AI in Context: From Human to Machine Intelligence

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Fall 2025 - Lecture 1 of 4

Course Introduction

Module goals

- Historical context/understanding of intelligence (human/AI)
- Modern goals/definition/evaluation of artificial intelligence
- Critical examination of dynamics of "define and design"
- Implications for society and technology

Core Questions

1. What does it mean to define (and measure) "intelligence"?
2. How do historical patterns repeat in modern AI evaluation?
3. What are the ethical implications of reducing complex capabilities to numbers?
4. Is defining + designing intelligence what we *should* be doing?

Today's Agenda

- Module overview and lecture series structure
- Course philosophy and responsibilities
- Instructor background
- The power of names in AI
- (Why history matters for understanding present)
- History: The measurement of intelligence: Spearman to benchmarks
- Critical perspectives and the path forward
- Hands-on notebook exploration

Intelligence module: Overview (1)

Lecture 1: The Birth of Quantifying Intelligence (Today!)

- Spearman's g-factor (1904) and its legacy
- PCA and dimensionality reduction
- AI benchmarks and leaderboard culture
- Critical analysis of quantification

Intelligence module: Overview (2)

Lecture 2: AI as How We Think We Think (1900s-1950s)

- Cognitive revolution: behaviorism to computation
- Turing's imitation game
- Cybernetics and feedback loops
- Early neural networks

Intelligence module: Overview (3)

Lecture 3: AI 1.0 - The Era of Rules (1960s-1980s)

- Expert systems and knowledge encoding
- Logic and reasoning (GOFAI)
- The AI winters
- Knowledge representation

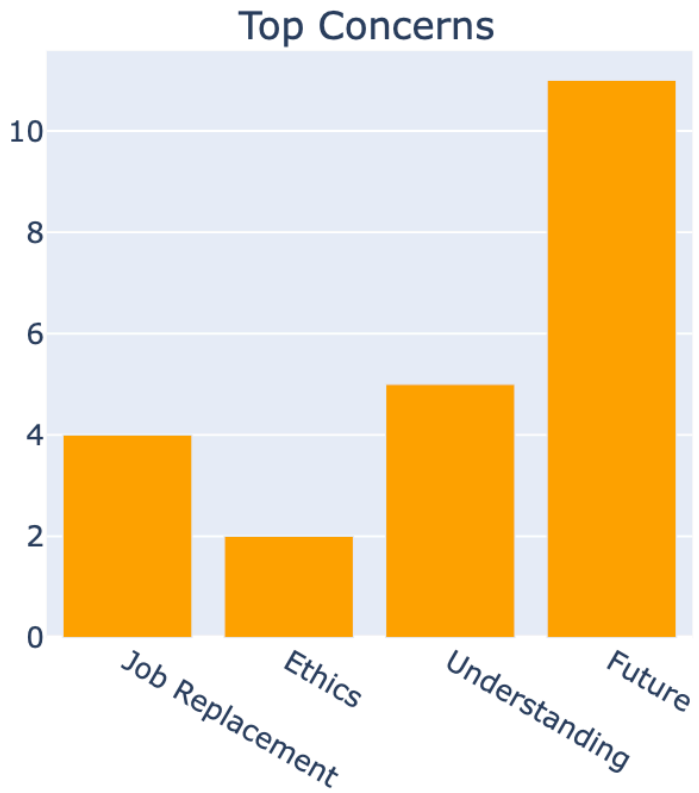
Intelligence module: Overview (4)

Lecture 4: AI 2.0 - The Data Revolution (1990s-2025)

- Statistical turn: from rules to patterns
- Deep learning revolution
- Large language models
- Future directions: AGI and alignment

Background & Perspective

What You Want to Learn



Background & Perspective

What You Want to Learn

Based on pre-course surveys:

- Understanding AI capabilities and limitations
- Historical context for current developments
- Hands-on experience with AI tools
- Critical thinking about societal impact

Instructor Background

Education & Experience

- Applied mathematics PhD (machine learning focus)
- 20+ years in data science and AI research
- Chief Data Scientist industry experience

Example works

- *How Data Happened* (2023): Technical + social history (cf. Ch 4 on Intelligence)
- *Data Science in Context* (2021): Foundations + opportunities
- Papers on ML fairness, interpretability, applications

Principle 1: Kranzberg's First Law (1985):

> *"Technology is neither good nor bad; nor is it neutral... The same technology can have quite different results when introduced into different contexts or under different circumstances."*

Key Insight: AI's impact depends on:

- Who builds it
- Who uses it
- What problems it addresses
- Which values it embodies

Principle 2: Capabilities have politics

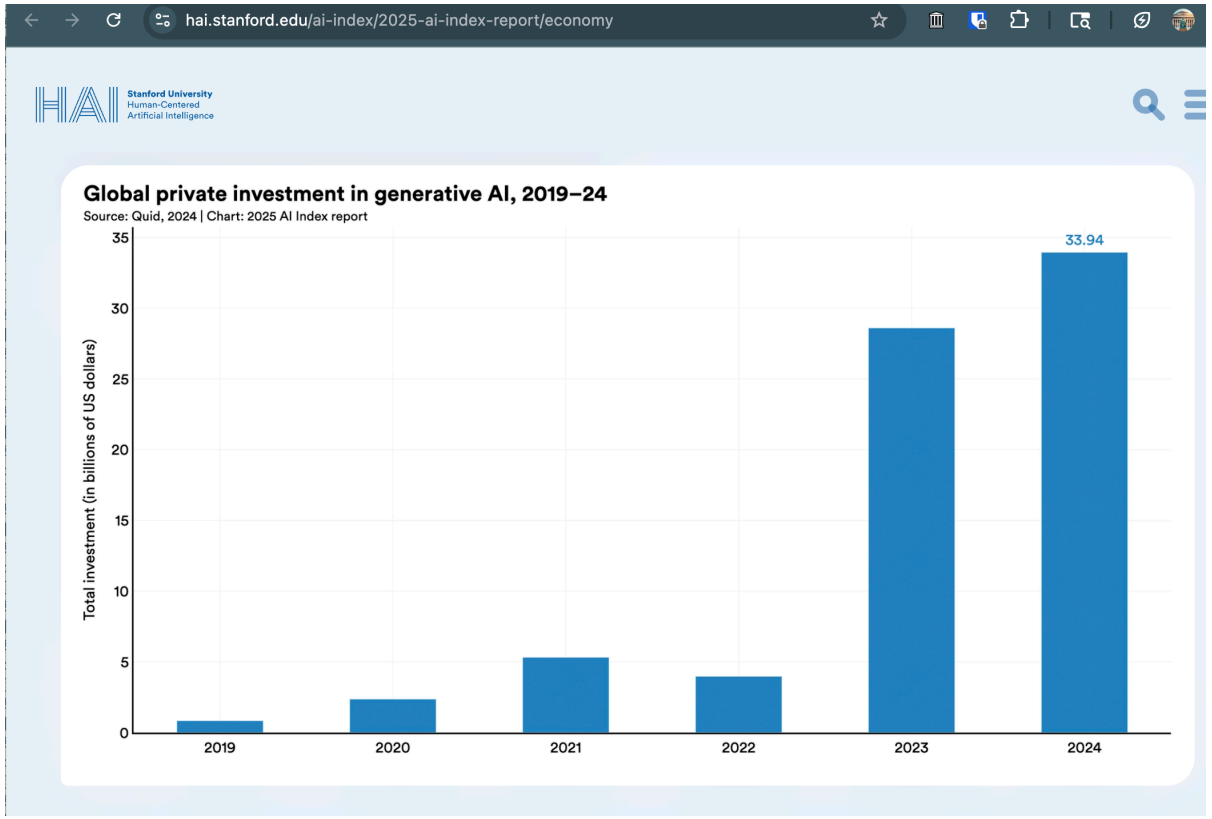
Phillip Rogaway (2015):

> *"Cryptography rearranges power: it configures who can do what, from what. This makes cryptography an inherently political tool, and it confers on the field an intrinsically moral dimension."*

Replace "cryptography" with "AI" — the statement remains true.

What we talk about when we talk about AI...

...and how did we get here?



McCarthy's Coinage (1955)

AI, definition (70 yrs ago):

> *"Every aspect of learning or intelligence can be precisely described so a machine can simulate it."*
>
> *— Dartmouth Conference Proposal on AI*

An aspiration, not a method (ch 7, HDH)

1. “Automatic Computers” (programming languages)
2. “How Can a Computer be Programmed to Use a Language” (natural language processing)
3. “Neuron Nets” (neural nets and deep learning)
4. “Theory of the Size of a Calculation” (computational complexity)
5. “Self-improvement” (machine learning)
6. “Abstractions” (feature engineering)
7. “Randomness and Creativity” (Monte Carlo methods including stochastic learning).

The term “artificial intelligence,” in 1955, was an aspiration rather than a commitment to one method. AI, in this broad

AI...found a way (diverging methods)

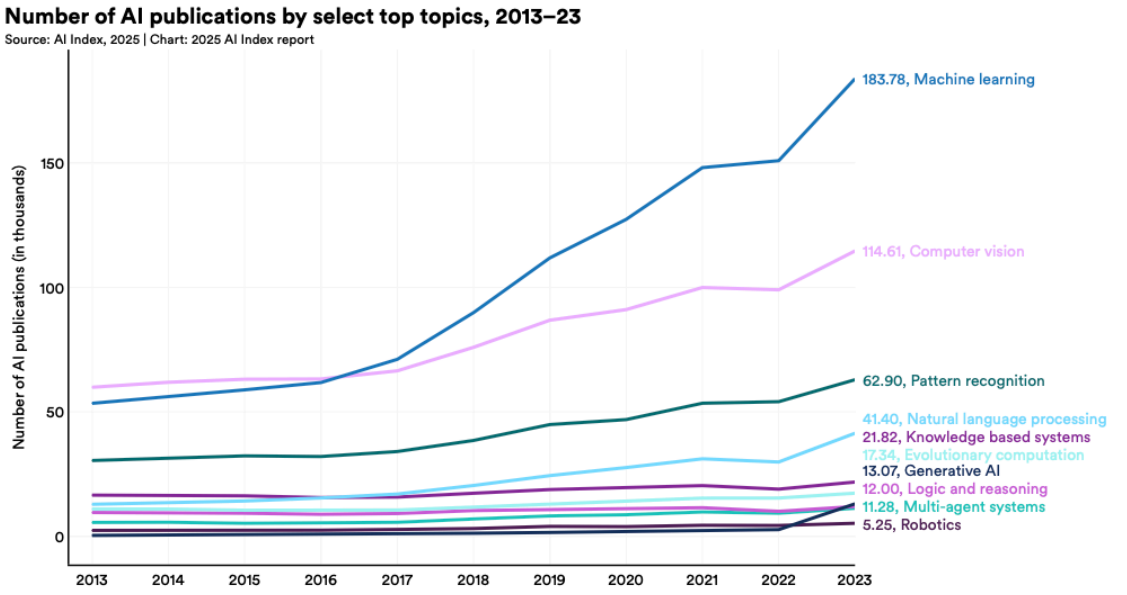


Figure 1.1.10[3]

JCM and the 1955 Coining of AI

Later Admission:

> *"I invented the term artificial intelligence because... we were trying to get money for a summer study."*
>
> *— John McCarthy, Lighthill Debate (1973)*

Q1/post-1955: Why "AI" Succeeded

The term succeeded because it:

- **Captured imagination**
- **Secured funding**
- **Set expectations**
- **Created identity**
  - for field
  - esp. among Homo Sapiens
  - JCM reflected on this definition in 2007

Alternative Histories

What if we'd chosen different terms?

- "Augmented Reasoning"
- "Computational Cognition"
- "Synthetic Problem-Solving"
- "Machine Understanding"

Would the field have developed differently?

Q2/pre-1955: What did "intelligence" even mean to JCM et al?

> *"Every aspect of learning or intelligence can be precisely described so a machine can simulate it."*

To answer *that* we will use history...

Why History Matters

Pattern Recognition

1. Common Patterns

- Hype cycles repeat (1960s, 1980s, 2010s, 2020s)
- Technical barriers recur (data, compute, algorithms)
- Social concerns persist (jobs, bias, control)

Making the Present Strange

2. Alternative Perspectives

- Current approaches aren't inevitable
- Alternative paths were/are possible
- Today's "obvious" was yesterday's "impossible"

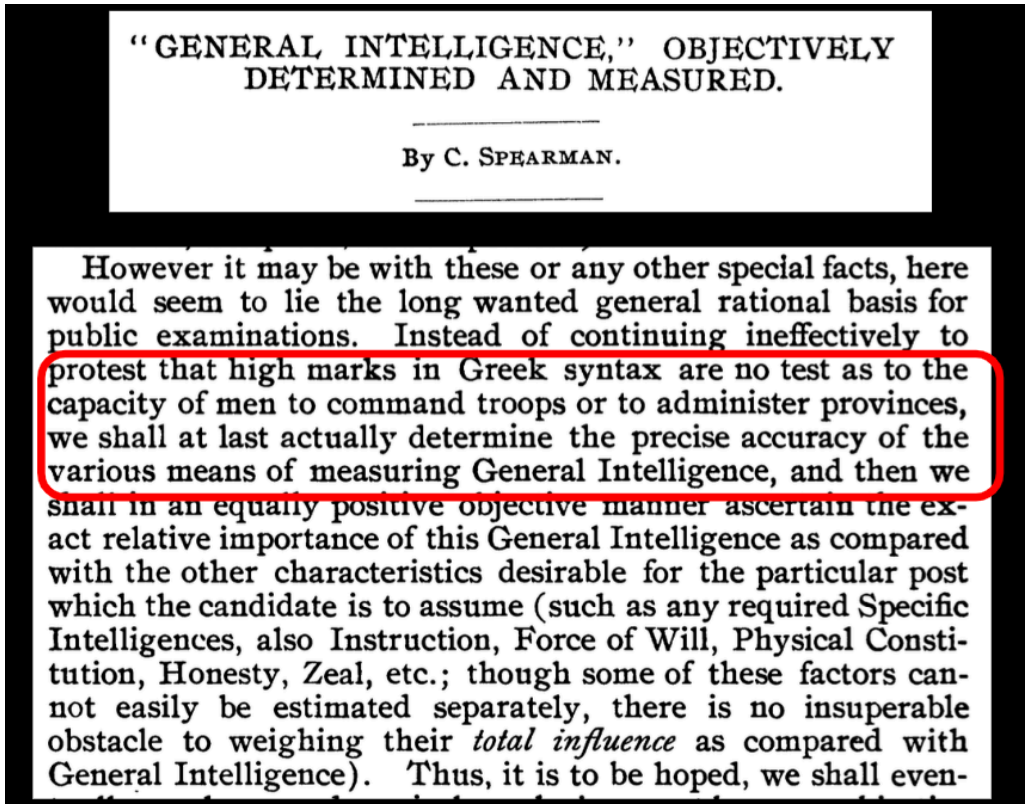
Disrupting Determinism

3. Agency and Choice

- Technology doesn't develop in straight lines
- Social choices shape technical directions
- Multiple futures remain possible

The Measurement of Intelligence

Spearman's Revolution (1904)



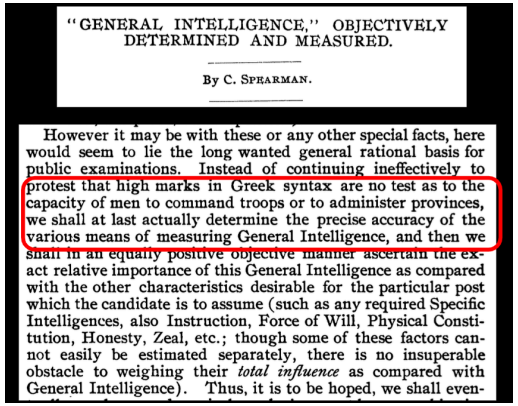
"GENERAL INTELLIGENCE," OBJECTIVELY DETERMINED AND MEASURED.

By C. SPEARMAN.

However it may be with these or any other special facts, here would seem to lie the long wanted general rational basis for public examinations. Instead of continuing ineffectively to protest that high marks in Greek syntax are no test as to the capacity of men to command troops or to administer provinces, we shall at last actually determine the precise accuracy of the various means of measuring General Intelligence, and then we shall in an equally positive objective manner ascertain the exact relative importance of this General Intelligence as compared with the other characteristics desirable for the particular post which the candidate is to assume (such as any required Specific Intelligences, also Instruction, Force of Will, Physical Constitution, Honesty, Zeal, etc.; though some of these factors cannot easily be estimated separately, there is no insuperable obstacle to weighing their *total influence* as compared with General Intelligence). Thus, it is to be hoped, we shall even-

The Measurement of Intelligence

Spearman's Revolution (1904)



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"'General Intelligence,' **Objectively** Determined and Measured"

- Published in American Journal of Psychology
- Introduced the **g-factor** concept
- Novel statistical techniques (factor analysis)
- Claimed "objective" measurement

From many grades, 1 number

High Class Preparatory School for Boys.

A. Original Data.

Age.		Discriminative Threshold.			Place in School (*before modification to eliminate Age*).			
		Pitch From Ex.Ser. IV.	Light 1:200	Weight 1:200	Classics	French	English	Mathem.
10	9	50	10	4	16	19	10	7
12	4	3	10	6	5	6	6	5
11	1	10	10	9	13	11	11	13
10	11	> 60	10	9	22	23	22	22
13	7	4	12	5	1	1	1	2
12	6	2	10	10	4	2	2	1
10	4	4	10	11	12	14	13	18
9	5	20	10	11	23	22	23	23
12	0	11	10	12	8	8	15	15
10	2	11	12	11	3	5	4	4
11	2	24	14	10	7	7	7	6

From many "attributes", 1 number

Village School, 24 Oldest Children.

A. Original Data.

Sex.	Age.		Discriminative Threshold.			Intellectual Rank.		
			Pitch	Light	Weight	Common Sense out of School.		Cleverness in School.
	Years	Months	1/3 v. d.	1:200	1:200	(A)	(B)	
f	11	6	8	4	4	6	5	2
m	12	11	15	3	4	11	7	22
f	12	8	14	6	4	16	10	7
f	13	8	13	4	9	1	1	1
m	11	4	5	14	7	3	2	3
f	11	11	25	7	4	10	14	9
f	11	3	10	19	8	8	19	12
f	13	1	10	12	10	2	4	6
m	12	5	18	11	9	5	6	11
m	12	7	14	30	7	21	22	19
f	12	8	60	3	10	12	9	4

Spearman's Core Ideas

Four Key Insights

1. **Low-D Manifold**: Cognitive tasks correlate
2. **Hidden Factor**: Single underlying intelligence
3. **Mathematical Extraction**: Statistics reveal factors
4. **Practical Application**: Objective rankings

The Statistical Innovation

Spearman's Process:

```
Many test scores → Correlation matrix →
Factor analysis → Single g-factor
```

Spearman's findings

Activity.	Correlation with Gen. Intell.	Ratio of the common factor to the specific factor.
Classics,	0.99	99 to 1
Common Sense,	0.98	96 4
Pitch Dis.,	0.94	89 11
French,	0.92	84 16
Cleverness,[3]	0.90	81 19
English,	0.90	81 19
Mathematics,[4]	0.86	74 26
Pitch Dis. among the uncultured,[5]	0.72	52 48
Music,	0.70	49 51
Light Dis.,[5]	0.57	32 68
Weight Dis.,[5]	0.44	19 81

Spearman's findings

> *“In the above Hierarchy one of the most noticeable features*
> *is the high position of languages; to myself, at any rate,*
> *it was no small surprise to find Classics and even French*
> *placed unequivocally above English.”*

Spearman's findings

> *"Instead of continuing ineffectively to protest that high marks in Greek syntax are no test as to the capacity of men to command troops or to administer provinces, we shall at last actually determine the precise accuracy of the various means of measuring General Intelligence, and then we shall in an equally positive objective manner ascertain the exact relative importance of this General Intelligence as compared with the other character" (1904, p. 277).*

- how does this rearrange power?

Spearman's findings

> *Conclusion. On the whole, then, we reach the profoundly important conclusion that there really exists a something that we may provisionally term "General Sensory Discrimination" and similarly a "general Intelligence," and further the functional correspondence between these two is not appreciably less than absolute.*

- how does this rearrange power?

Hands-On: Notebook Exploration

Today's Interactive Notebook

What You'll Explore:

- 2D/3D PCA visualizations with real data
- Synthetic experiments showing dimensionality reduction
- Student grade analysis revealing hidden patterns
- AI benchmark evolution over time

Link: Colab Notebook

Modern Equivalent (PCA)

PCT today..

```
High-dimensional data → Covariance matrix →
Eigendecomposition → Principal components
```

Same mathematical intuition, 120 years apart!

Post-Spearman, pre-JCM Intelligence: "IQ"

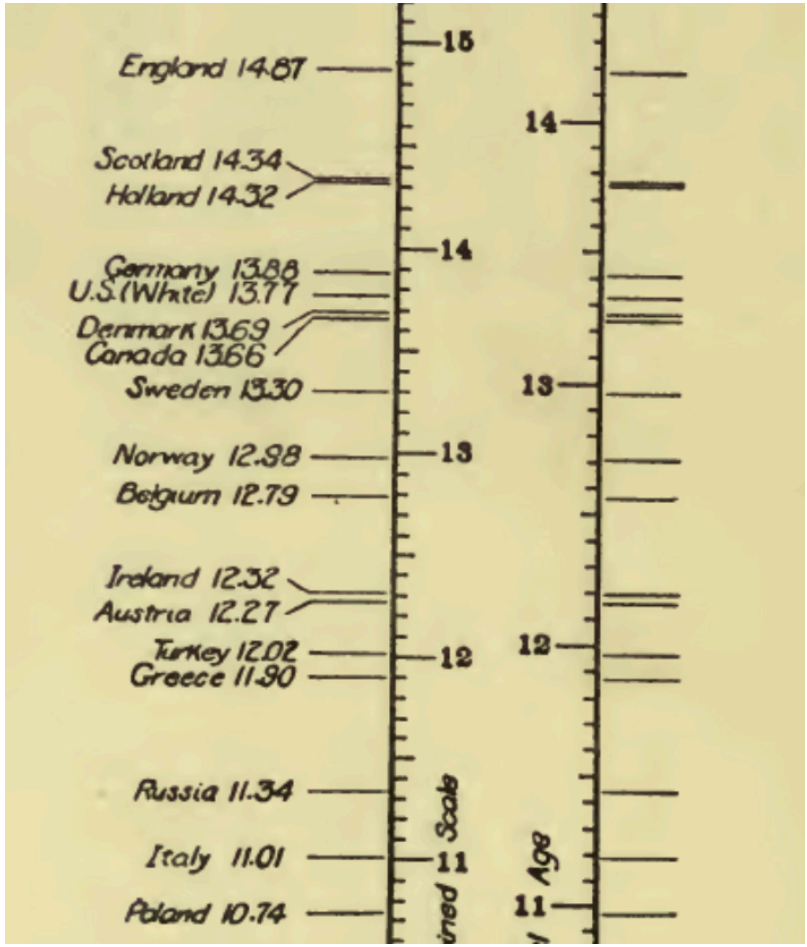
Intelligence testing and eugenics [edit]

In 1917, Yerkes served as president of the American Psychological Association (APA). Under his influence, the APA began several programs devoted to the war effort in World War I. As chairman of the Committee on the Psychological Examination of Recruits, he developed the Army Alpha and Army Beta Intelligence Tests, the first nonverbal group tests, which were given to over 1 million United States soldiers during the war.

Although Yerkes claimed that the tests measured native intelligence, and not education or training, this claim is difficult to sustain in the face of the questions themselves. Question 18 of Alpha Test 8 reads: "Velvet Joe appears in advertisements of ... (tooth powder)(dry goods) (**tobacco**)(soap)."[6]

Reduction to 1 number, 1 ordering

Post-Spearman, pre-JCM Intelligence: "IQ"



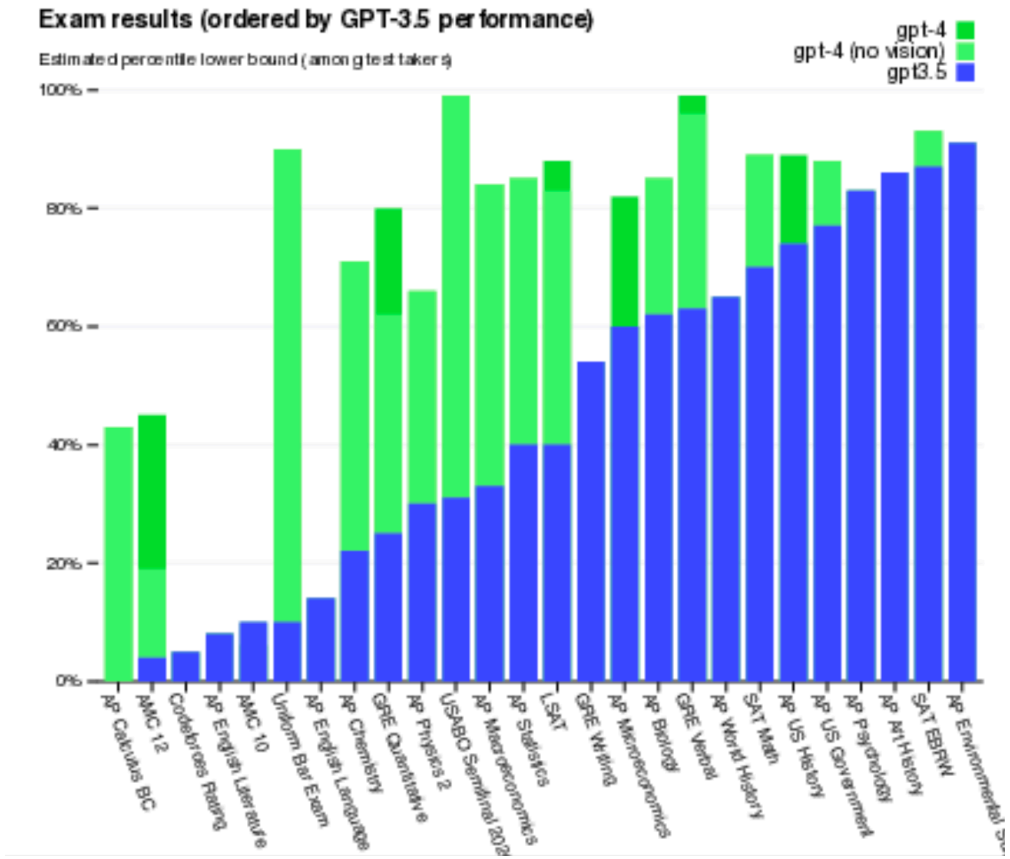
Reduction to 1 number, 1 ordering

But Wait... Is This Obvious for AI?

If human intelligence is a smooth, low-dimensional manifold...

Shouldn't AI intelligence work the same way?

Should AI... take "tests"?



see also 2023 "Sparks of Artificial General Intelligence: Early experiments with GPT-4"

Moravec's Paradox (1988)

The Historical Foundation

https://en.wikipedia.org/wiki/Moravec%27s_paradox

As Moravec writes:

> Encoded in the large, highly evolved sensory and motor portions of the human brain is a billion years of experience about the nature of the world and how to survive in it. The deliberate process we call reasoning is, I believe, the thinnest veneer of human thought, effective only because it is supported by this much older and much more powerful, though usually unconscious, sensorimotor knowledge. We are all prodigious olympians in perceptual and motor areas, so good that we make the difficult look easy. Abstract thought, though, is a new trick, perhaps less than 100 thousand years old. We have not yet mastered it. It is not all that intrinsically difficult; it just seems so when we do it.[8]

Moravec's Key Insight

As Moravec writes:

> *"Encoded in the large, highly evolved sensory and motor portions of the human brain is a billion years of experience about the nature of the world and how to survive in it. The deliberate process we call reasoning is, I believe, the thinnest veneer of human thought, effective only because it is supported by this much older and much more powerful, though usually unconscious, sensorimotor knowledge."*

Hard for humans = Easy for AI

Easy for humans = Hard for AI

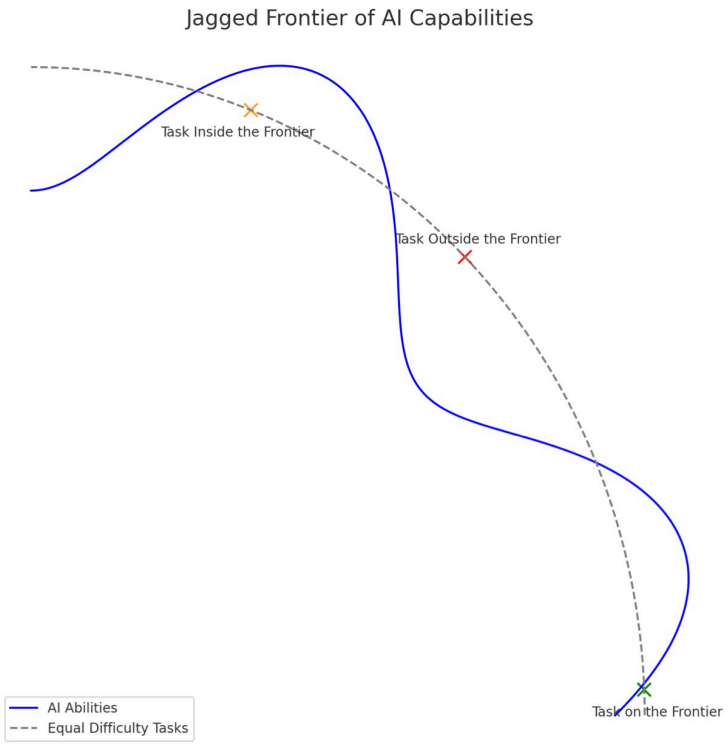
The Jagged Frontier of AI (2023)

Modern Validation of Moravec's Paradox

Navigating the Jagged Technological Frontier: Field Experimental Evidence of the Effects of AI on Knowledge Worker Productivity and Quality*

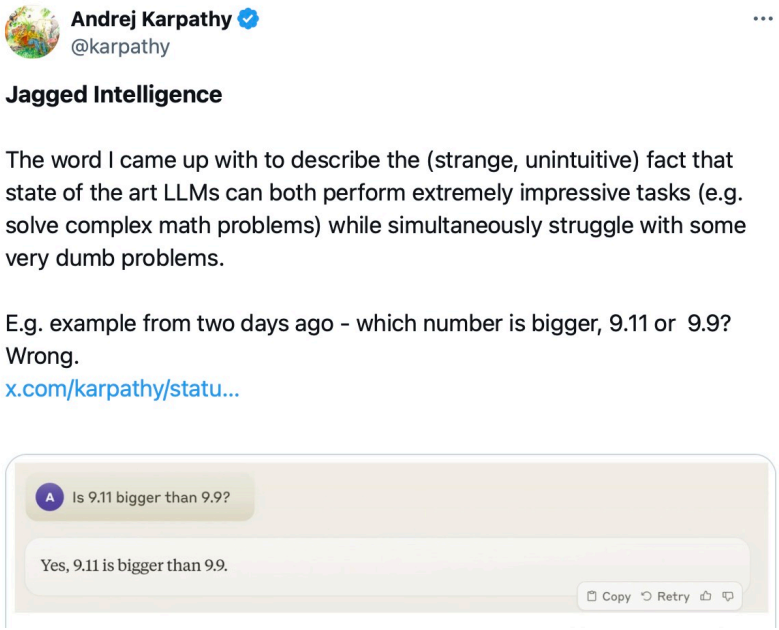
Fabrizio Dell'Acqua[1], Edward McFowland III[1], Ethan Mollick[2], Hila Lifshitz-Assaf[1,3], Katherine C. Kellogg[4], Saran Rajendran[5], Lisa Krayer[5], François Candelon[5], and Karim R. Lakhani[1]

Visualizing the Jagged Frontier



The frontier is irregular and unpredictable - some "simple" tasks are outside AI capabilities while "complex" ones are inside.

Karpathy's "Jagged Intelligence"



Perfect example: AI can solve complex math but fails at "Is 9.11 bigger than 9.9?"

Jagged vs Human Intelligence

Human Intelligence (Spearman's model)

- Smooth, correlated abilities
- If you can do A, you can probably do simpler task B
- Single g-factor explains performance

AI Intelligence (Jagged model)

- Unpredictable, non-correlated abilities
- Excelling at A tells us nothing about ability to do B
- No single factor explains capabilities

Why This Breaks Everything

Spearman's Fundamental Assumption: Abilities correlate smoothly

AI Reality: The frontier is invisible and jagged

Implication: Traditional psychometric approaches fail for AI

This challenges our entire framework for measuring intelligence

From Human g-factor to AI Benchmarks

The Striking Parallel (Part 1)

1904: Human Intelligence	2025: AI Intelligence
Multiple test scores	Multiple benchmark scores
Reduce to single g-factor	Reduce to leaderboard rank
IQ tests emerge	MMLU, HumanEval emerge

The Striking Parallel (Part 2)

1904: Human Intelligence	2025: AI Intelligence
Testing industry	AI evaluation industry
College admissions (SAT)	Company hiring (benchmarks)
Cultural bias debates	Dataset bias debates

The Striking Parallel (Part 3)

1904: Human Intelligence	2025: AI Intelligence
Teaching to the test	Training to benchmarks
Standardization pressure	Benchmark optimization
"Scientific" ranking	"Objective" leaderboards

Language Understanding Benchmarks

Current State-of-the-Art (2025)

- MMLU: 92% (GPT-4o)
- HellaSwag: 95% (Claude 3.5)
- TruthfulQA: 68% (Gemini Ultra)

Reasoning & Code Benchmarks

Reasoning & Math

- GSM8K: 94% (GPT-4)
- MATH: 76% (Claude 3.5)
- GPQA: 59% (Gemini Ultra)

Code & Multimodal Benchmarks

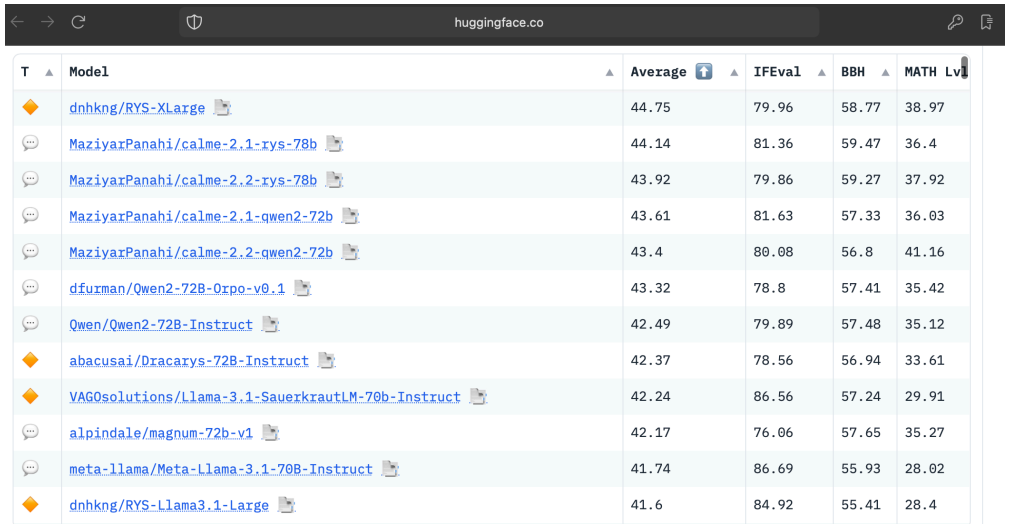
Code Generation

- HumanEval: 92% (Claude 3.5 Sonnet)
- MBPP: 89% (GPT-4)
- SWE-bench: 24% (GPT-4 + tools)

Multimodal

- MMBench: 83% (GPT-4V)

"Leaderboard" meme persists



T	Model	Average ⬆️	IFEval	BBH	MATH Lv
🔶	dnhkng/RYS-XLarge	44.75	79.96	58.77	38.97
💬	MaziyarPanahi/calme-2.1-rys-78b	44.14	81.36	59.47	36.4
💬	MaziyarPanahi/calme-2.2-rys-78b	43.92	79.86	59.27	37.92
💬	MaziyarPanahi/calme-2.1-qwen2-72b	43.61	81.63	57.33	36.03
💬	MaziyarPanahi/calme-2.2-qwen2-72b	43.4	80.08	56.8	41.16
💬	dfurman/Qwen2-72B-Orpo-v0.1	43.32	78.8	57.41	35.42
💬	Qwen/Qwen2-72B-Instruct	42.49	79.89	57.48	35.12
🔶	abacusai/Dracarys-72B-Instruct	42.37	78.56	56.94	33.61
🔶	VAGOsolutions/Llama-3.1-SauerkrautLM-70b-Instruct	42.24	86.56	57.24	29.91
💬	alpindale/magnum-72b-v1	42.17	76.06	57.65	35.27
💬	meta-llama/Meta-Llama-3.1-70B-Instruct	41.74	86.69	55.93	28.02
🔶	dnhkng/RYS-Llama3.1-Large	41.6	84.92	55.41	28.4

Risks: (i) gaming the metric (Flynn effect) (ii) train/test corruption (iii) jagged

Performance increasing

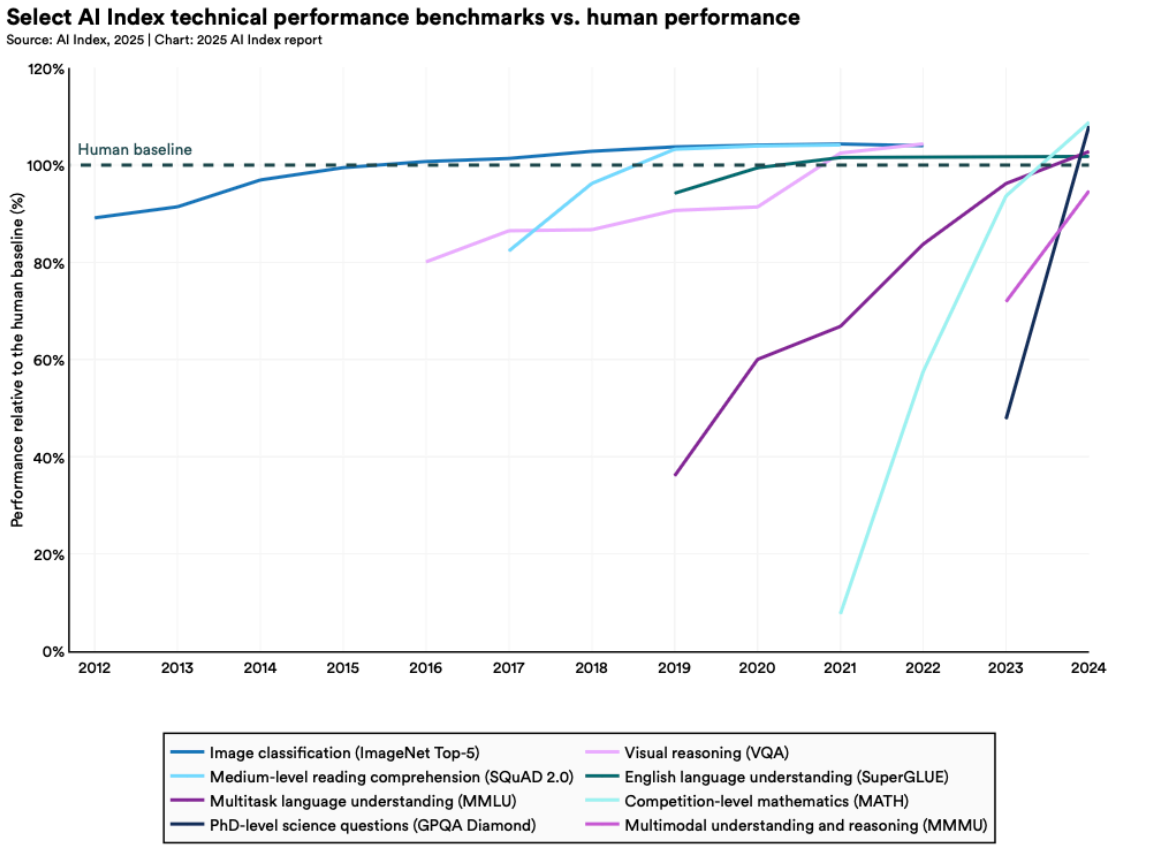


Figure 2.1.33[2]

PCA: The Mathematical Magic

What PCA Does

The Process

Input: High-dimensional correlated data

Process: Find directions of maximum variance

Output: Orthogonal components ranked by importance

Goal: Dimensionality reduction with minimal information loss

PCA for Student Grades

Example Application:

- Input: Math, Science, History, Art scores
- PC1: Often "general academic ability"
- PC2: Often "STEM vs Humanities"
- Insight: Few components explain most variation

PCA for AI Benchmarks

Hypothetical Application:

- Input: MMLU, HumanEval, GSM8K scores
- PC1: "General capability"?
- PC2: "Language vs Code"?
- Question: Meaningful or reductionist?

The Irony

Historical Continuity

We use 120-year-old psychometric techniques to evaluate cutting-edge AI!

- Same mathematical foundations
- Same reductionist impulses
- Same social implications
- Different technological context

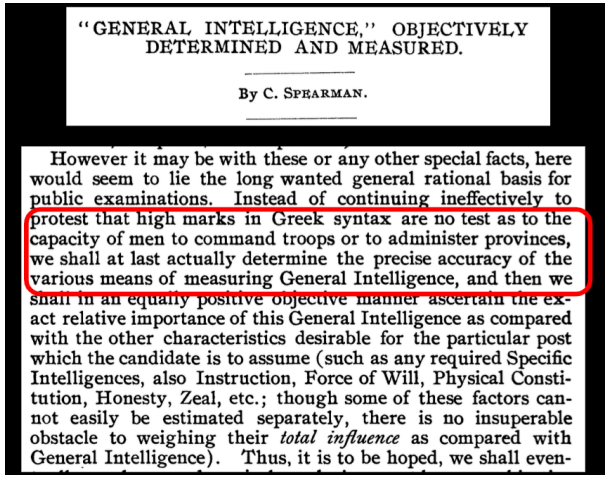
Critical Perspectives

Stephen Jay Gould on Reification

The Warning:

> *"We recognize the importance of mentality in our lives and wish to characterize it, in part so that we can make the divisions and distinctions among people that our cultural and political systems dictate. We therefore give the word "intelligence" to this wondrously complex and multifaceted set of human capabilities. This shorthand symbol is then reified and intelligence achieves its dubious status as a unitary thing"*
>
> *— The Mismeasure of Man (1981)*

Technical Issues with AI Benchmarks



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Current Problems

- Data contamination (test in training)
- Distribution shift (lab vs. real world)
- Spurious correlations
- Gaming and overfitting

Assignment & Resources

This Week's Assignment

Critical Reflection (500 words, due next week)

Choose ONE prompt:

1. **Historical Parallel**: How does IQ testing inform AI evaluation?
2. **Design Challenge**: Create a new AI benchmark avoiding pitfalls
3. **Philosophical Question**: Is "general intelligence" misguided?
4. **Practical Application**: How might PCA be misused in AI applications?

Looking Ahead

Next Week Preview

Lecture 2: "AI as How We Think We Think"

- The computational metaphor of mind
- Turing's imitation game implications
- Early neural networks

Questions?