Dual Processes in Reasoning and Decision Making: Fuzzy Rationality

Valerie F. Reyna,
Departments of Human Development, Psychology, & Cognitive Science
Center for Behavioral Economics and Decision Research
Cornell University

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Overview

- Commonalities and distinctions between fuzzy-trace theory and other dual-process approaches
- Experimental and modeling data support dual processes
- Extends dual processes in new directions

What is fuzzy-trace theory?

- Theory of memory, reasoning, and development
- Memory
  - Gist and verbatim representations (but *independent*)
- Reasoning
  - Rely mainly on gist: Fuzzy-processing preference
- Development
  - Fuzzy-processing preference increases with age and experience

Source	Key Results
Cognitive Psychology (1985)	**Logical and mathematical reasoning dissociated from verbatim memory for problem information. WM capacity predictions violated.**
Developmental Psychology (1988)	**Arithmetic problem solving dissociated from verbatim memory for problem information. WM capacity predictions violated.**
Psychological Science (1990)	**Verbatim memory and gist memory control different aspects of recall.**
Annals of Operations Research (1990)	**Transitive inference dissociated from verbatim memory for premises but associated with gist memory. WM capacity predictions violated.**
Journal of Behavioral Decision Making (1991)	**Decision framing controlled by gist processing; numerical processing interferes with framing illusion. WM capacity predictions violated.**

Source	Key Results
Psychological Science (1992)	Review: Several forms of logical, mathematical, scientific, and pragmatic reasoning are dissociated from verbatim memory and controlled by gist.
Psychological Review (1993)	Process model of relations between verbatim memory, gist memory, and reasoning. Counterintuitive predictions about memory interference in reasoning.
Psychological Science (1990)	Verbatim memory and gist memory control different aspects of recall.
Journal of Experimental Psychology: General (1993)	Cognitive triage: Dual processes predict counterintuitive relations between recall accuracy and retrieval difficulty.
Psychological Science (1994)	Children are less susceptible to framing illusions than adults because they process numerical information rather than problem gist.

Source	Key Results
Developmental Psychology (1994a)	**Dissociation of verbatim and gist memory for narratives. Verbatim memory controls recognition but gist memory controls narrative inference.**
Developmental Psychology (1994b)	**Dissociation of verbatim and gist memory for arithmetic problems. Verbatim memory controls recognition but gist memory controls addition and subtraction.**
Cognitive Psychology (1995)	**Gist memory generates accurate mathematical reasoning but produces memory illusions about problem information.**
Journal of Memory and Language (1995)	**Gist processing foments false memories; verbatim processing suppresses them.**

Source	Key Results
Learning and Individual Differences (1995)	**Integrative theory of dual processes in judgment-and-decision-making, false memory, retrieval, and forgetting.**
Psychological Science (1995)	**Dual processes make counterintuitive predictions about the long-term stability of true versus false memories.**
Psychological Science (1998)	**Dual processes make counterintuitive predictions about the ease of "remembering" false events.**
Psychological Review (1999)	**Mathematical model of dual processes in memory and reasoning.**
Journal of Experimental Psychology: Learning, Memory, and Cognition (2001)	**Dual processes predict counterintuitive phantom recollection in false memory.**

Source	Key Results
Current Directions in Psychological Science (2002)	**Overview of FTT's dual-process principles of memory.**
Journal of Memory and Language (2002)	**Mathematical model of dual processes in recall.**
Archives of Internal Medicine (2001)	**Dual processes predict counterintuitive reasoning errors in physicians decisions about genetic testing.**
Child Development (2002)	**Dual processes predict counterintuitive age trends in false memory.**
Journal of Memory and Language (2003)	**Dual processes predict counterintuitive phantom recollection in recall.**

Source	Key Results
Psychological Review (2003)	**Dual-process theory of false-memory suppression.**
Current Directions in Psychological Science (2004)	**Overview of FTT's dual-process analysis of judgment-and-decision-making.**
Journal of Experimental Psychology: Applied (in press)	**Dual processes prediction counterintuitive relations between medical expertise and use of verbatim details in cardiac treatment. WM predictions violated.**

Examples of Tasks

- Piagetian
  - Class-inclusion
  - Conservation
  - Probability judgment
- Logical reasoning
  - Syllogistic reasoning
  - Transitive inference (linear)
- Pragmatics
  - Spatial inference
  - Metaphorical interpretation
- Judgment and decision making tasks
  - Framing effects
  - Hindsight bias
  - Conditional reasoning (Bayes theorem)
  - Conjunction and disjunction fallacies

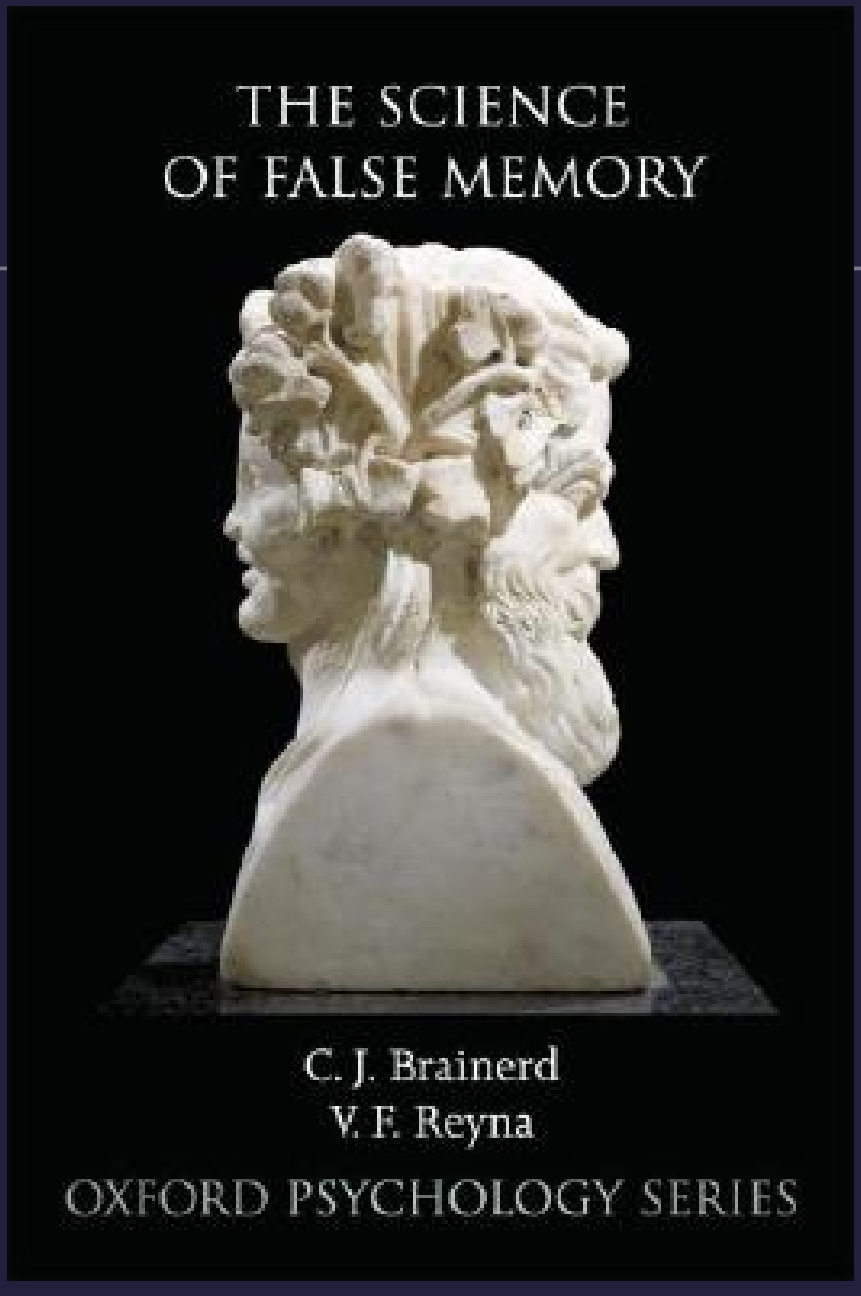
Spatial Inference Task

- Study
  - The bird is in the cage.
  - The cage is under the table.
  - The bird has yellow feathers.
- Test
  - The cage is under the table (verbatim).
  - The cage is below the table (gist paraphrase)
  - The bird is under the table (gist inference).
  - The cage is on the table (false).
- Results
  - Independent recognition of verbatim sentences and gist inferences.
  - Dependent recognition of gist paraphrases and gist inferences.
  - Delay: All gist, positively dependent.
  - Metaphor: All verbatim, negatively dependent.

Memory

- Evidence for core dualistic assumption
  - Gist and verbatim memory representations are encoded, stored, and retrieved independently
  - Data from many tasks, age groups, countries, different labs
- Manipulating dual representations
  - Produced positive dependency, negative dependency, or independence, as theory predicts.
- Modeled mathematically
  - Estimates of independent contributions of verbatim and gist memories, and judgment processes, in a variety of tasks.

Gist



Verbatim

Reasoning and Decision Making

- How do these independent representations affect reasoning?
  - Inference task: Reliance on gist
    - Reason for independence effect
  - Stability, simplicity, resistance to interference: Gist preferred
  - More so with development: Intuition is advanced, but predictable pitfalls
  - Task calibration: Hierarchy of gist

Framing Task

Gain Frame:

- Program A: 200 people saved.
- Program B: 1/3 probability that 600 people will be saved and 2/3 probability that no one will be saved.

Loss Frame:

- Program C: 400 people die.
- Program D: 2/3 probability that 600 people will die and 1/3 probability that no one will die

Gist of Framing

Gain:

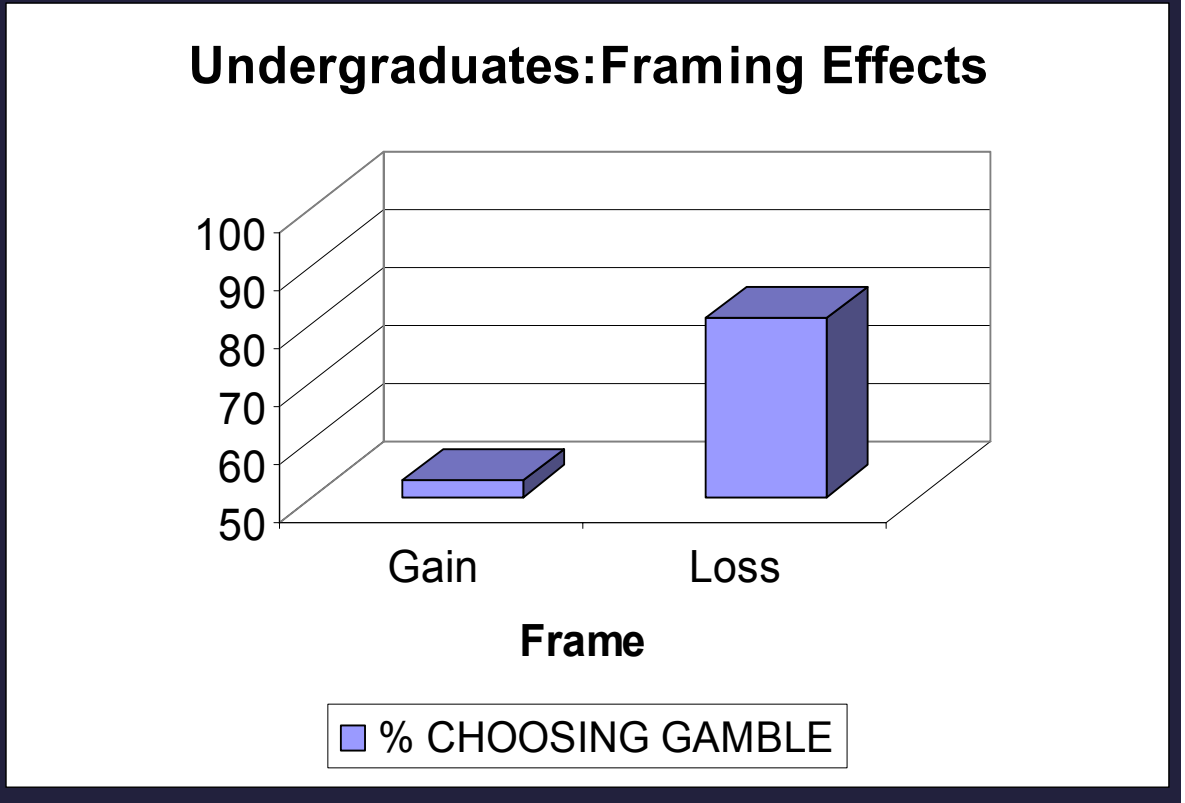
- A. Save some people.
- B. Save some people or save none.
  - *Saving some people better than saving none.*

Loss:

- C. Some people die.
- D. Some people die or none die.
  - *None dying is better than some dying.*

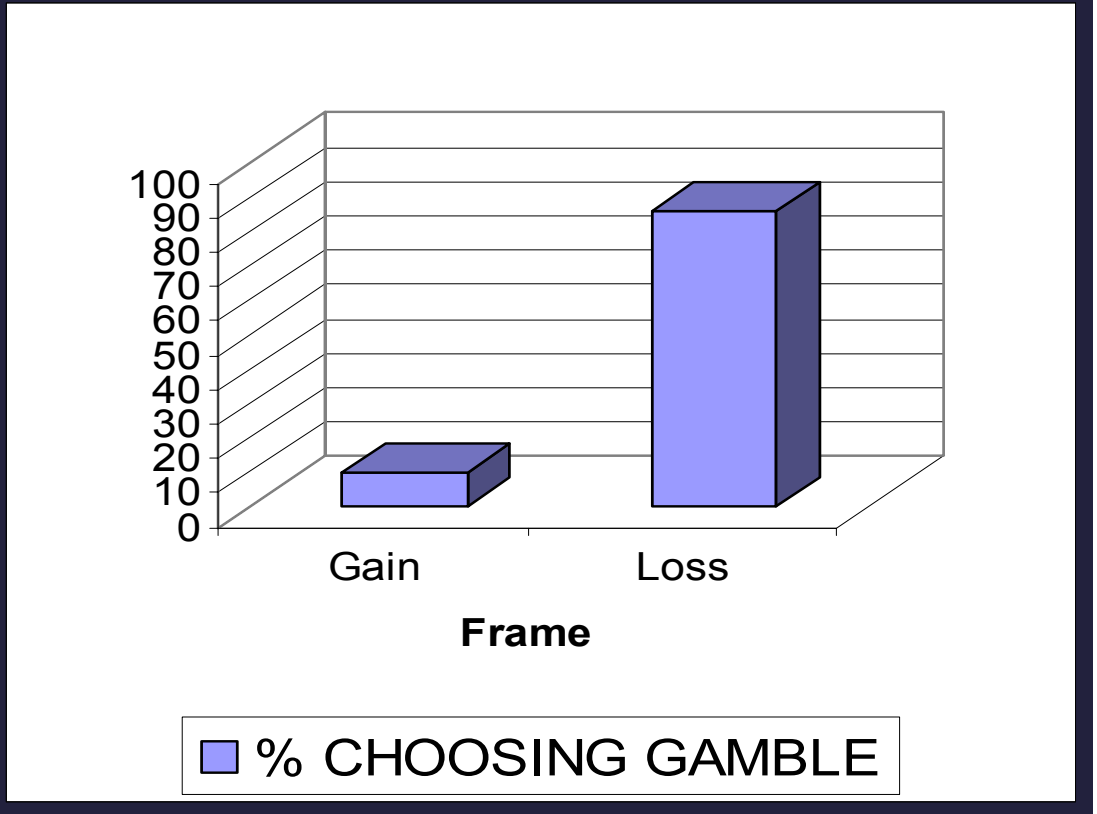
Framing Effect

- Disease problem
- Business majors
- Between subjects



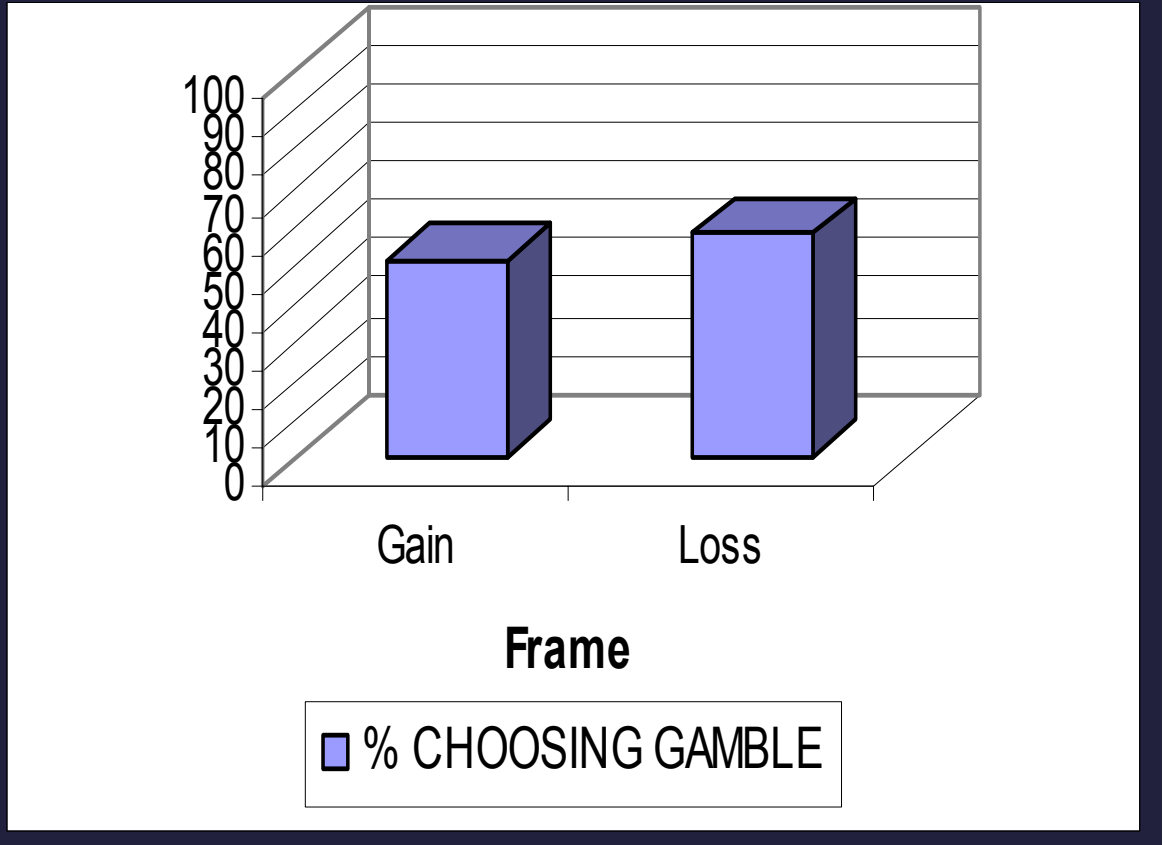
Numbers Deleted

- Disease problem
- Education majors
- Between subjects



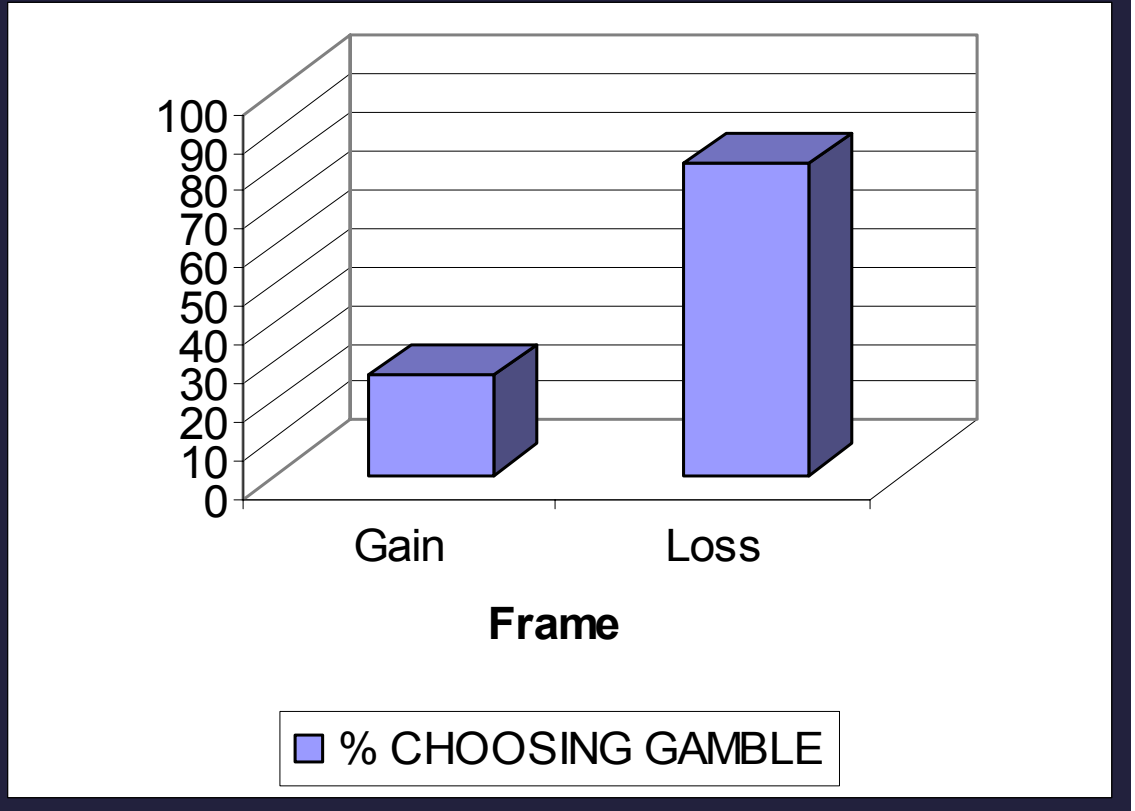
Selective Processing: Numbers

- Disease problems
- Business majors
- Between subjects

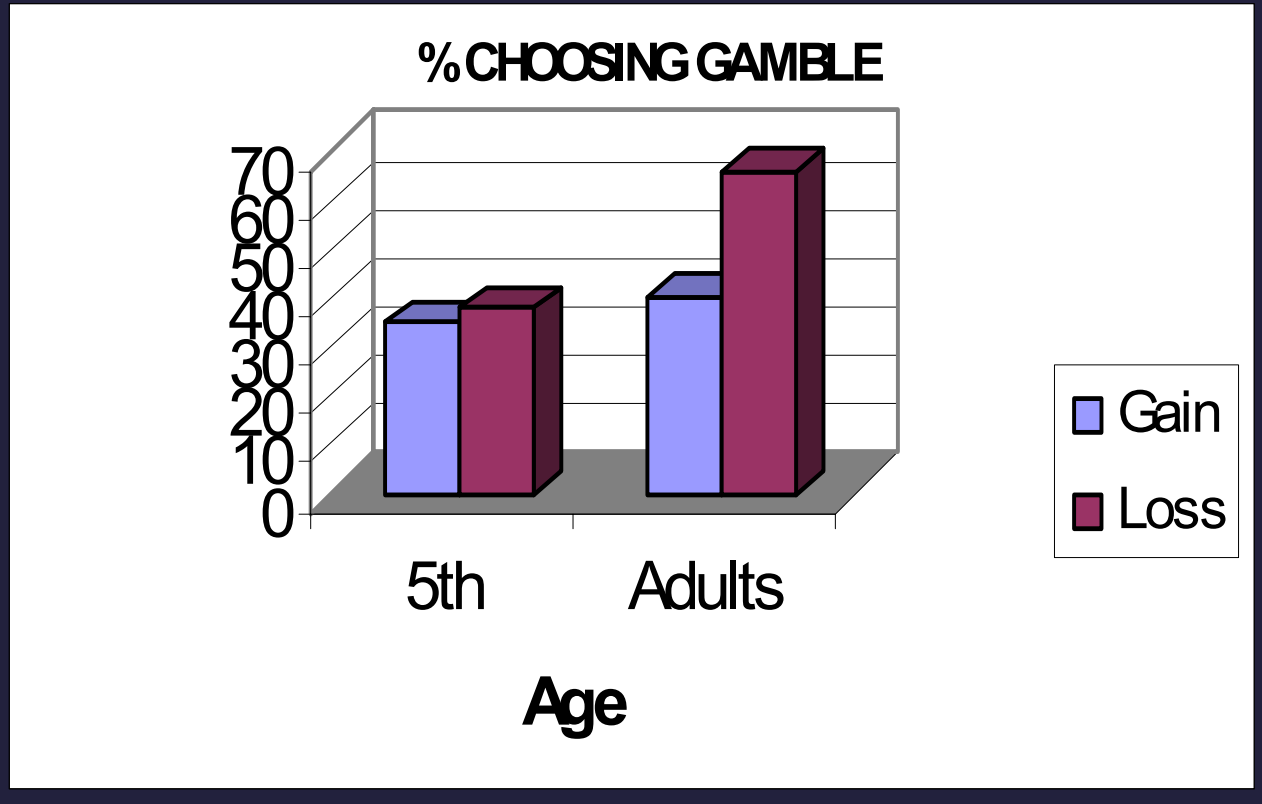


Selective Processing: Zero Complement

- Disease problem
- Business majors
- Between subjects



Framing: Development



Reasoning: Inclusion Illusions

- Conjunction fallacy
- Syllogistic reasoning
- Conditional reasoning
  - Many other cognitive illusions
- Overlapping classes
  - Part-whole confusions
- Focus on target class
- Neglect parentheticals (denominators)
- Remedy: Disentangle overlapping classes
  - Not logic, memory, or conceptual problem

Probability Judgments

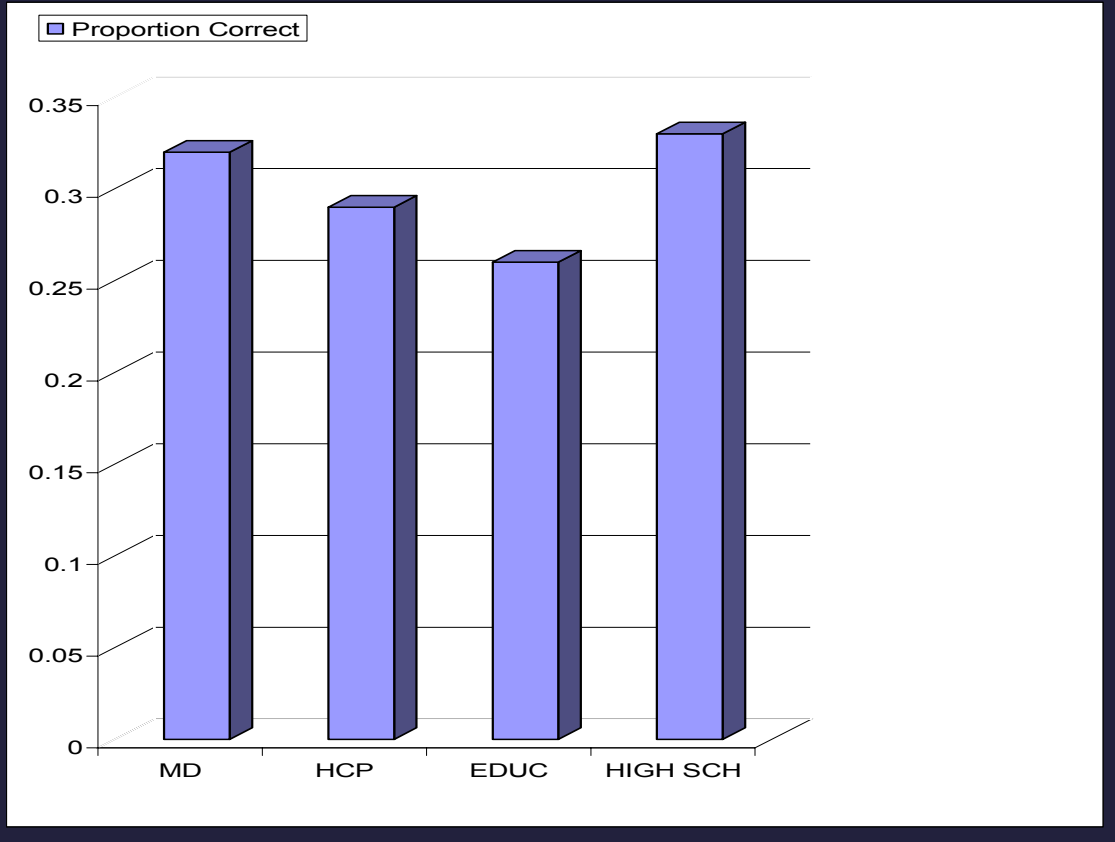
- Judgments involve a target class (patients who had treatment and survived) and larger, more inclusive class (patients who had treatment).
- People compare target events and automatically extract the gist of which class is "bigger."
- Part-whole interference (inclusion illusion)
- Neglect non-targets (did not survive) and hence the more inclusive class, the "denominator."
- Result: ***Denominator neglect***

Overestimation of Low Risks

- Risks of smallpox vaccination (1978):
  - 8 deaths per 2.05 X 10^8 U.S. residents
  - Subjects estimated 23 deaths per 2.05 X 10^8 U.S. residents
- Risks of smallpox vaccination (Associated Press, March 29, 2003):
  - 17 with heart problems per 25,000 vaccinated
  - “Despite the low numbers,” the Institute of Medicine says vaccination is sufficient for terror attack; two states suspended programs.
- It’s the large denominator that makes the risks low.

Denominator Neglect: Knowledge, Experience Little Effect

10% prevalence rate
80% with disease have + test;
80% with no disease have – test
Positive result: 30% or 70% chance of disease?



Explanation and Intervention

- Pre-test probability = 1 out of 10
  - D NN NNNNNNN
- + ++ - - - - - - -

  D NN NNNNNNN
- 1D out of 3 +’s
- Intervention virtually eliminated errors

Conjunction Fallacy

- Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

Rank in terms of probability

- Linda works in a bookstore.
- Linda is active in the feminist movement.
- Linda is a psychiatric social worker.
- Linda is a bank teller.
- Linda is an insurance salesperson.
- Linda is a bank teller and is active in the feminist movement.

- Retrieval *and* processing difficulties

Classes Distinct: Estimate P(BT & F); P(BT or F)

	Bank teller YES	Bank teller NO
Feminist YES	Both	Fem not BT
Feminist NO	BT not Fem	Neither

Testing Processing Hypothesis

General Method for 3 Experiments

- Scenarios like Linda example
- Vary Set Relations:
  - Overlap, Subset, Identical, Mutually Exclusive
- Vary analogy, or table, or both
- Replication: 2 scenarios for each set relation
  - 2 replications X 4 sets = 8 scenarios
- Different random order of scenarios
- Judgments: P (A); P (B); P (A & B); P (A OR B); P (Z)

Experiments

- Experiment 1
  - N = 62
  - Analogy (that corresponds to set relation): Found effect
- Experiment 2
  - N = 123
  - Analogy X Table: Effect of both on accuracy; Table on fallacies
- Experiment 3 (Web)
  - N = 140
  - Table on both accuracy and fallacies

Analogy and Table: Increase Accuracy

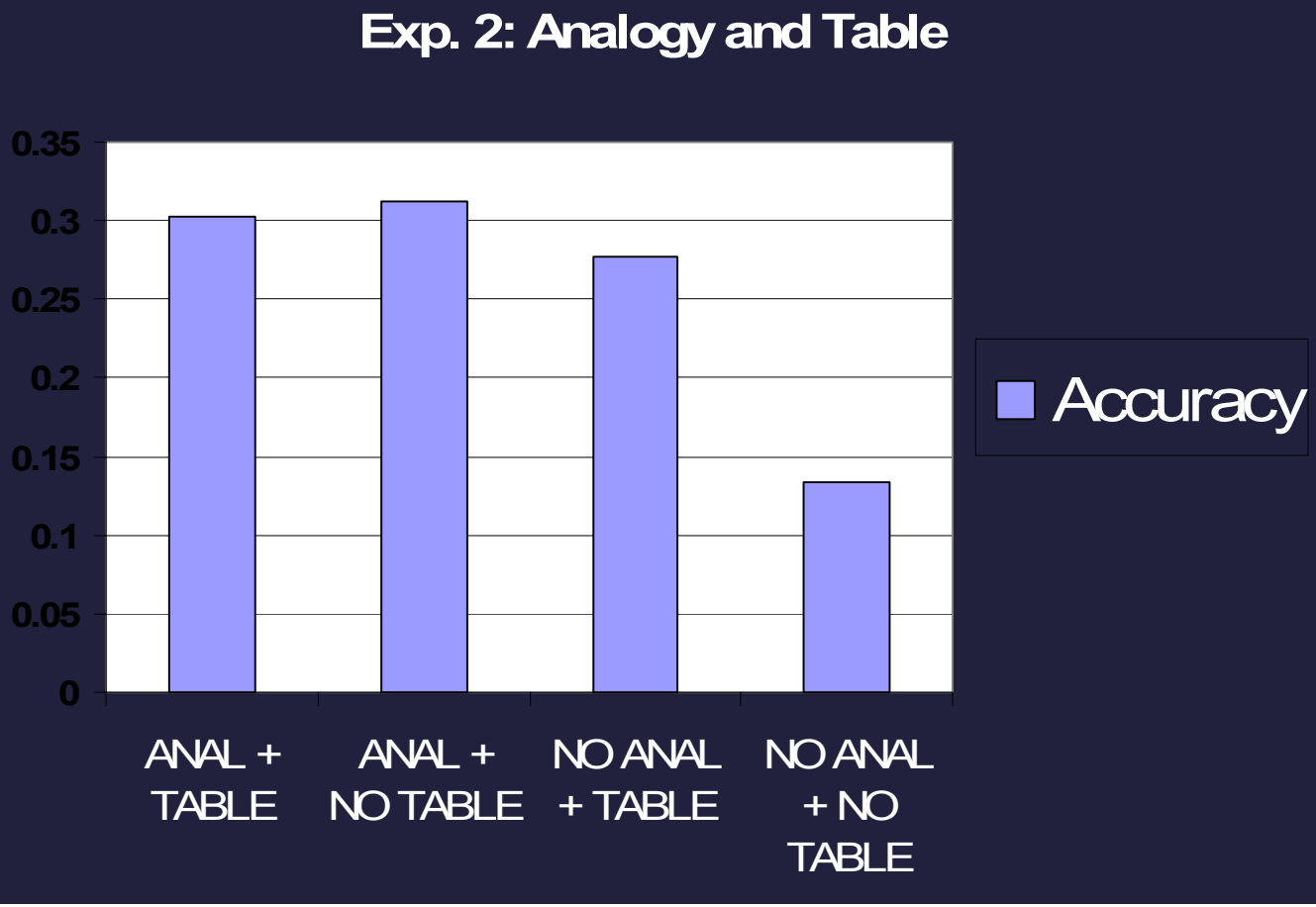
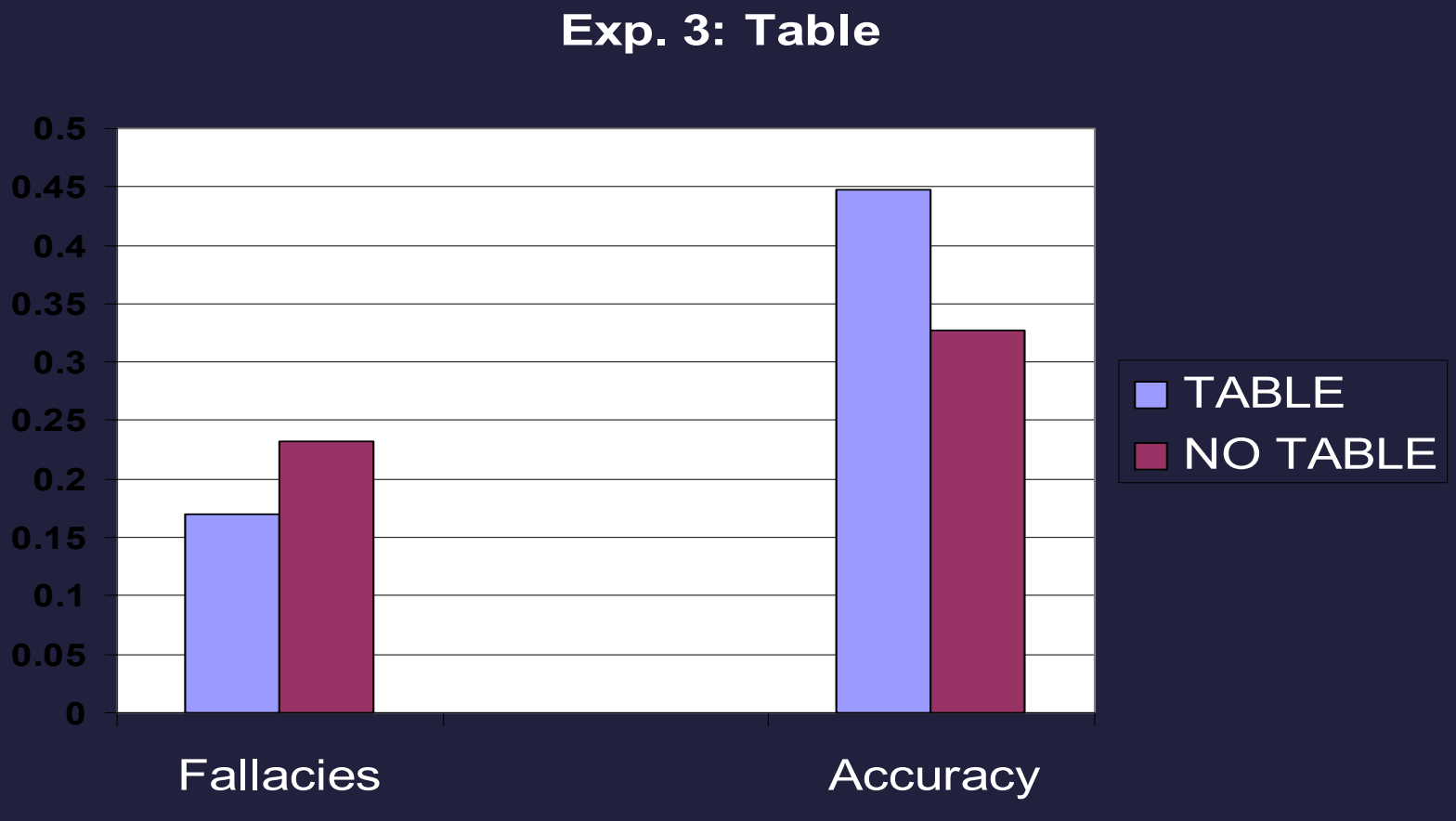


Table: Decreases Errors

Table: Decreases errors, increases accuracy



Core Evidence for Dual Processes

- Most basic level
  - Dissociations between two forms of memory
    - Verbatim and gist
- Highest level
  - Dissociations between two forms of reasoning
    - Computational and intuitive solutions
    - Ex: Better memory, poorer reasoning in class inclusion reasoning
    - Ex: Pictures improve memory, but hurt reasoning in transitive inference
    - Ex: Larger framing effect when strip away the numbers
      - Intuitive reasoning, not computational
- Dual processes from top to bottom

Commonalities

- Analytical, quantitative, and operates on precise memory representations toward the verbatim end of a continuum

- Intuitive, qualitative, and operates on gist representations toward the fuzzy end of the continuum

Distinctions

- Jacobs & Potenza (1991) —representativeness
  - Base rate in 1st grade-behavior not verbal justifications
  - Bias increased-1st grade to college
- Reyna & Brainerd (1994)—probability
- Reyna & Ellis (1994)—framing
- Davidson (1995)—conjunction fallacy
- Markovits & Dumas (1999)—transitivity bias (Reyna & Brainerd, 1990: competence present)

- Intuitive processing increases with development, despite analytic competence

Reasoning: Developmental Paradox

- Early precocity
  - Reasoning competence present in first graders
- Increasing cognitive illusions with age
  - Framing, representativeness heuristic, availability heuristic, transitive inference, etc.

Fuzzy-trace theory

- Intuition defined as an advanced mode of thought
- Explains how the same intuitive processes that make reasoning more reliable, and hold the key to rationality, also make biases more reliable

Expertise: Fuzzy-trace Theory

- Alternative approach to rationality
  - Higher quality decisions are typically simpler, i.e. gist-based
    - In contrast to computational approach, i.e. greater precision and complexity
  - As expertise develops, decision processes become simpler
  - Processing interference remains for advanced reasoners

Example: Medical Decision Making

- Presented 9 patient profiles at varying levels of risk to 75 physicians and students
- Patients varied in risk of acute myocardial infarction (AMI) and likelihood of coronary artery disease (CAD)
- Physician judgments of risk of AMI (heart attack), CAD (coronary artery disease), and triage admission decisions

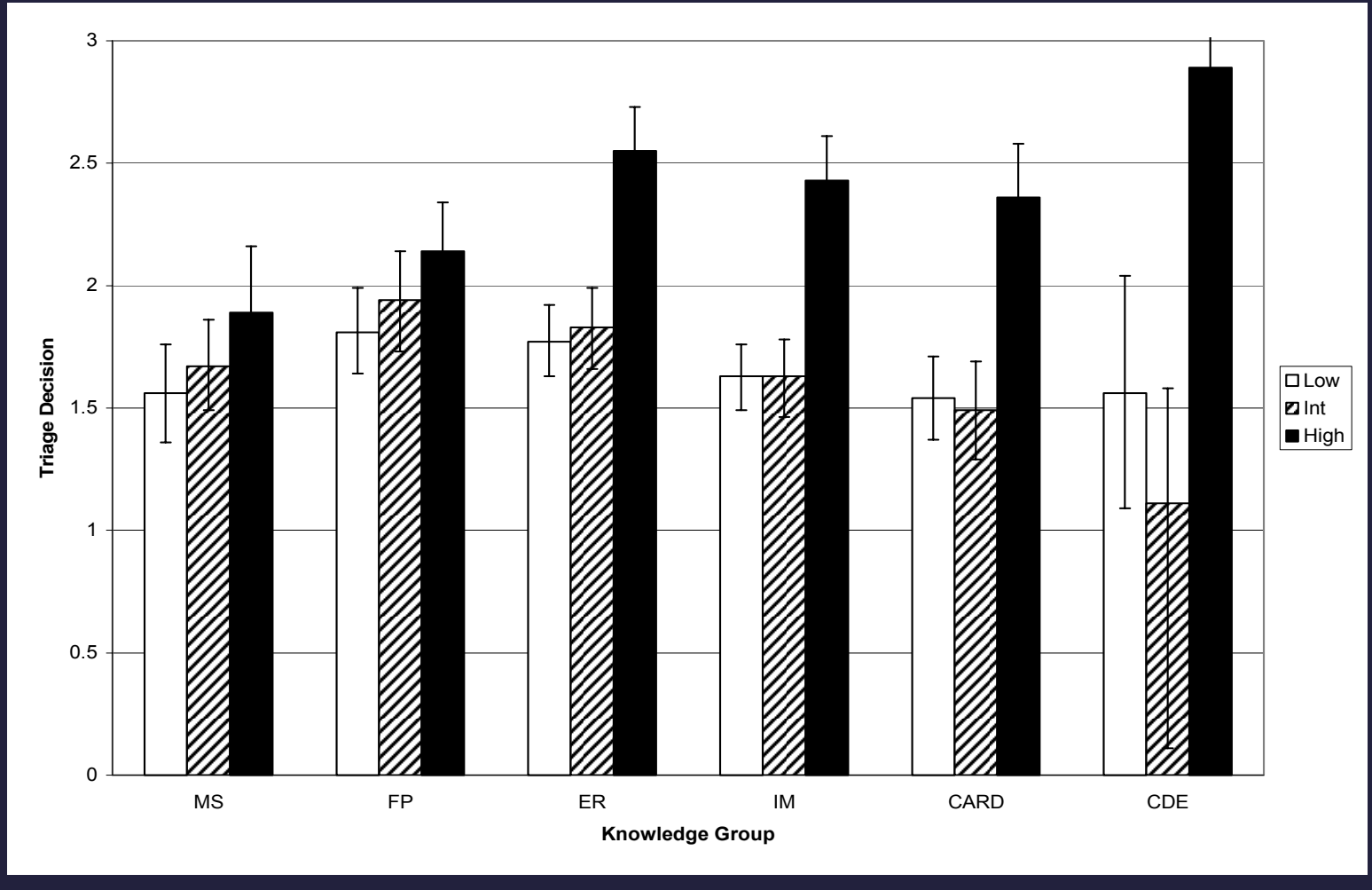
Physician Selection

- Cardiology-- 13
- Internal Medicine-- 21
- Family Practice-- 12
- Emergency Medicine-- 20
- Medical students-- 9

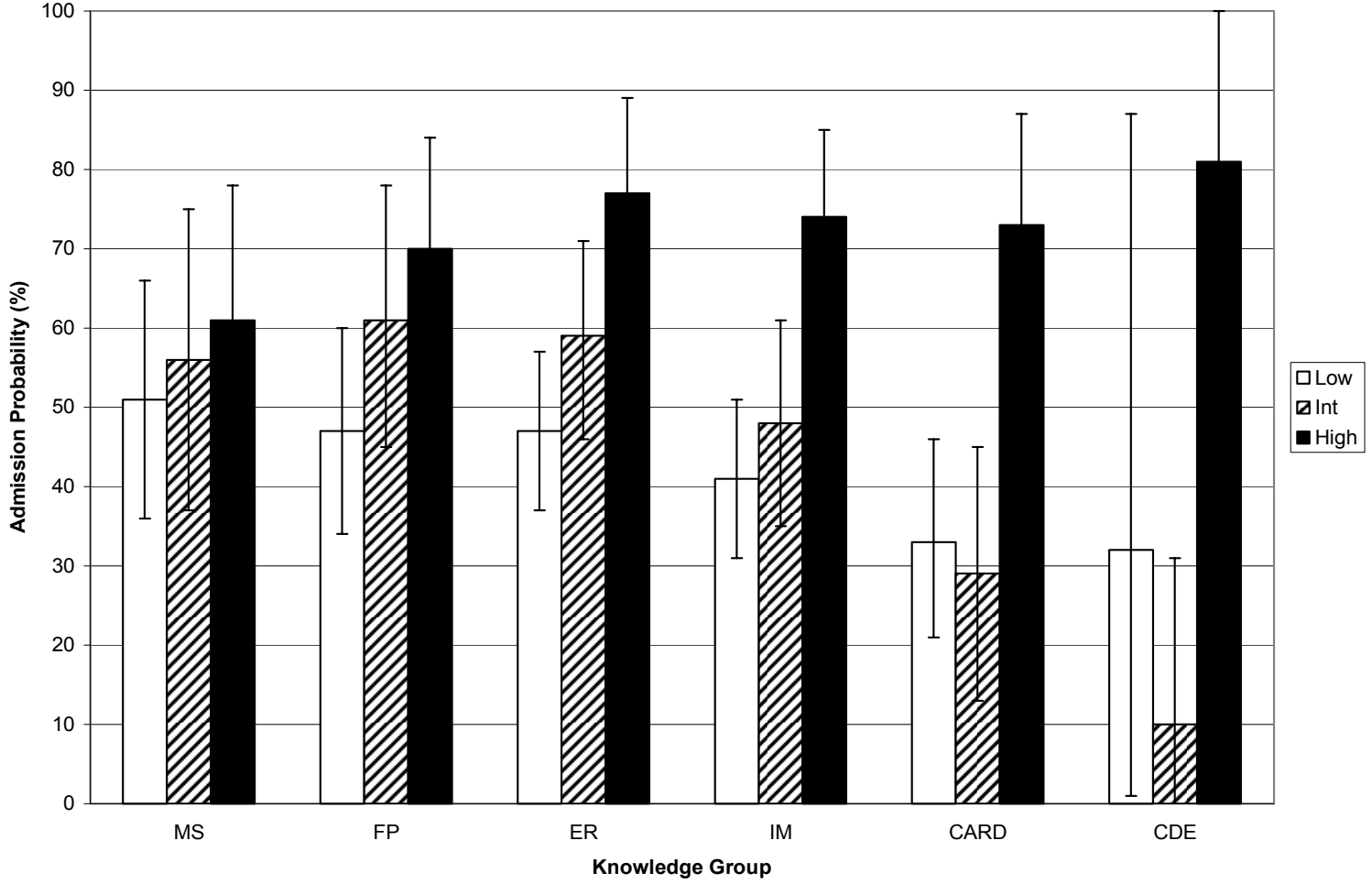
Patient Profiles

- Three patient profiles at each of three levels of overall risk
  - Low, intermediate, and high
- Key patient characteristics such as age, gender and type of chest pain were varied

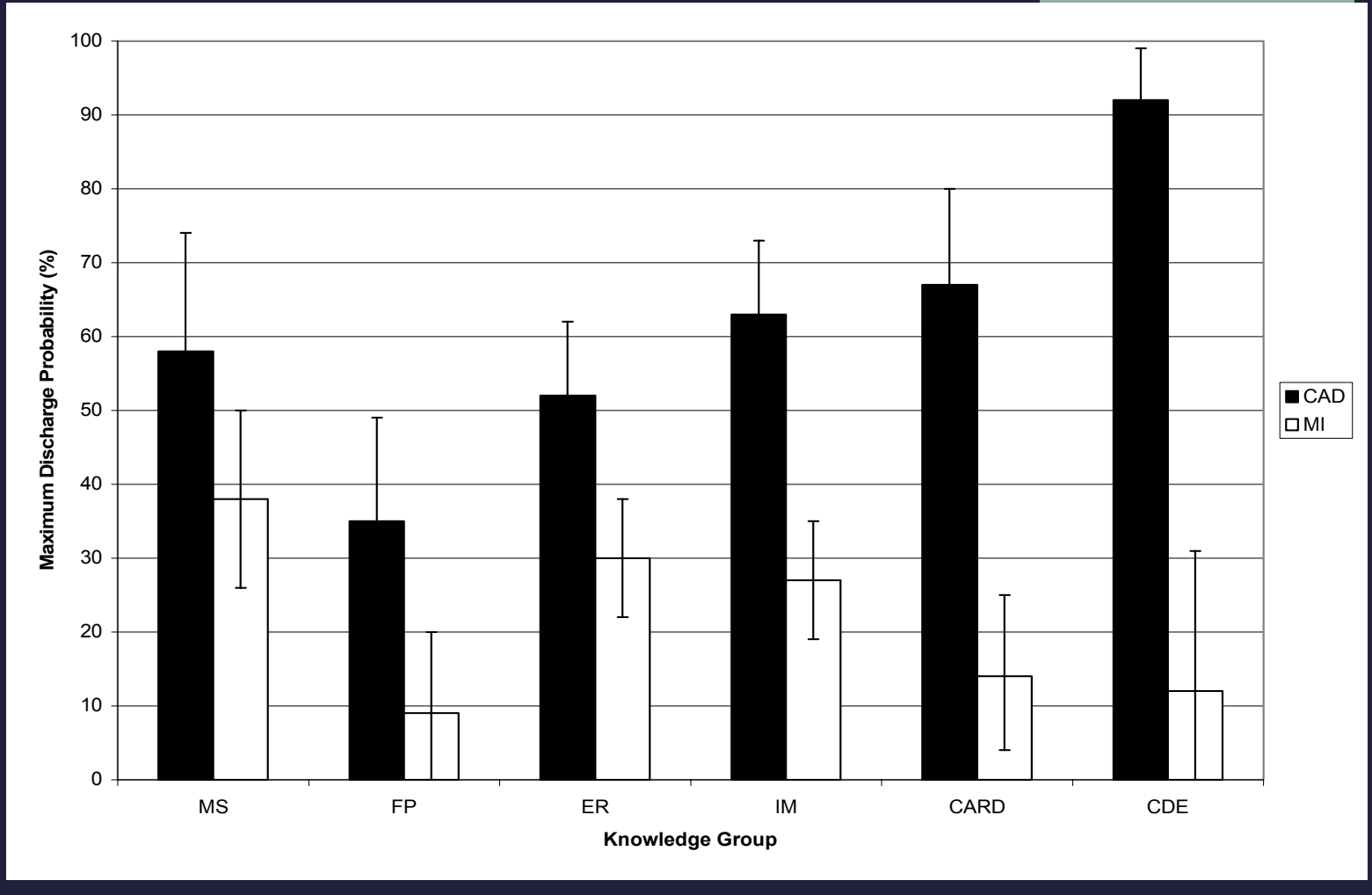
Higher Knowledge, Better Discrimination



Higher Knowledge, Better Discrimination



Higher Knowledge, Fewer Dimensions



Correlations between Estimates of Risk of Heart Attack (MI) and Probability of Coronary Artery Disease (CAD) with Admission Probability and Admission Decision (Level of Triage) for Groups Differing in Knowledge of Cardiovascular Disease

Knowledge Group	Admission Probability		Admission Decision	
	CAD	MI	CAD	MI
Students	.85**	.88**	.78**	.85**
Family Practice	.68*	.95**	.57	.96**
Emerg Medicine	.92**	.97**	.73*	.82**
Internal Medicine	.87**	.93**	.76*	.86**
Cardiology	.62	.93**	.63	.95**
Cardiology Experts	.10	.83**	.34	.95**

Intuition: Advanced

- Higher knowledge groups relied on fewer dimensions of information than lower knowledge groups.
- Experts made sharper all-or-none distinctions among decision categories.
- Consistent with fuzzy-trace theory, experts achieved better discrimination by processing less information, more crudely.

Matching: Wason Card Task

- Matching bias (Evans, 2003)
  - If vowel on one side, odd number on the other.
    - Turn over A and 7 (wrong)
  - If vowel on one side, there is not a 3 on the other.
    - Turn over A and 3 (right)
- Superficial matching explains both response patterns

Matching Explanation: FTT

- Superficial match = Verbatim processing
  - Impoverished gist (A's, 7's)
  - Like adding when word "more" or "together" appear anywhere in a mathematical word problem
- When materials are meaningful, rely on gist
  - Deontic, causal scenarios facilitate reasoning
  - Counterfactual scenarios interfere with reasoning
- Gist = CONTENT (meaning)
  - NOT abstract in sense of no content
- Rely on gist in reasoning, except when no gist

Process Models of Tasks in FTT

- Knowledge of content and reasoning principles
- Representations used in reasoning
- Retrieval of knowledge of content and reasoning principles (+self-correction)
  - Reasoning principles are gisty (vague)
- Application of principle to representation
  - Subject to interference
- Each of these processes shown to contribute independently to processing
  - Not just about representations

Further Distinctions

- Intuition is not S-R association, but is often automatic or unconscious (Sloman, 2002)
  - Serial as well as simultaneous dual processes = Task variability
- Intuition is not affect (Peters, Slovic), although accounts for same results
- Risky reactor (impulsive) is not risky calculator (Reyna & Farley, in press; Stanovich, 2004)
  - Evolutionary pressures-not smart in risk taking
- Emotion facilitates gist, interferes with verbatim, acts as cue to retrieve values and reasoning principles, and interferes with processing

Summary

Fuzzy-Trace Theory: Dual Memories

- Theory of memory, judgment, and decision making
- People have both verbatim and gist memories, but rely on gist.
- Evidence:
  - Manipulating either or both forms of representation produced positive dependency, negative dependency, or independence, as predicted.
  - Modeled mathematically to secure estimates of the contributions of verbatim and gist memories, and associated judgment processes, in a variety of tasks.

Fuzzy-Trace Theory: Dual Reasoning

- Verbatim, precise, analytic *vs*. gist, fuzzy, intuitive
  - Reasoning ≠ logic.
- Intuitive gist vs. decision analysis
- Gist is more advanced

Traditional: Intuition Primitive

- Intuition precedes analysis in childhood.
- Endures into adulthood as a vestigial, primitive processing mode.
- Biases in risk perception and decision-making—steeped in emotion—are attributed to this primitive mode.

Problems for Traditional Dual Processes

- Intuitive biases emerge with age and advanced development;
- Advanced reasoners often prefer intuition despite demonstrated analytic competence;
- Emotion can aid rational decision-making.
  - Emotion can also be a pitfall.
- Computation source of risk taking

Resolution of Problems of Traditional Dual Processes

- Support for many commonalities with traditional dual processes
- Theoretical resolution of conflicts with evidence now well established by multiple lines of evidence.
- Children to adults; novices to experts
  - Progression from detail-oriented and computational (trading off the magnitudes of risk and reward) → fuzzy and intuitive (processing less information more qualitatively).
  - Example: 75 physicians
- Many tasks, experimental control: Data
- Not more logical, computationally complex.

Distinctions: Dual Processes

- New View: Intuition not computation
  - Best decision makers use simple gist
  - Avoid trading off, increasingly as mature and gain experience
    - Russian roulette example
- Dual processes
  - Gist: Fuzzy processing preference
  - Verbatim: Can operate precisely, but not preferred

Connections

- Thompson-predictive power?
  - Yes, specific tests of counterintuitive predictions
- Keren & Schul-isolatable?
  - Yes, sensitive tests of stochastic dependence and tests of models incorporate assumption
  - Yes, much evidence available-FTT
- Klaczynski
  - FTT predicts children outperform adults under specific conditions
  - Tests IP constraints (not WM)
  - Explains why intuitive processing increases with age (core assumption)
    - More stable, interference-resistant, easier to manipulate
- Lieberman
  - Neuroscience underpinnings of FTT
  - Affect is gist
- Toates
  - Explicitly reconciles constructivism and learning theory traditions

Intuitionism

Reasoning is more like understanding poetry than it is like doing logic.

(Reyna & Kiernan, 1995, p. 328)

When you are doing it well**...**

- otherwise verbatim matching (rote or literal as opposed to gist-based or meaningful)