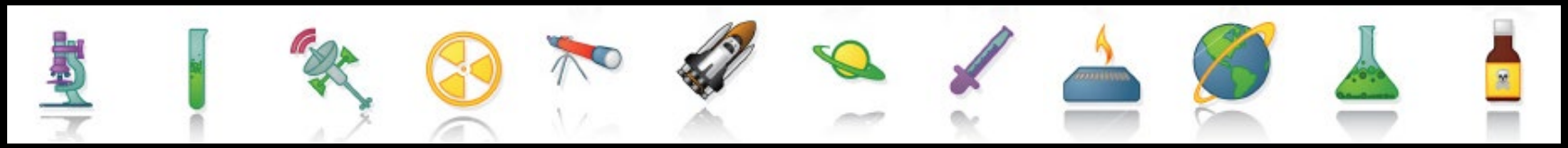
Misconceptions Never Fully Disappear



Andrew Shtulman
Department of Psychology, Occidental College

Intuitive Theories

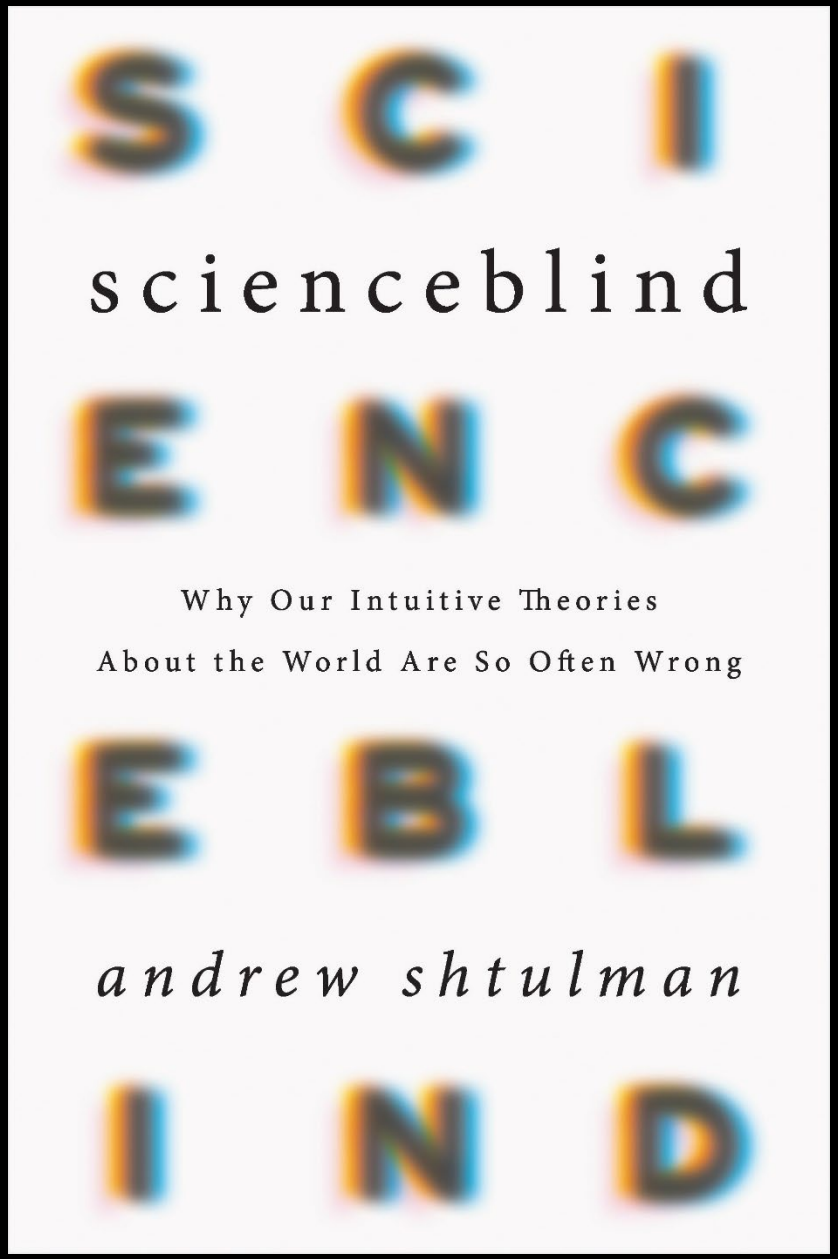
Before learning scientific theories we construct intuitive theories of the relevant phenomena.

They are *theories* in that they support explanation, prediction, intervention, and counterfactual reasoning.

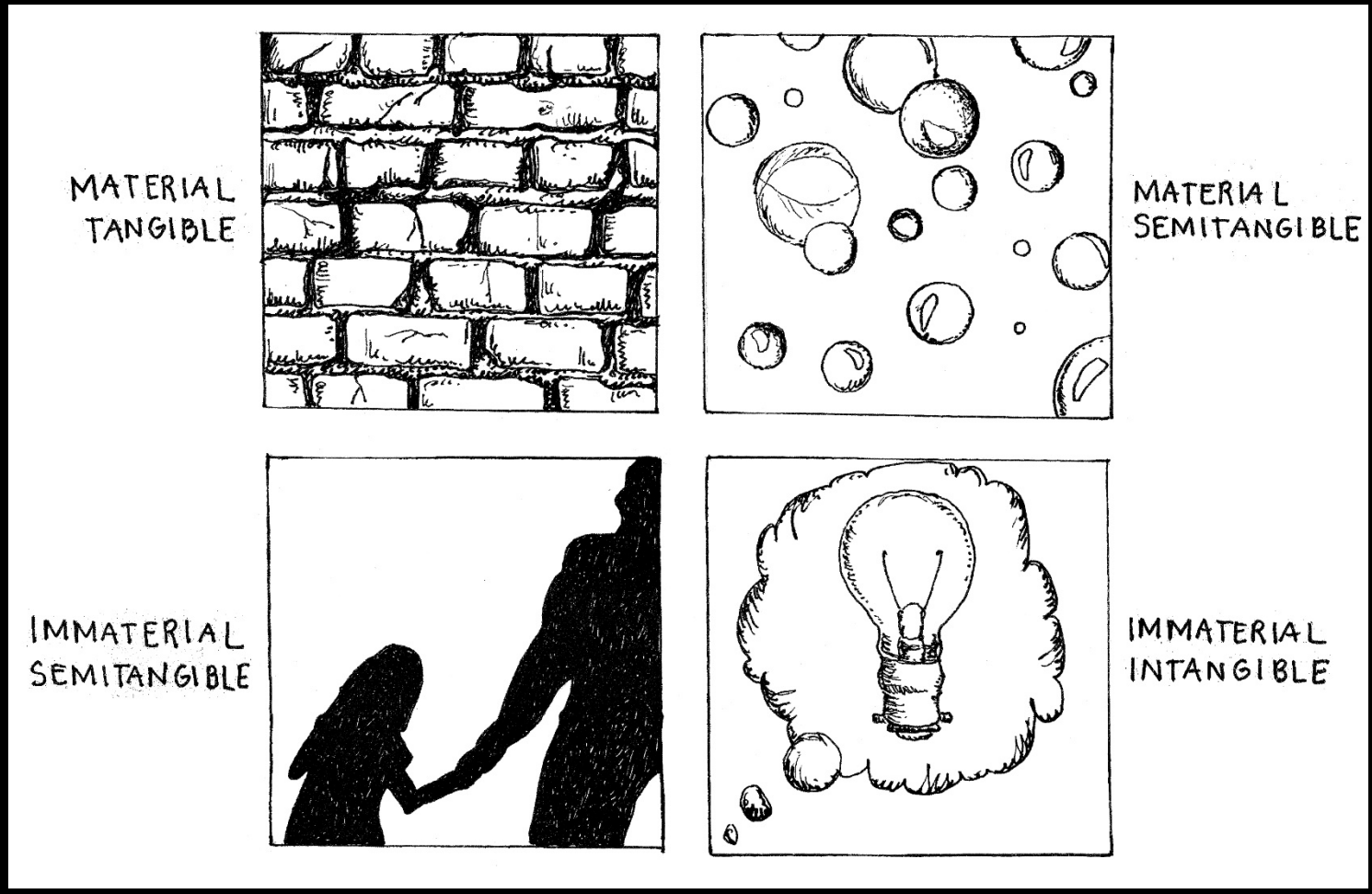
They are *intuitive* because they are less precise and less accurate than scientific theories.

Charting Intuition

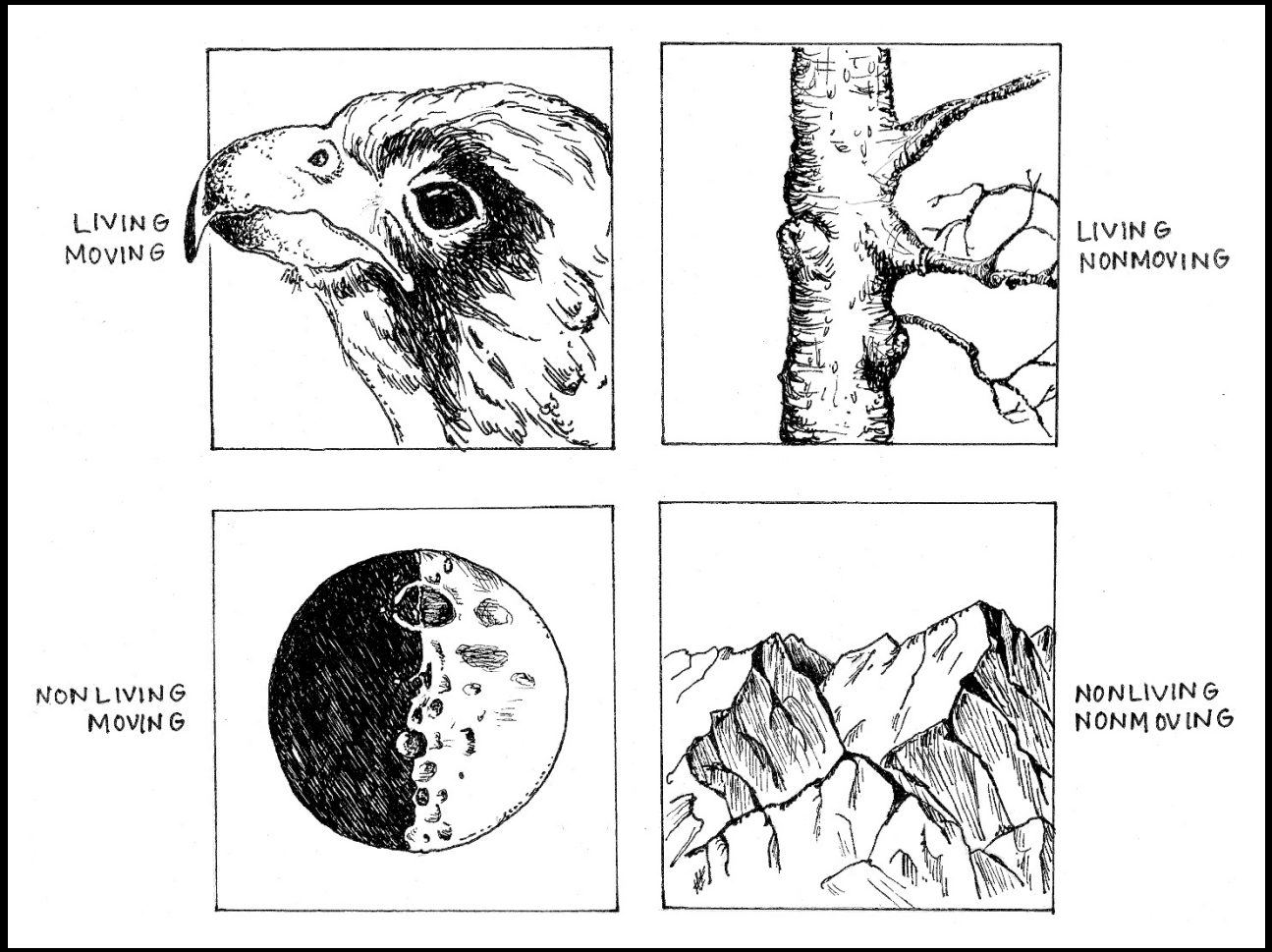
Astronomy	Geocentric → heliocentric model	Vosniadou & Brewer, 1994 Siegal et al., 2004
Evolution	Need-based → selection-based theory	Shtulman, 2006 Brumby, 1984
Fractions	Integer-based → division-based model	Moss & Case, 1999 Hartnett & Gelman, 1998
Heat	Substance-based → kinetic theory	Slotta & Chi, 2006 Wiser & Amin, 2001
Illness	Behavioral → microbial theory	Au et al., 2008 Solomon & Cassimatis, 1999
Inheritance	Trait-based → genetic theory	Springer & Keil, 1989 Duncan et al., 2009
Life	Psychological → vitalist theory	Slaughter & Lyons, 2003 Johnson & Carey, 1998
Light/sound	Substance-based → wave-based theory	Mazens & Lautrey, 2003 Linder & Erickson, 1989
Matter	Tactile → particulate theory	Smith, 2007 Nakhleh et al., 2005
Motion	Impetus-based → inertia-based theory	McCloskey, 1983 Clement, 1982


SCI
scienceblind
ENC
Why Our Intuitive Theories
About the World Are So Often Wrong
EBL
andrew shtulman
IND

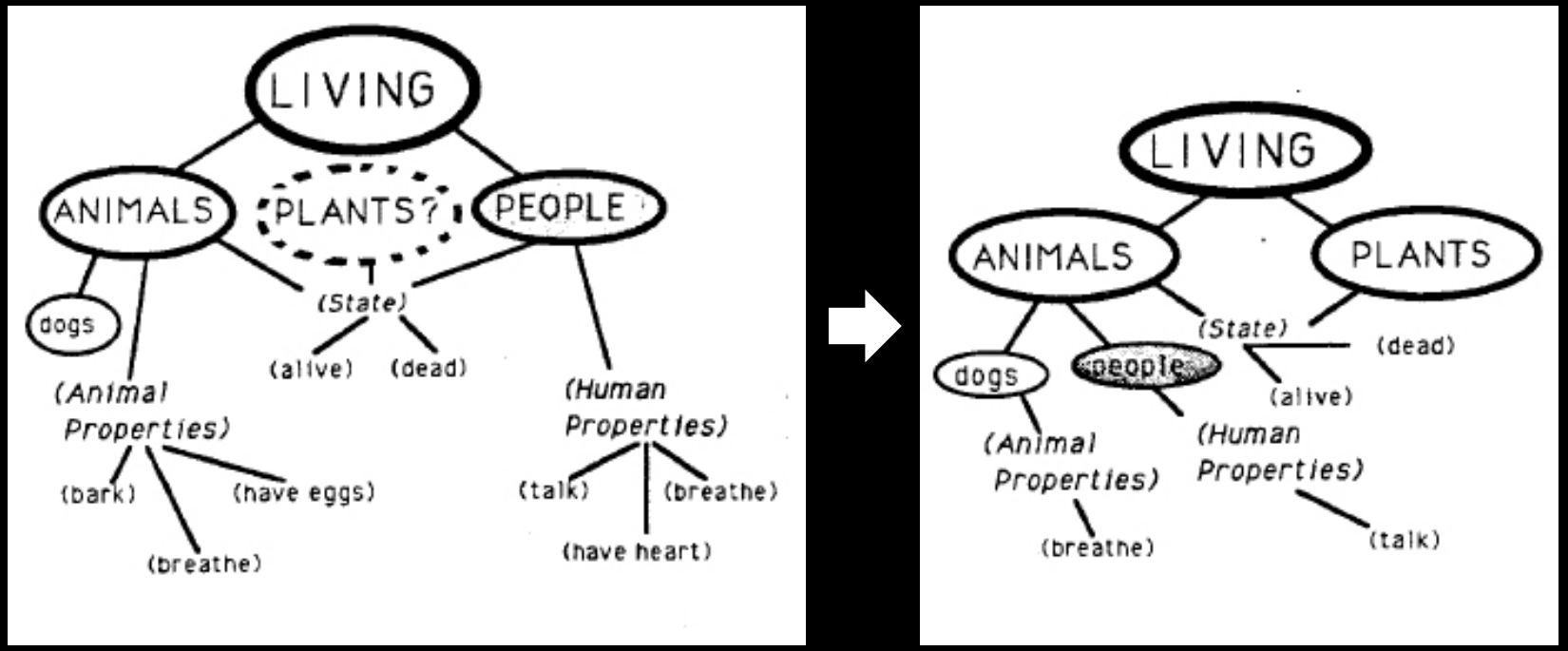
Intuitions About Matter



Intuitions About Life



Conceptual Change



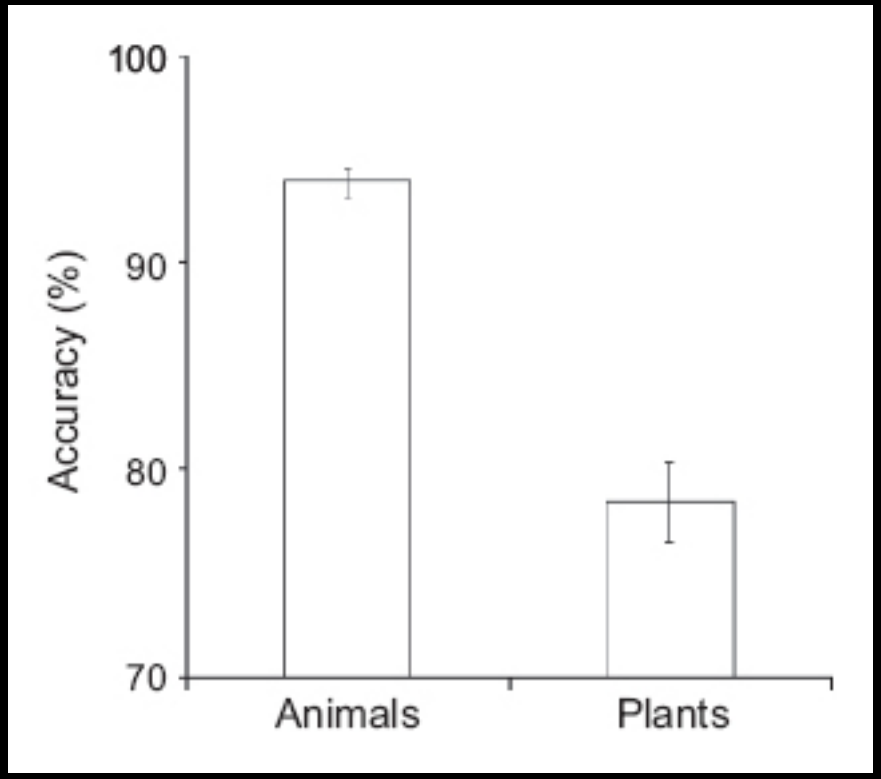
From Chi (1992)

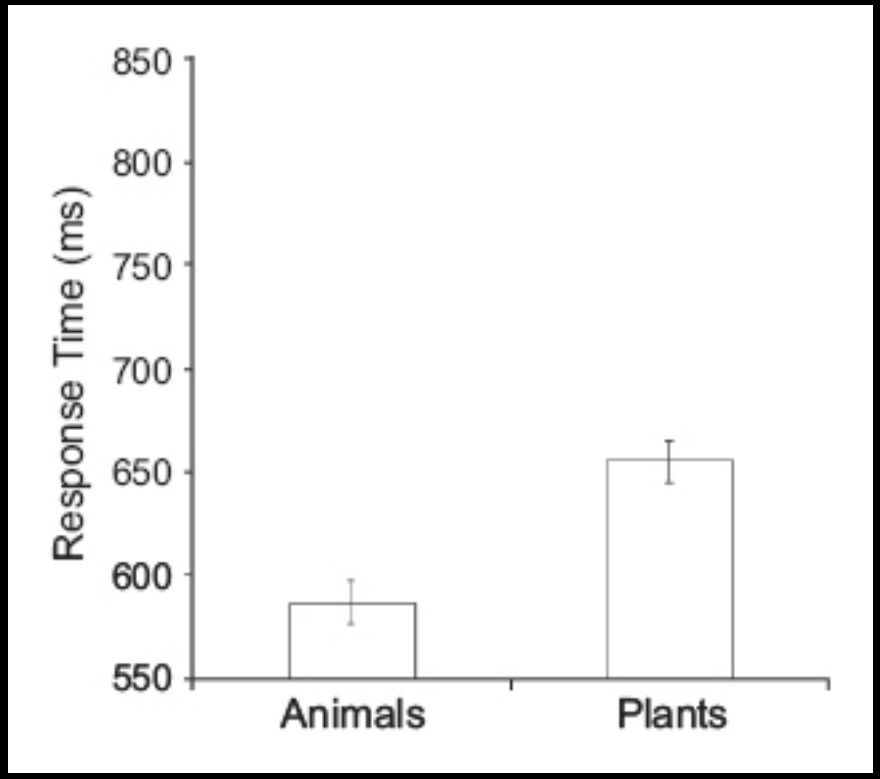
Reemergence of Animism

Participant group	*Animals*	*People*	*Plants*	*Inanimates*
Healthy young	95	85	75	0
Healthy elderly	100	95	75	0
Mild AD	100	67	22	0
Moderate AD	94	60	27	13

Zaitchik & Solomon (2008)

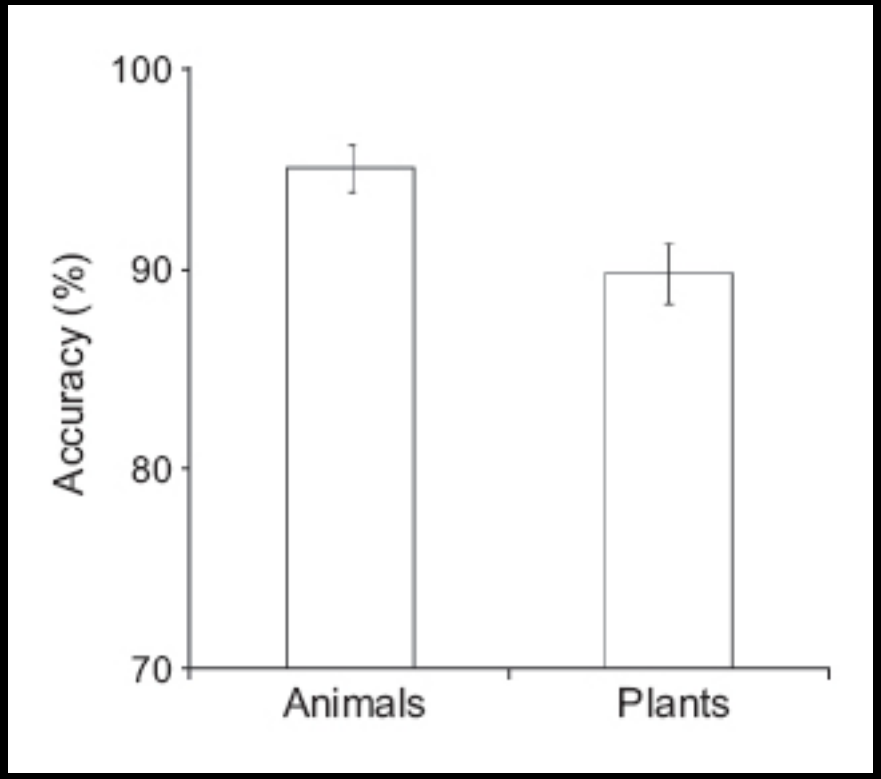
Animism in Undergrads

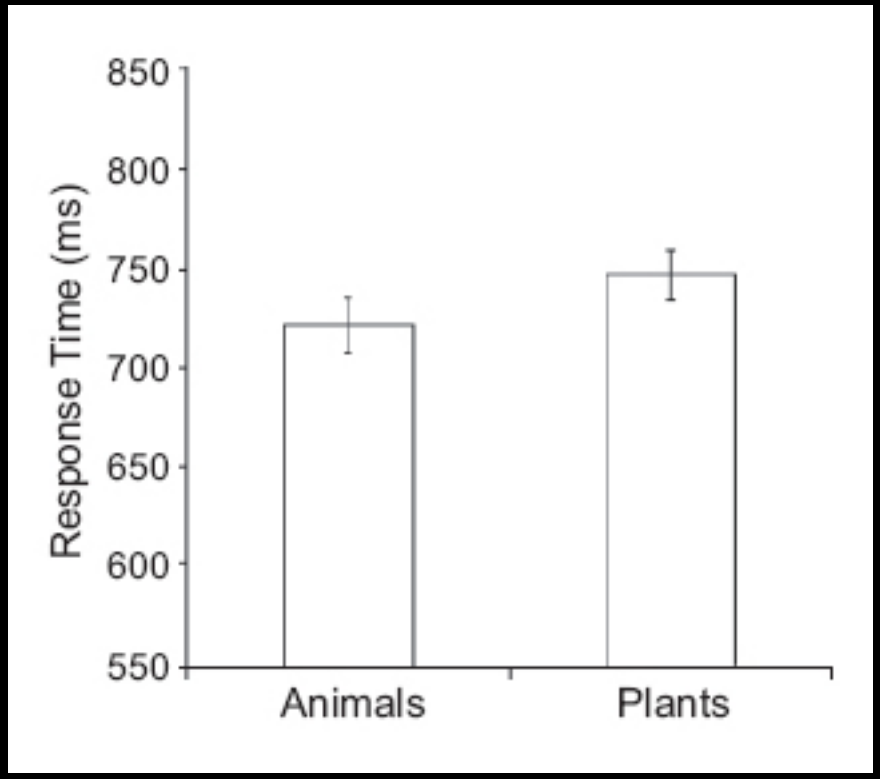




Goldberg & Thompson-Schill (2009)

Animism in Bio Professors





Goldberg & Thompson-Schill (2009)

Our Research

Using a speeded statement-verification task, we've found that intuitive theories compete with scientific theories:

(1) Across content domains
(2) Across age
(3) Across education
(4) Across contexts
(5) Despite targeted instruction

Method

Participants (150 undergrads) verified 200 statements as quickly as possible, 20 in each of 10 domains.

Half were true; half were false.

Half were consistent with intuition; half were not.

Materials

Consistent statements:

True on T1 and T2 (“Rocks are composed of matter”)
False on T1 and T2 (“Numbers are composed of matter”)

Inconsistent statements:

True on T1, false on T2 (“Fire is composed of matter”)
False on T1, true on T2 (“Air is composed of matter”)

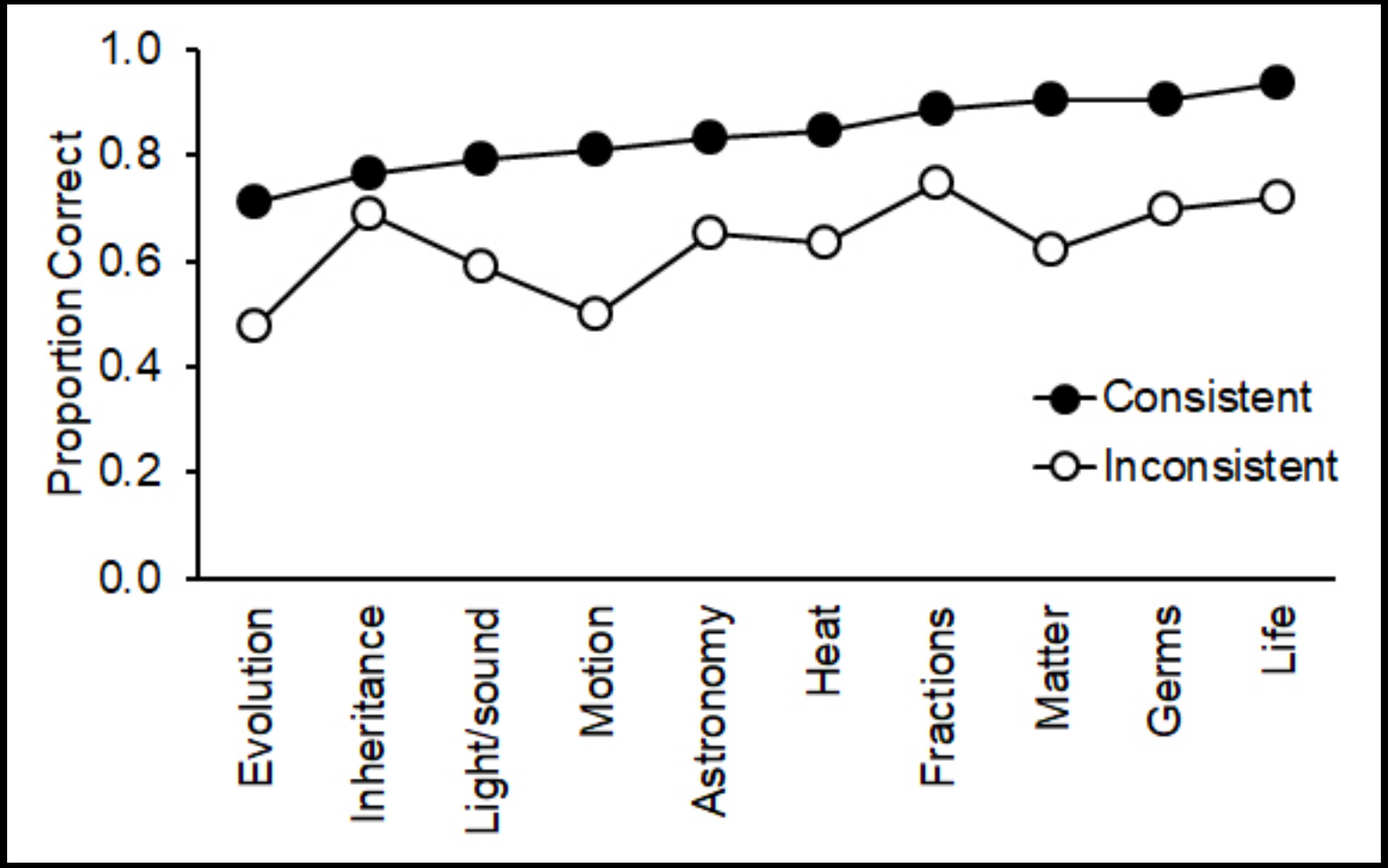
Other Examples

Domain	T1	T2	Statement
Heat	True	True	Ovens produce heat.
	False	False	Rain produces heat.
	True	False	Coats produce heat.*
	False	True	Pressure produces heat.*
Evolution	True	True	Humans are descended from tree-dwelling creatures.
	False	False	Humans are descended from plants.
	True	False	Humans are descended from chimpanzees.*
	False	True	Humans are descended from sea-dwelling creatures.*
Motion	True	True	A moving bullet loses speed.
	False	False	A moving bullet loses weight.
	True	False	A moving bullet loses force.*
	False	True	A moving bullet loses height.*

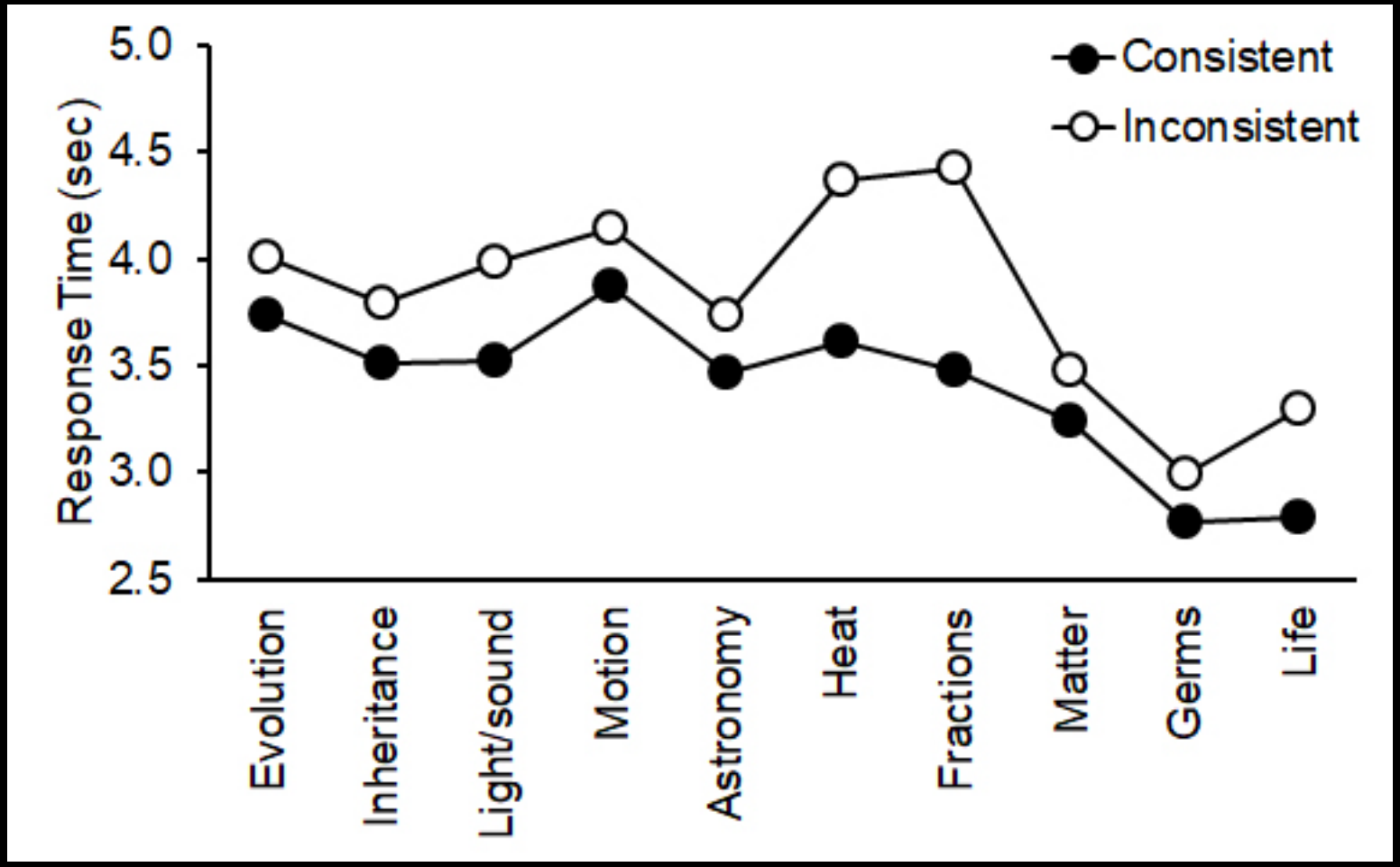
10 Domains, 50 Concepts

Domain	Concepts
Astronomy	Planet, star, solar system, lunar phase, season
Evolution	Common ancestry, phylogeny, variation, selection, adaptation
Fractions	Addition, division, conversion, ordering, infinite density
Heat	Heat, heat source, heat transfer, temperature, thermal expansion
Illness	Contagion, contamination, infection, sterilization, microbe
Inheritance	Heritability, chromosome, dominance, expression, mutation
Life	Life, death, reproduction, metabolism, kinship
Light/sound	Light, color, sound, propagation, reflection
Matter	Mass, weight, density, divisibility, atom
Motion	Force, velocity, acceleration, momentum, gravity

Response Accuracy



Response Latency



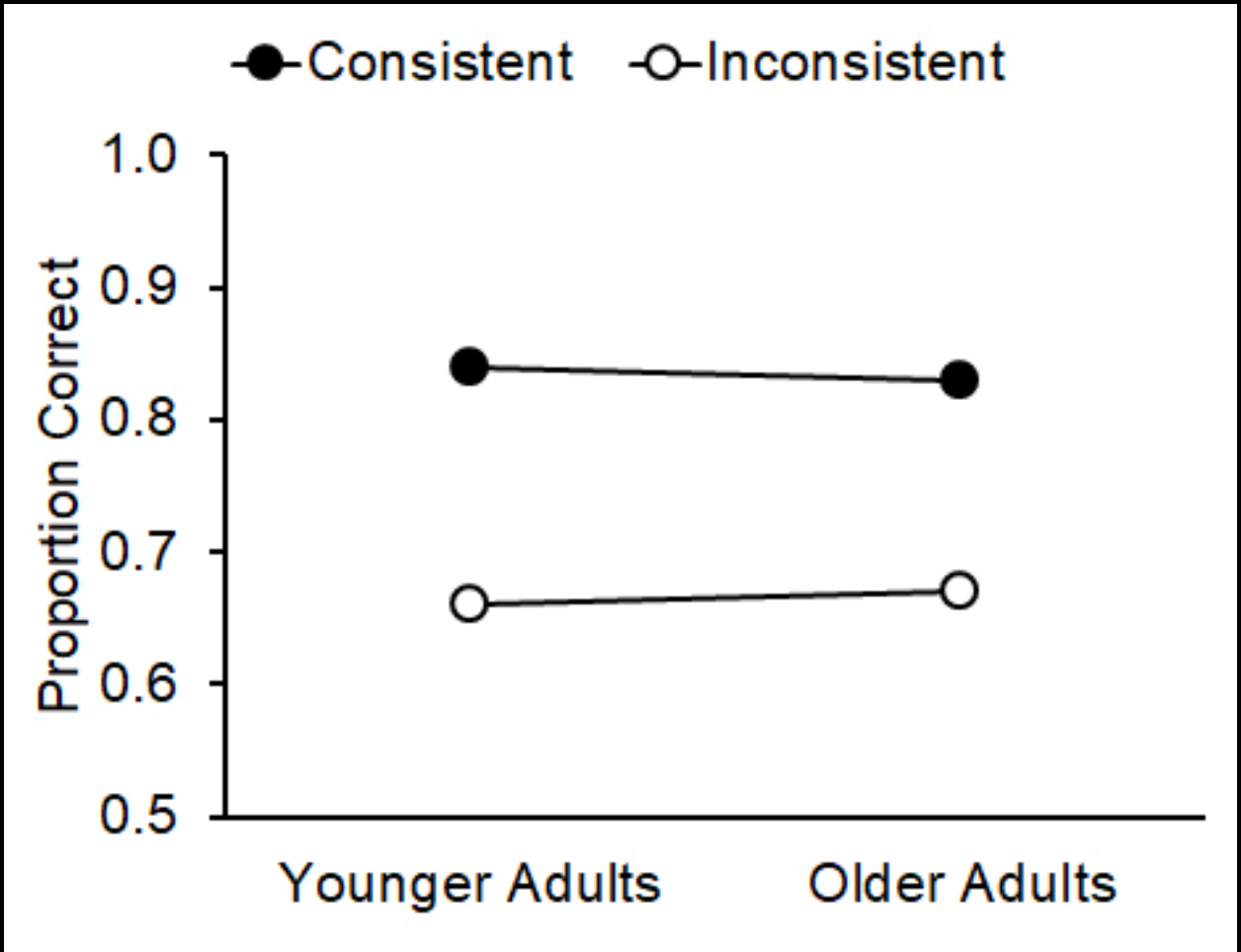
An Enduring Phenomenon?

Tensions between science and intuition may decrease with age and education.

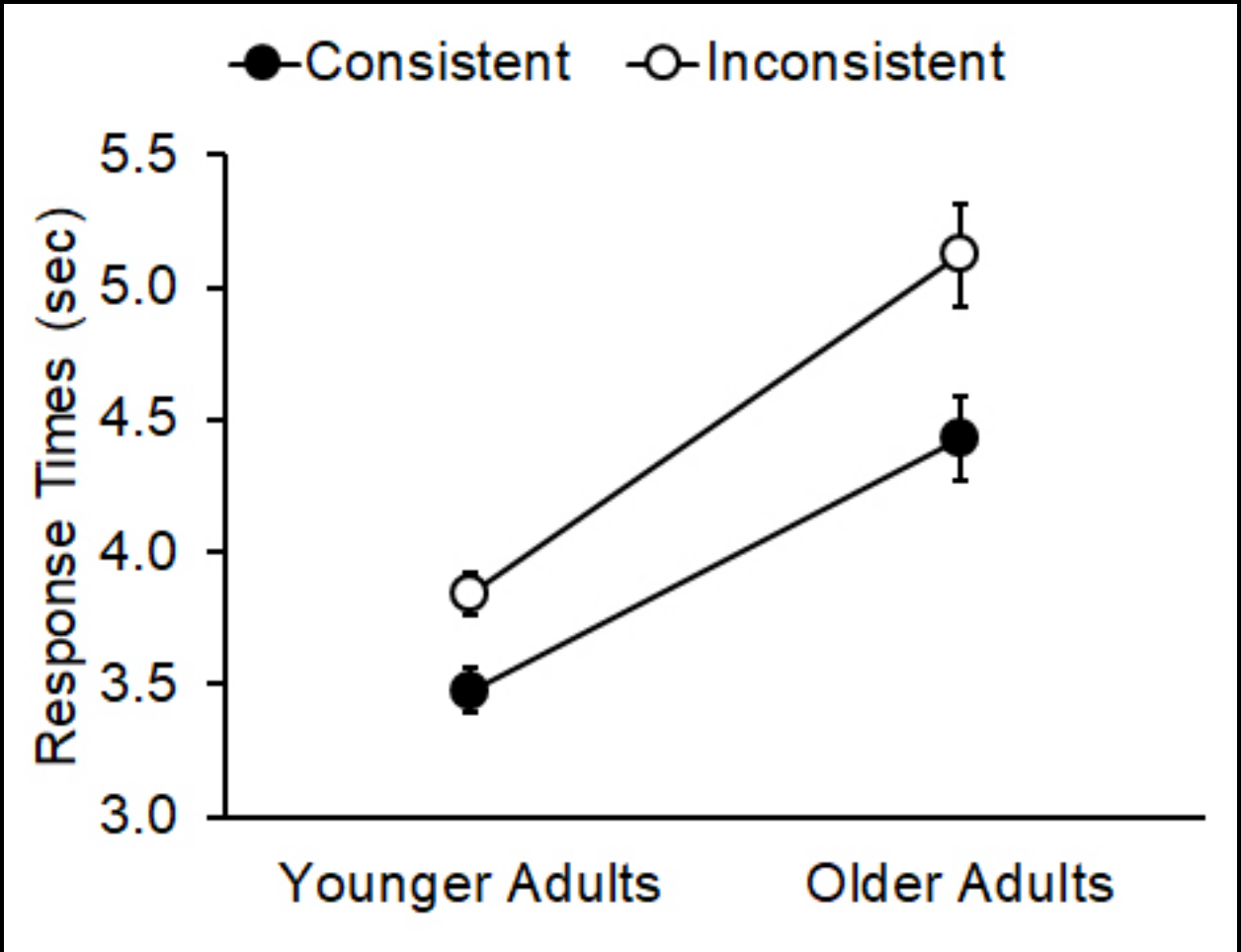
We administered the same task to 48 older adults, *M* age = 65.7 (range = 50 to 87).

Some were professional scientists.

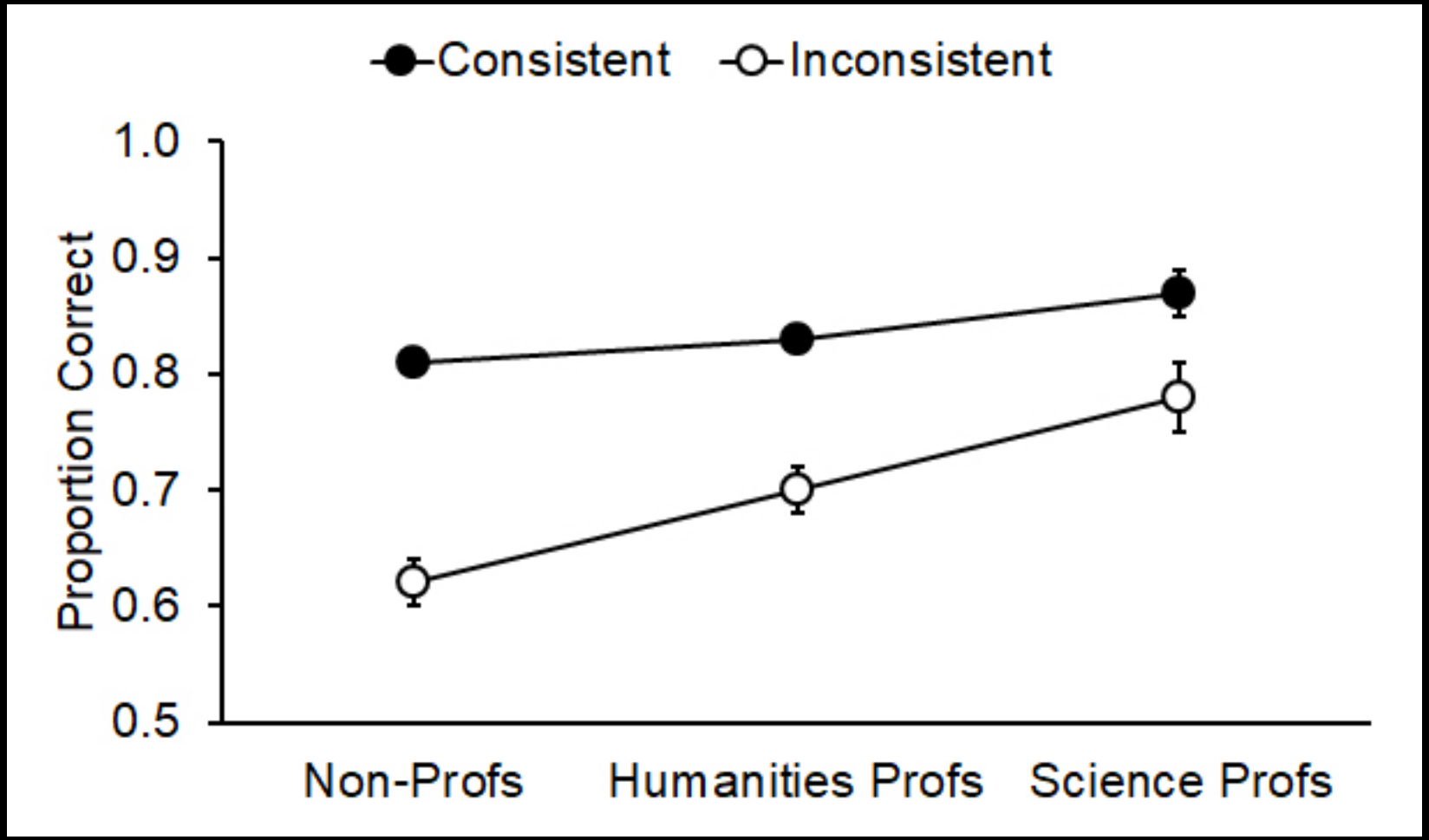
Accuracy by Age



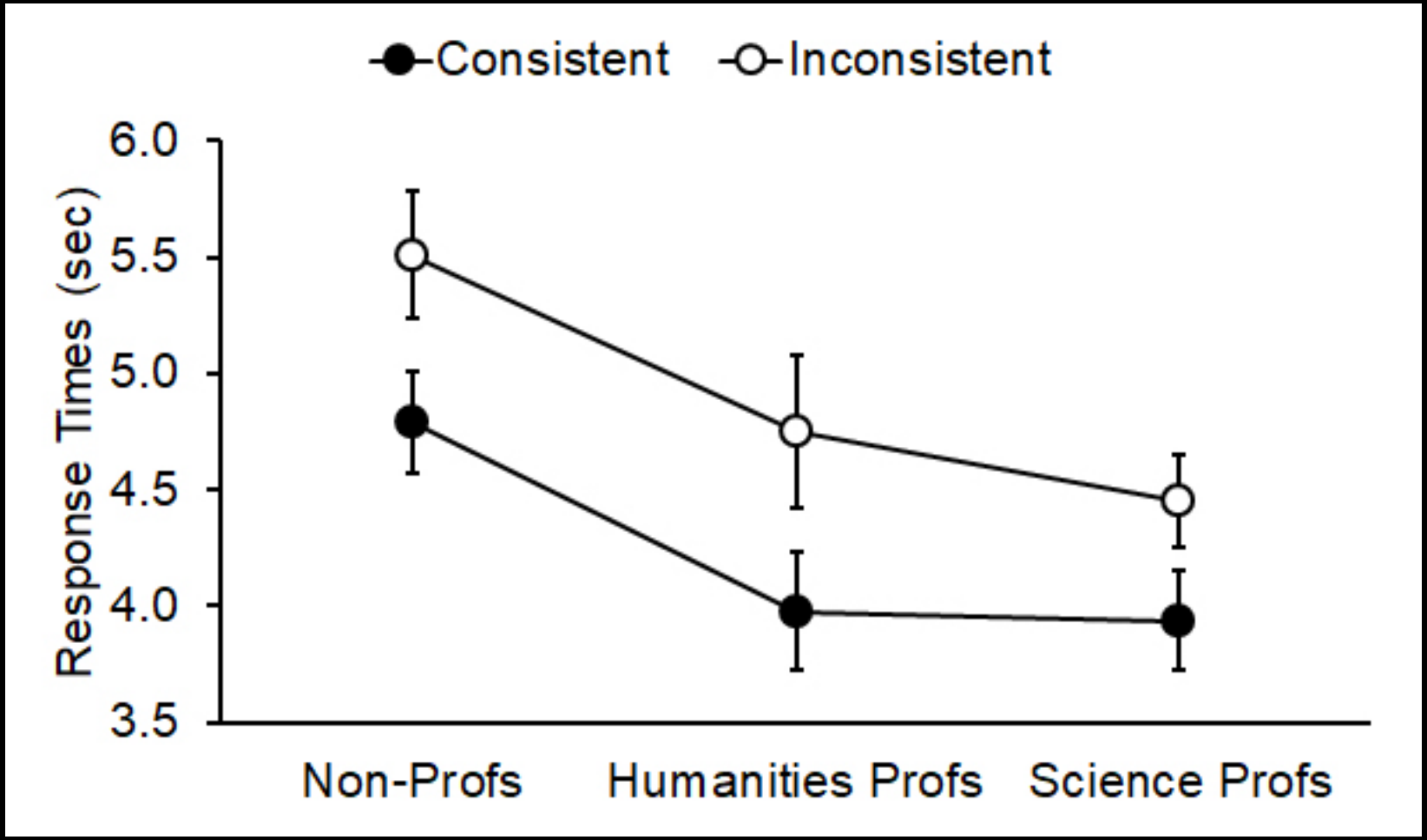
Latency by Age



Accuracy by Education



Latency by Education



Can We Be Primed to Do Better?

A statement like “air has weight” is difficult to verify because we represent two senses of weight:

Scientific: Product of mass and gravity
Intuitive: Heft

We sought to prime one sense or the other with images interspersed between statements (*n* = 100 undergrads).

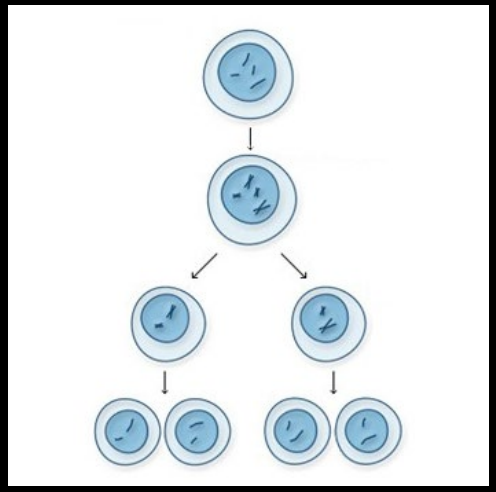
We focused on the domains of life and matter.

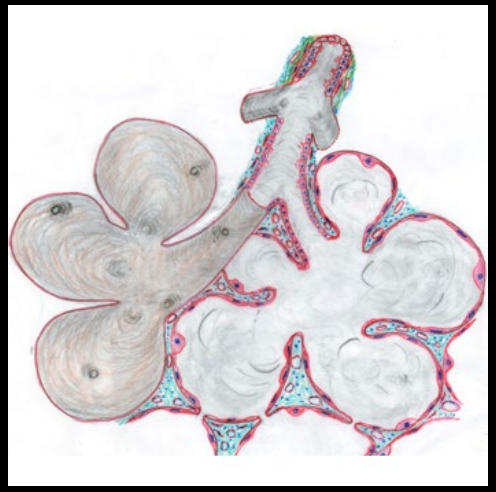
Materials

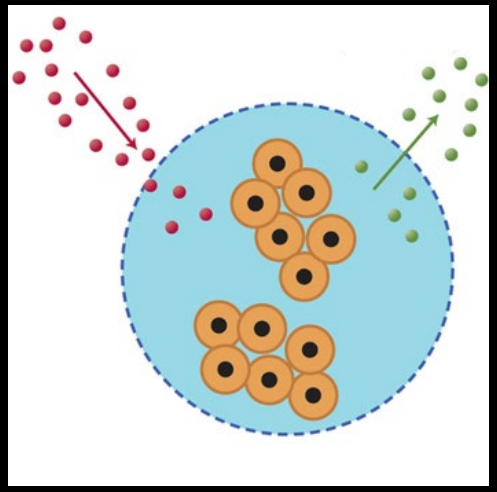
240 statements per domain = 80 items x 3 predicates

Biological predicates	Physical predicates
Reproduces	Has weight
Respires	Has a temperature
Needs nutrients	Occupies space

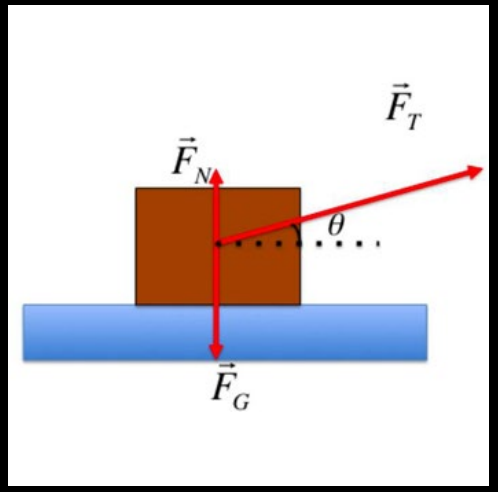
Sample Biological Primes

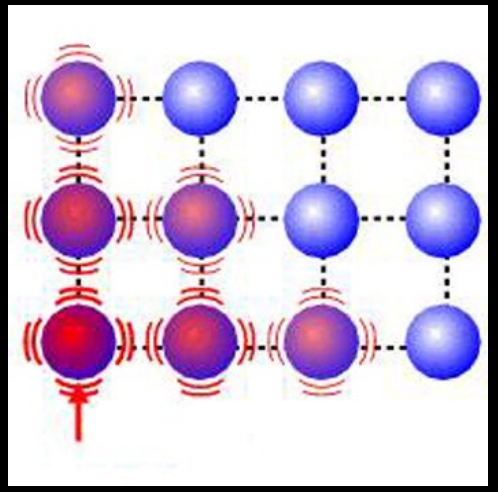


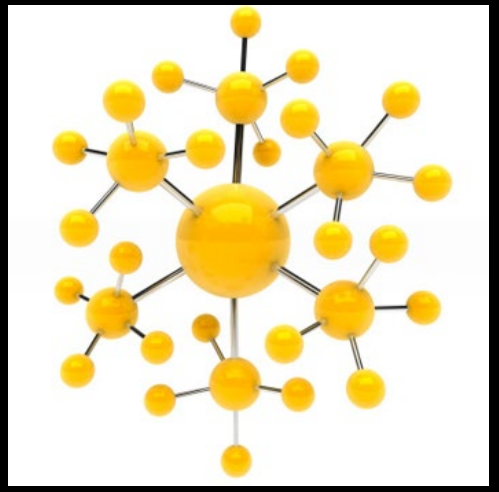




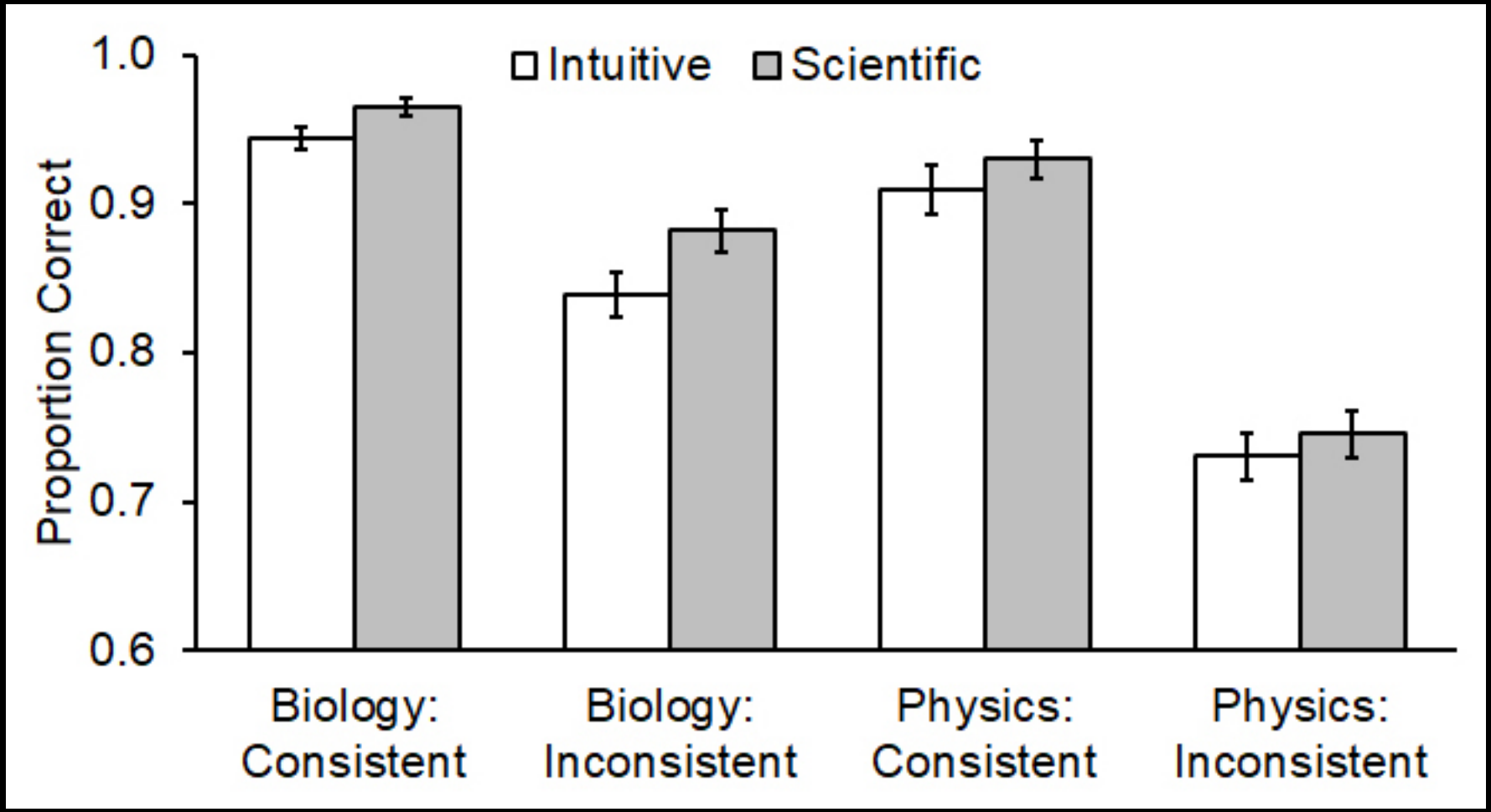
Sample Physical Primes



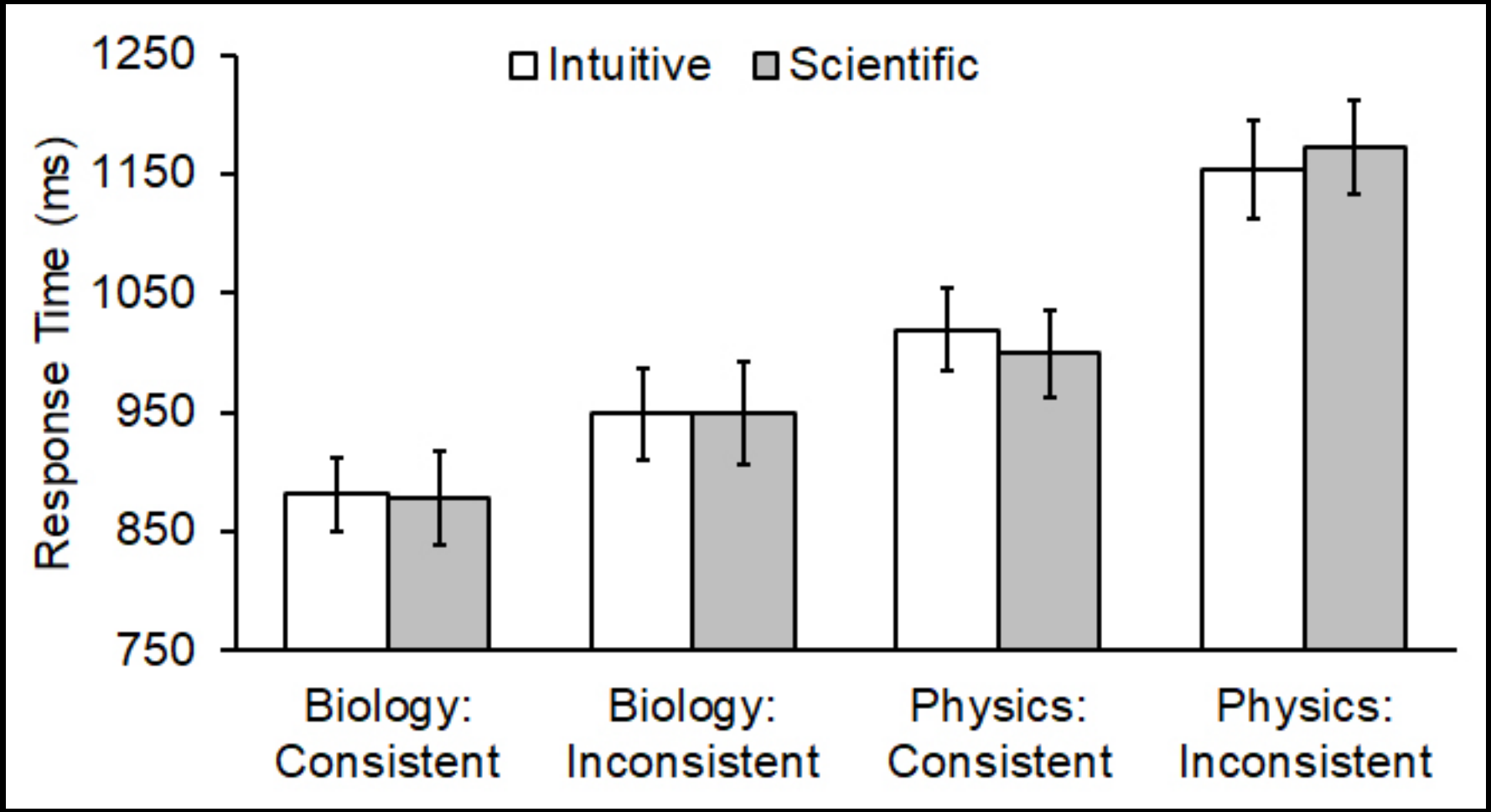




Accuracy by Prime



Latency by Prime



Can We Be Trained to Do Better?

Priming produced a small increase in accuracy but no increase in speed.

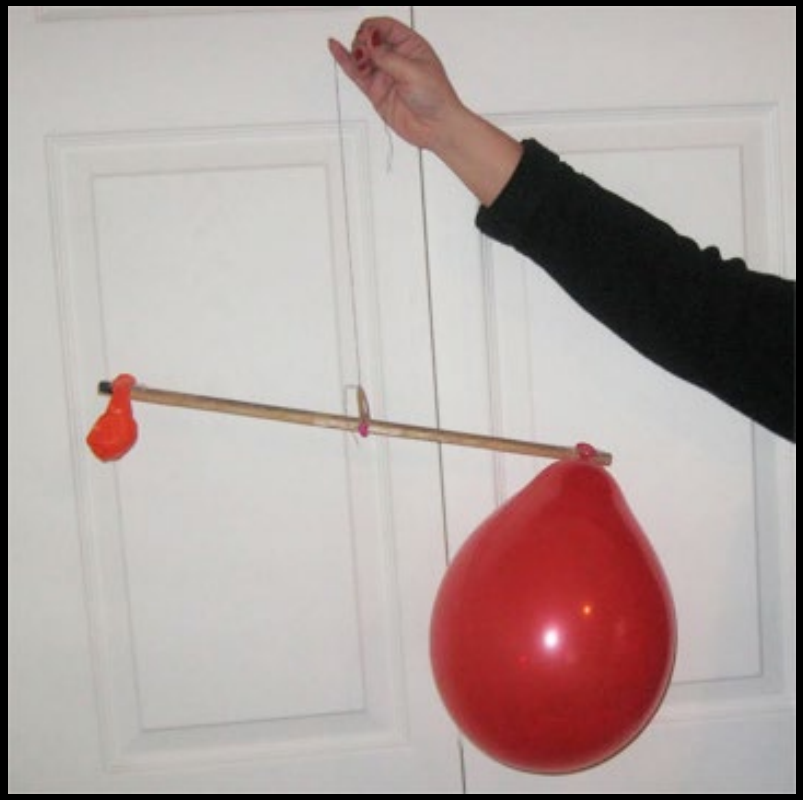
Would direct instruction close the gap between intuitive and counterintuitive statements? (*n* = 138 undergrads)

Design

Pretest:	240 speeded statement verifications, half on life and half on matter (intermixed)
Tutorial:	7-minute tutorial on life or matter, followed by attention checks
Posttest:	240 different statement verifications, half on life and half on matter

Tutorials

The tutorials emphasized the scientific properties of life and matter and refuted common misconceptions.

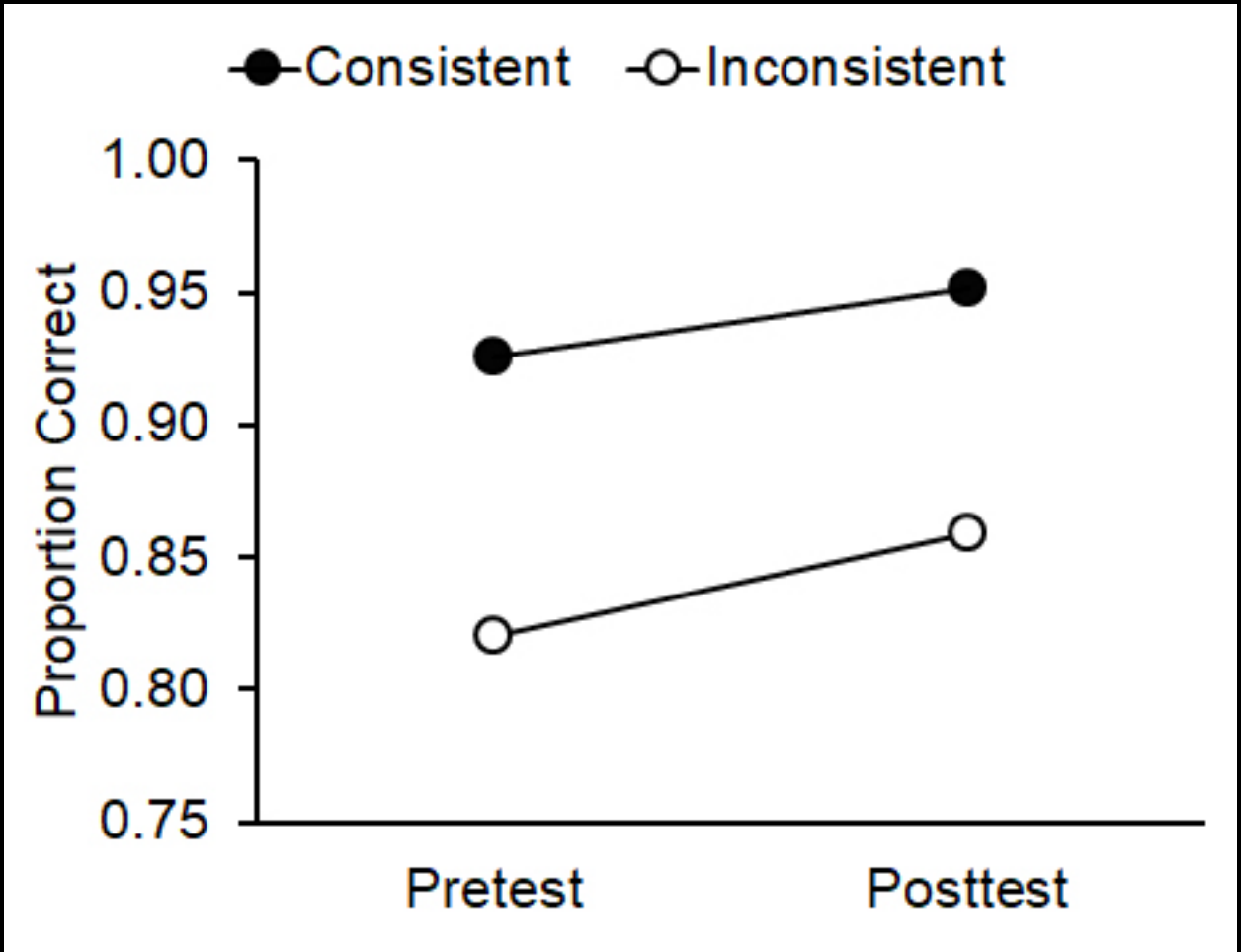


Analysis

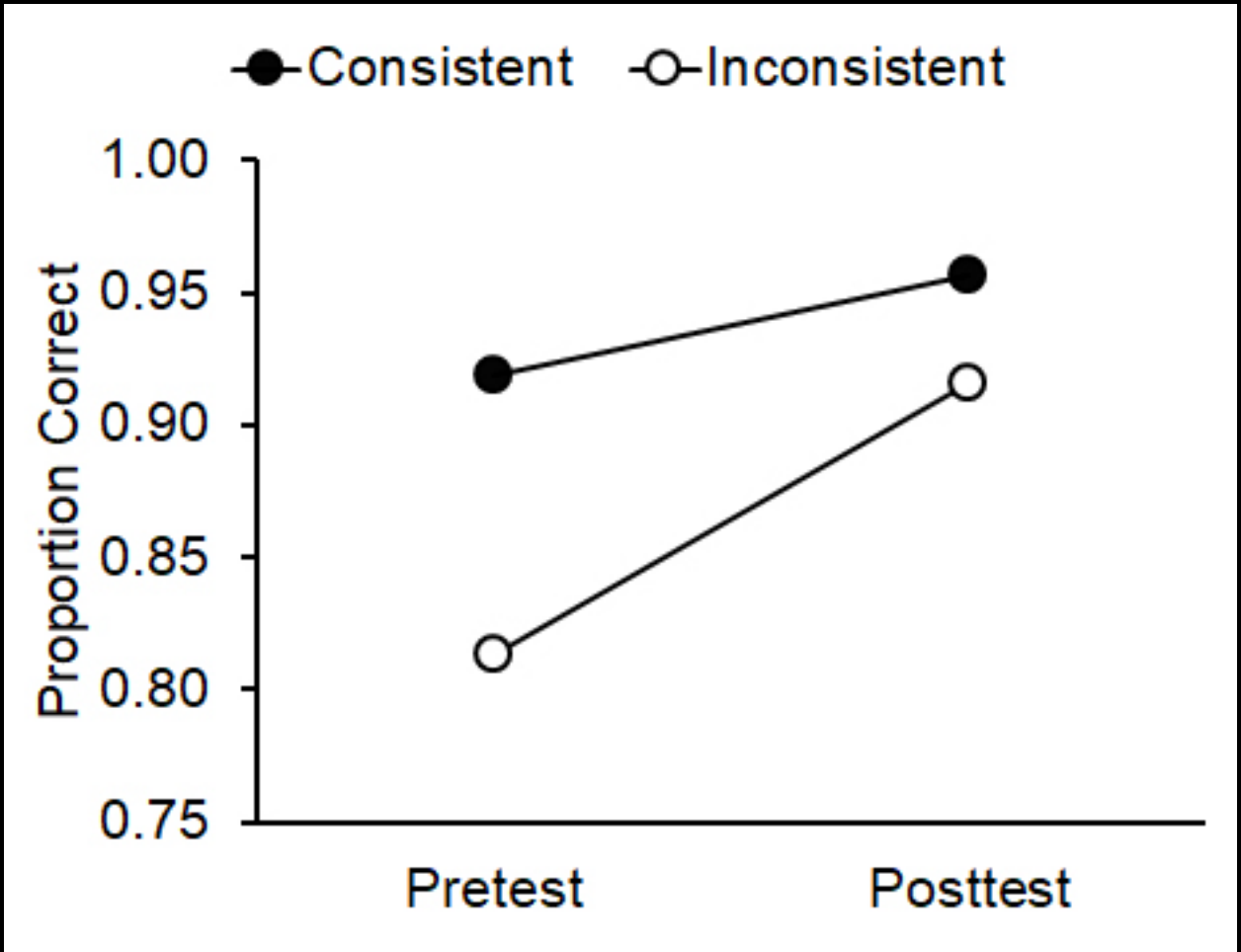
Pre-post differences are analyzed by whether they were in the domain targeted by instruction.

Life tutorial: Instructed = life, uninstructed = matter
Matter tutorial: Instructed = matter, uninstructed = life

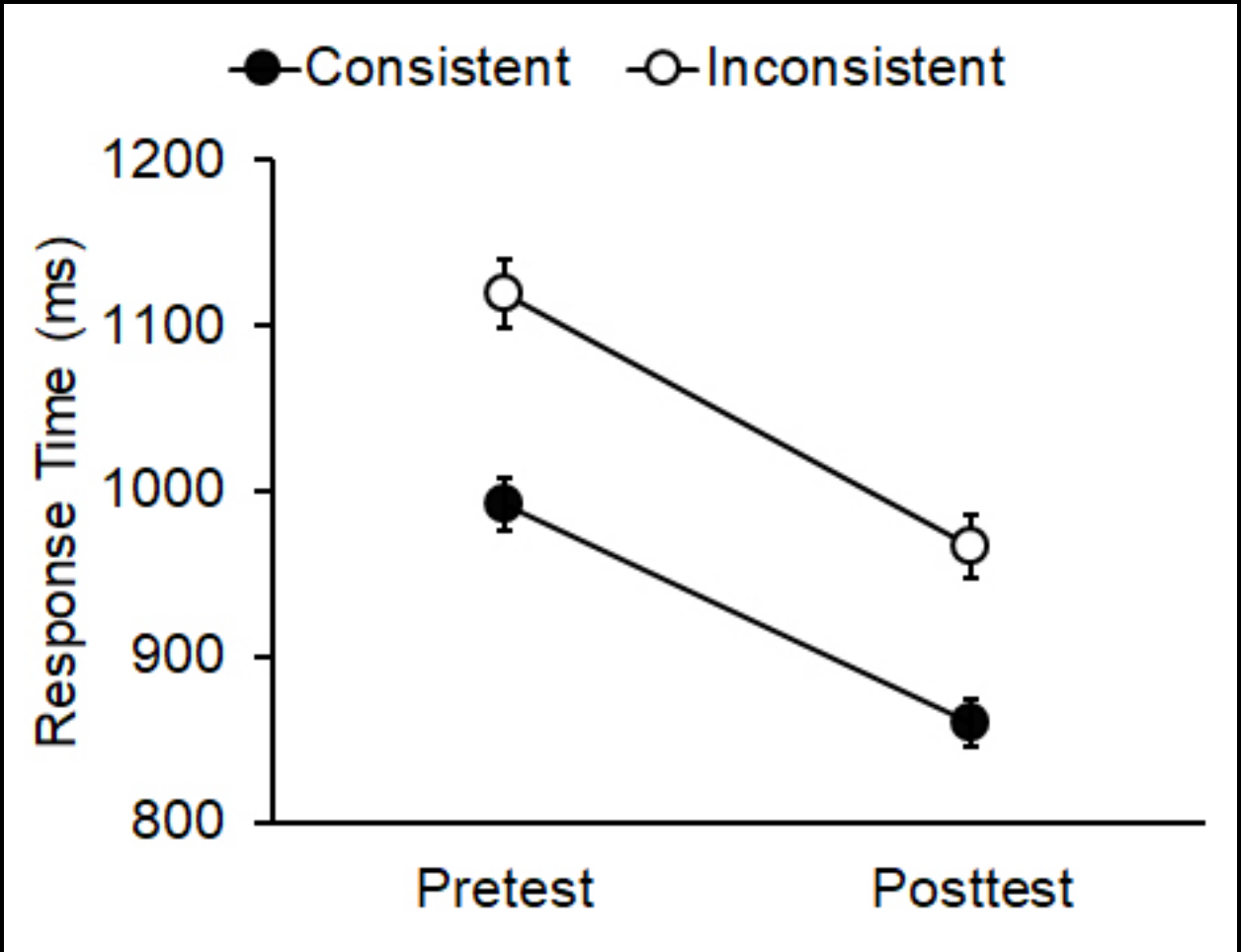
Accuracy: Uninstructed Domain



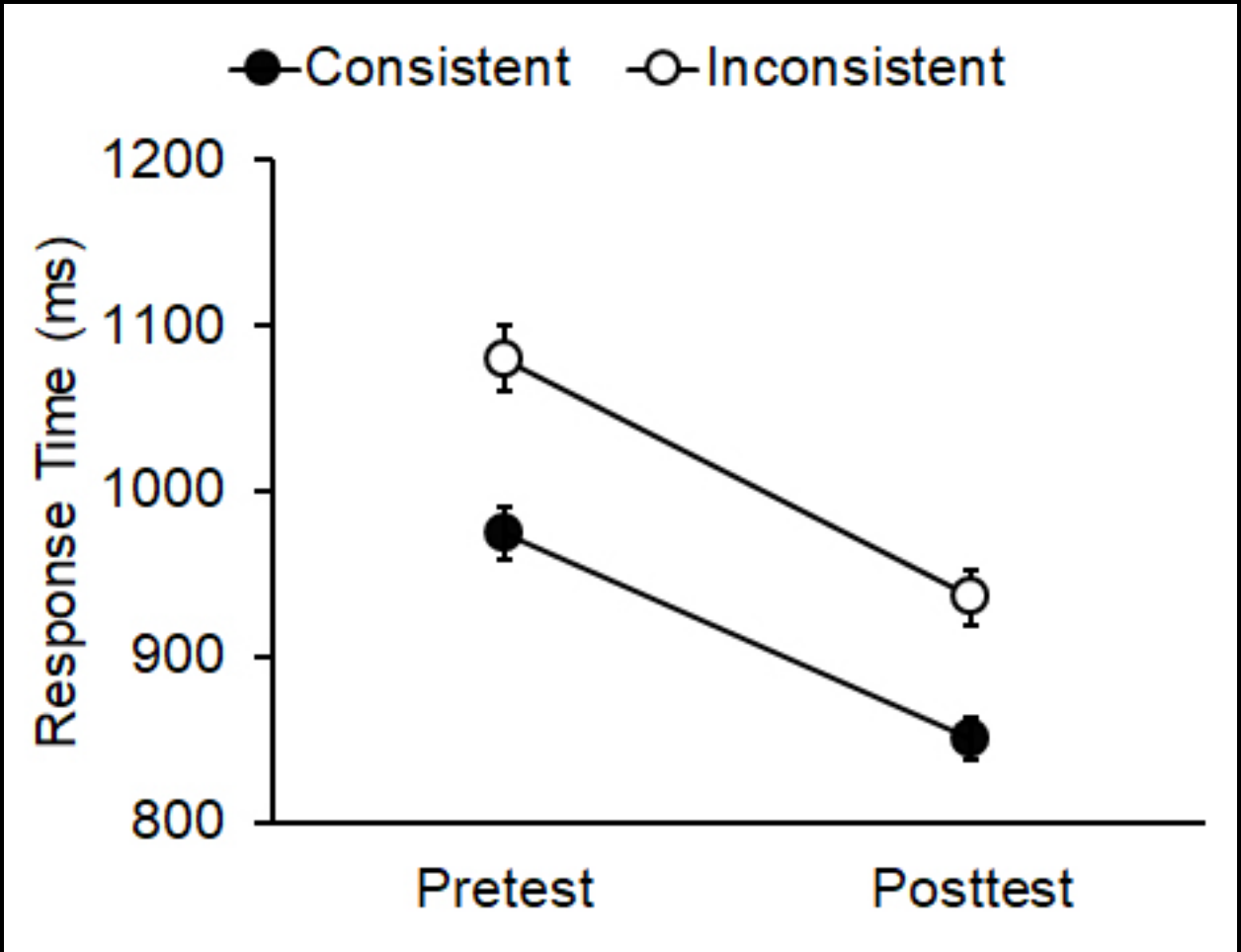
Accuracy: Instructed Domain



Latency: Uninstructed Domain



Latency: Instructed Domain



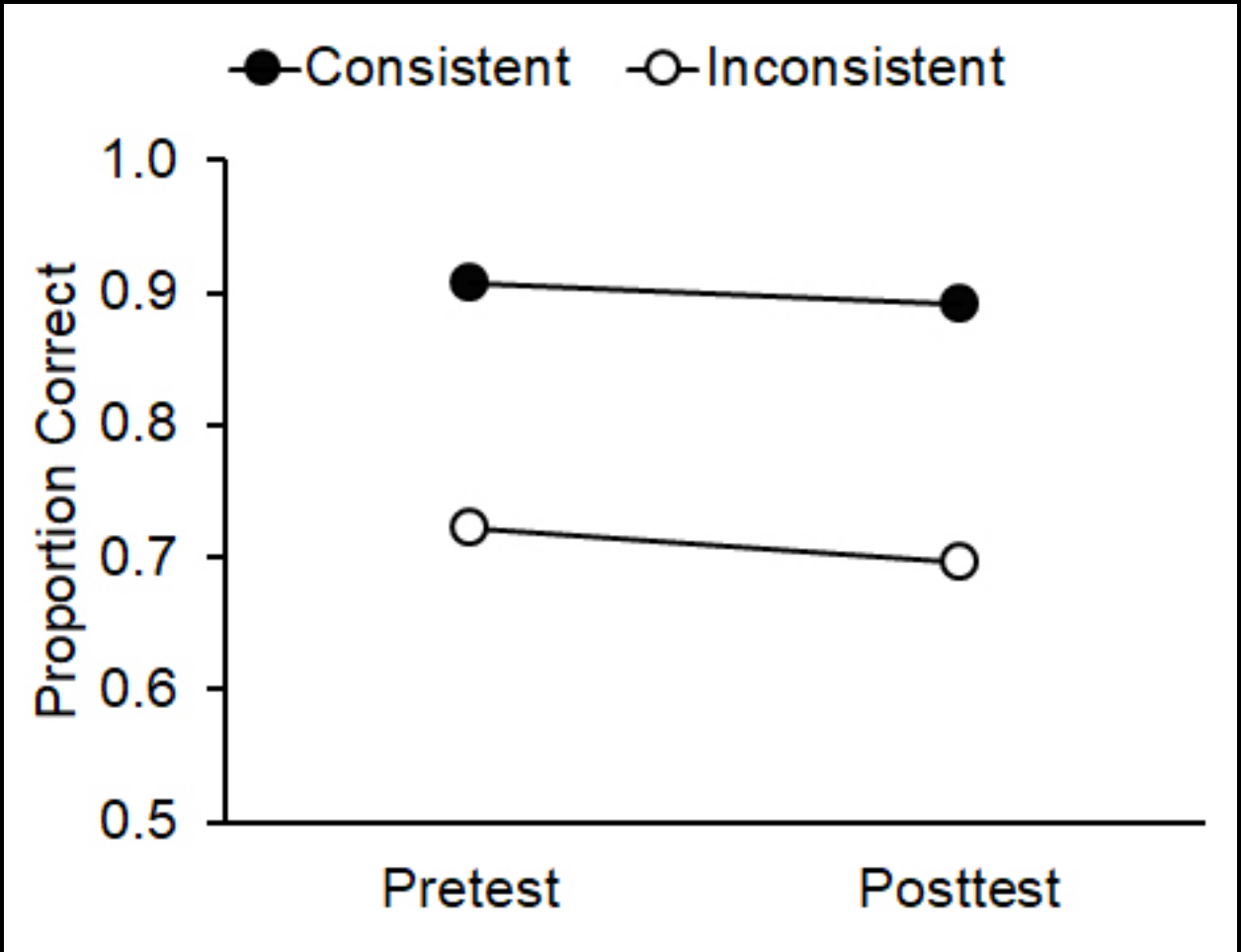
Would Children Show the Effect?

Adults learn the properties of life and matter as children; our tutorial was more of a reminder than a tutor.

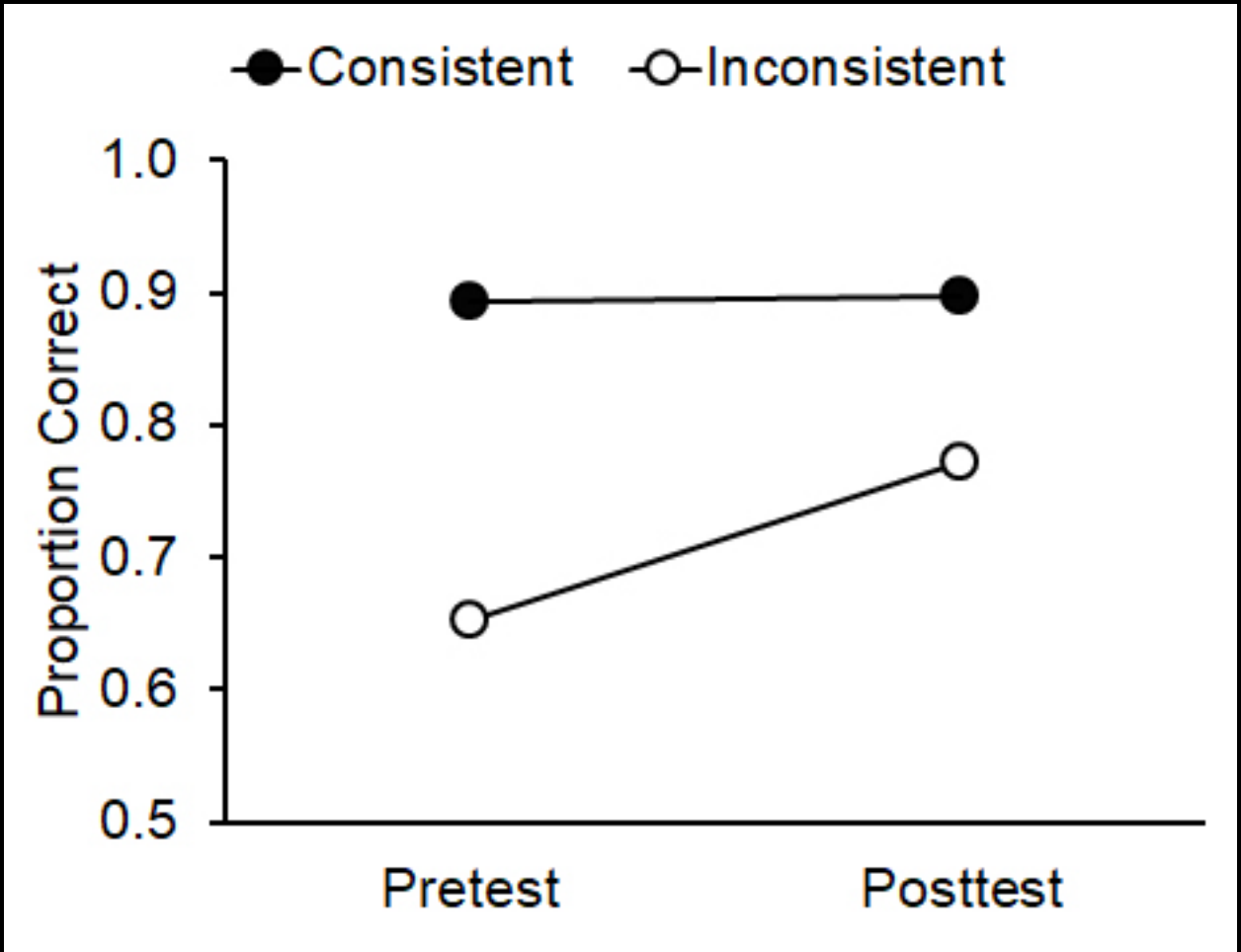
Perhaps the effect of instruction is more potent for those in the midst of constructing a scientific theory.

We administered the same task and the same tutorial to 78 children between 5 and 12 (*M* age = 8.7).

Accuracy: Uninstructed Domain



Accuracy: Instructed Domain



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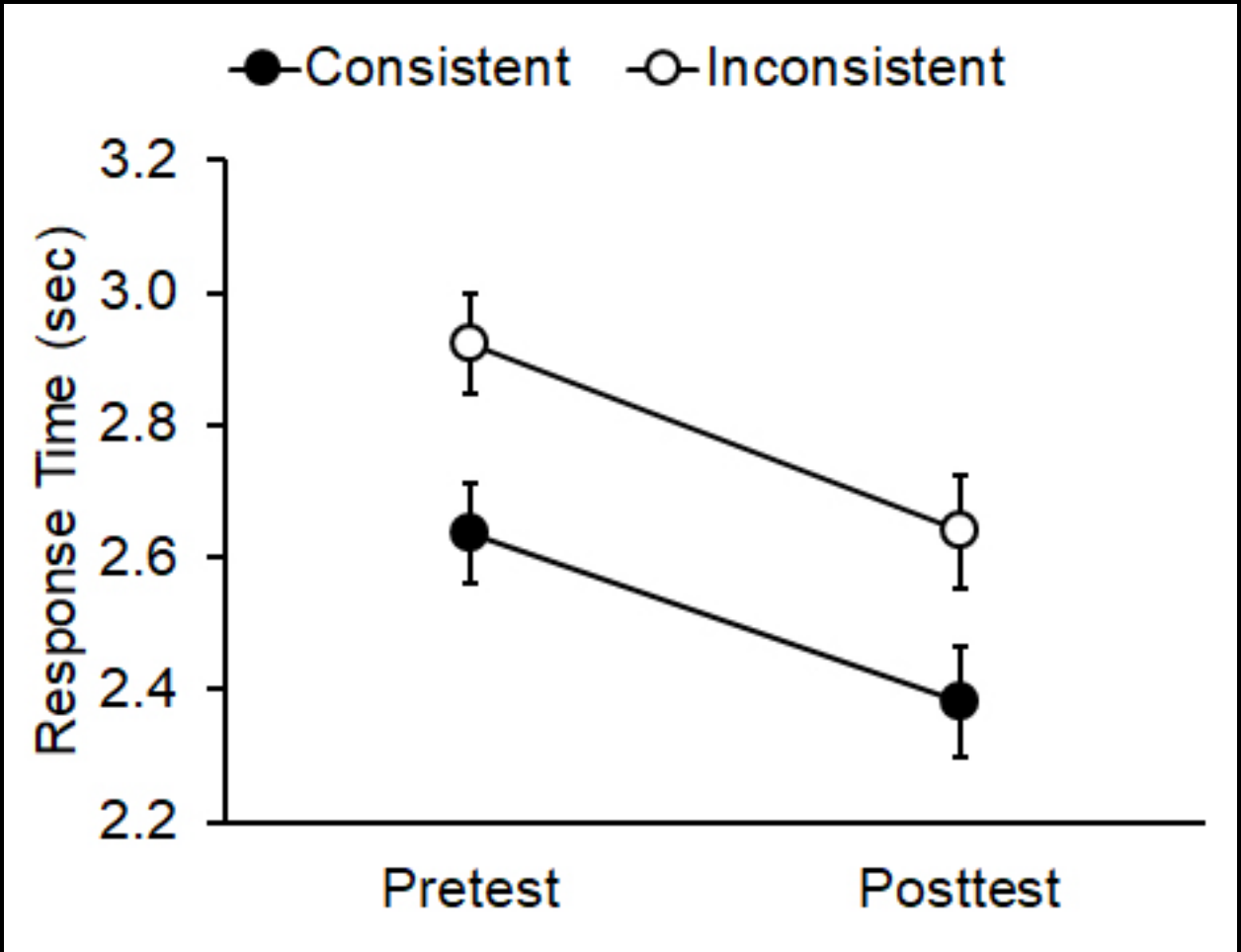

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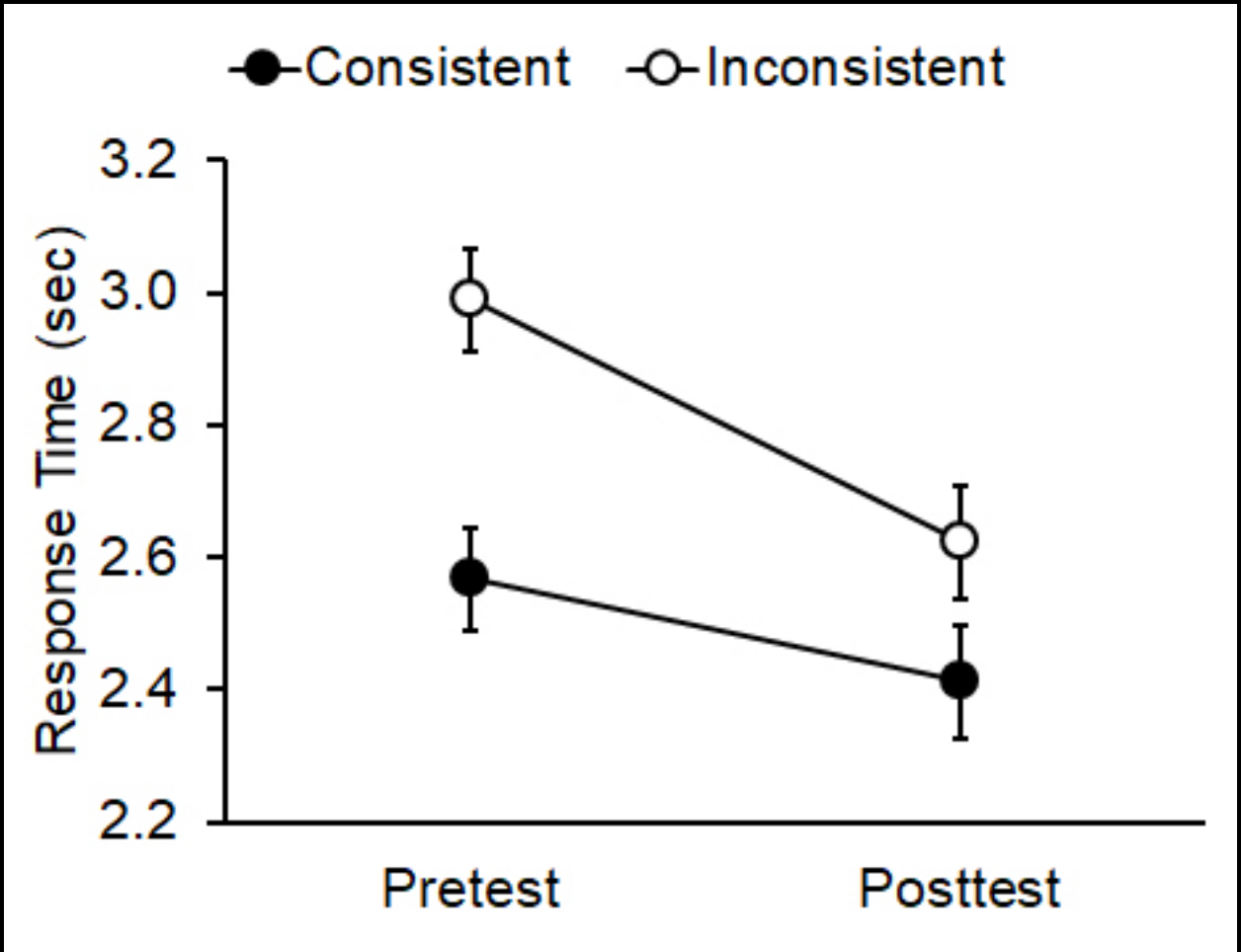

Conclusions

Counterintuitive scientific ideas are verified more accurately given the right:

(1) Context
(2) Instruction
(3) Expertise

But response lags persist, implying that intuitive ideas are elicited automatically and must be suppressed.

Implications

Message from 1980-2010: students hold intuitive theories *prior to* instruction.

Message today: students hold intuitive theories *even after* instruction.

Students need help differentiating beliefs/behaviors based on intuition from those based on science.

Acknowledgments

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References: www.oxy.edu/thinking-lab

Questions?

Sunrise on Mars

i never knew mars had a sun