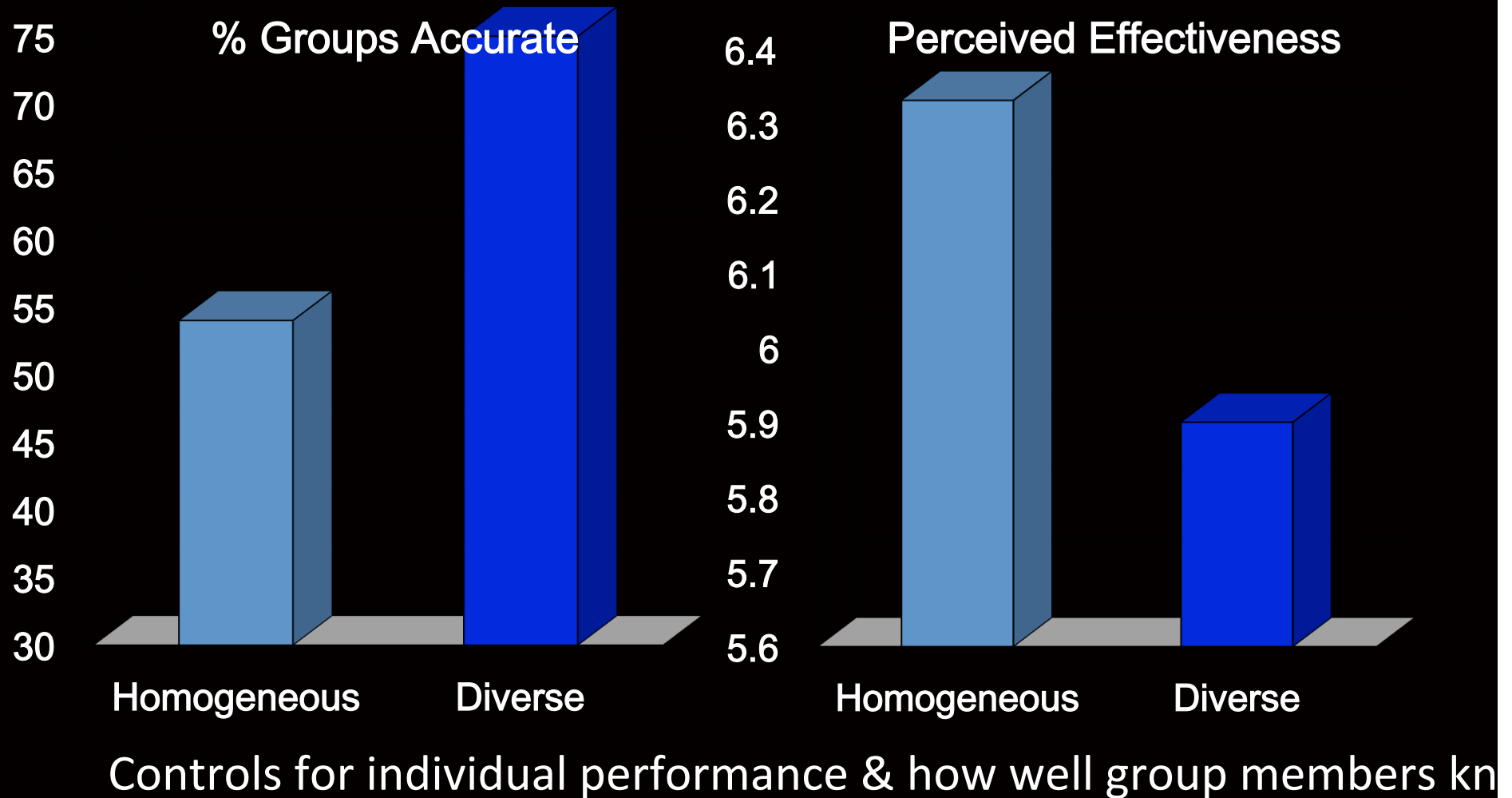




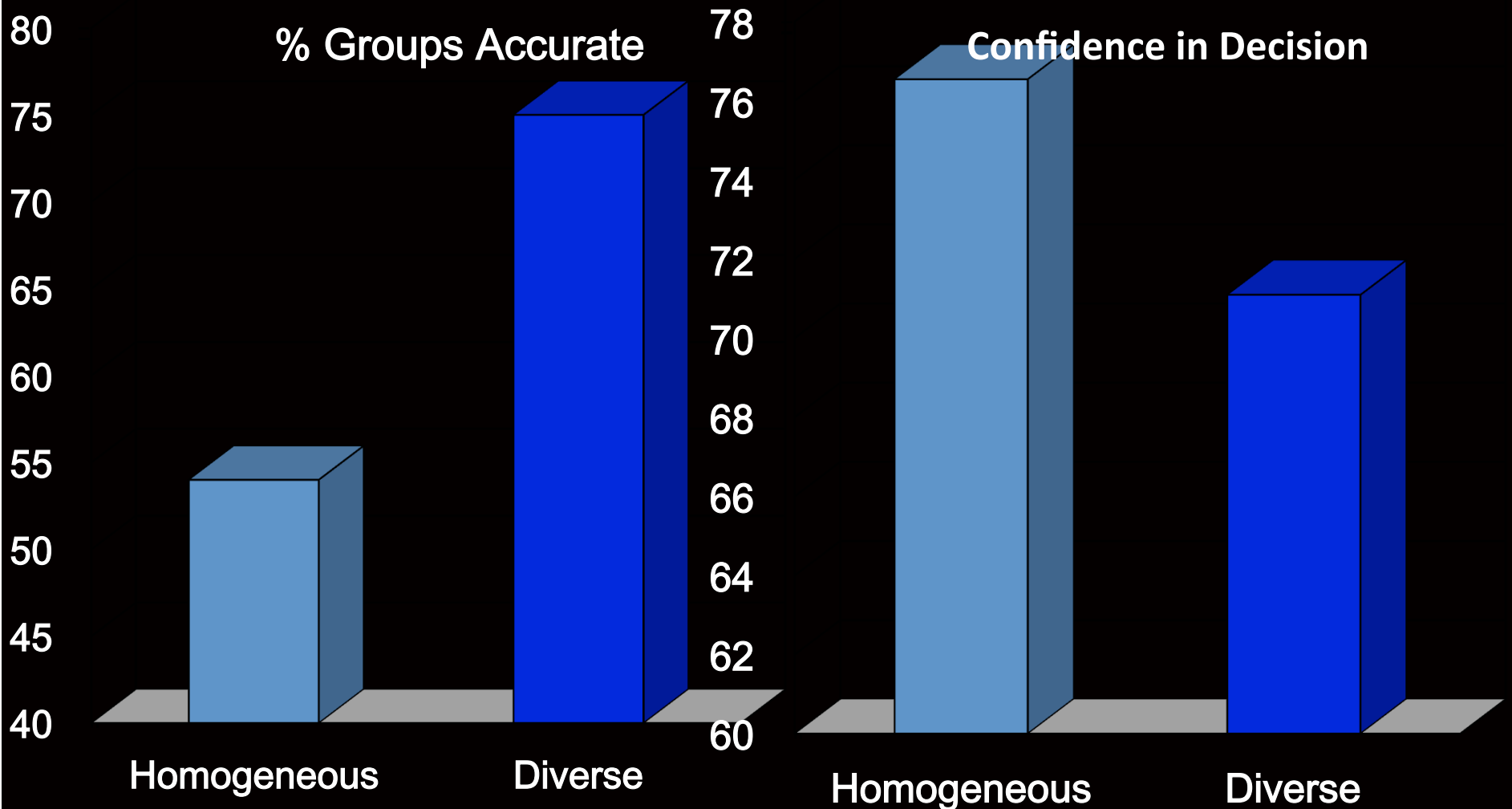
DEPARTMENT OF
SOCIOLOGY

Group Accuracy & Perceived Effectiveness

Phillips, Liljenquist, & Neale, 2009



Group Objective Accuracy vs Confidence in Decision



The Prepared Mind



The Prepared Mind Community

