Rational Inattention in Economic Choice

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Attentional and Perceptual Foundations of Economic Behavior
Inaugural Symposium

Claims

1. Attention is a scarce resource in economic choice
2. Incentives affect the information that people gather
3. Models of 'rational inattention' capture the trade offs in attentional choice
4. 'State dependent stochastic choice' data are great for testing models of inattention
5. We have made progress in understanding the behavioral implications of rational inattention
6. There are many open questions and much work still to be done

Outline

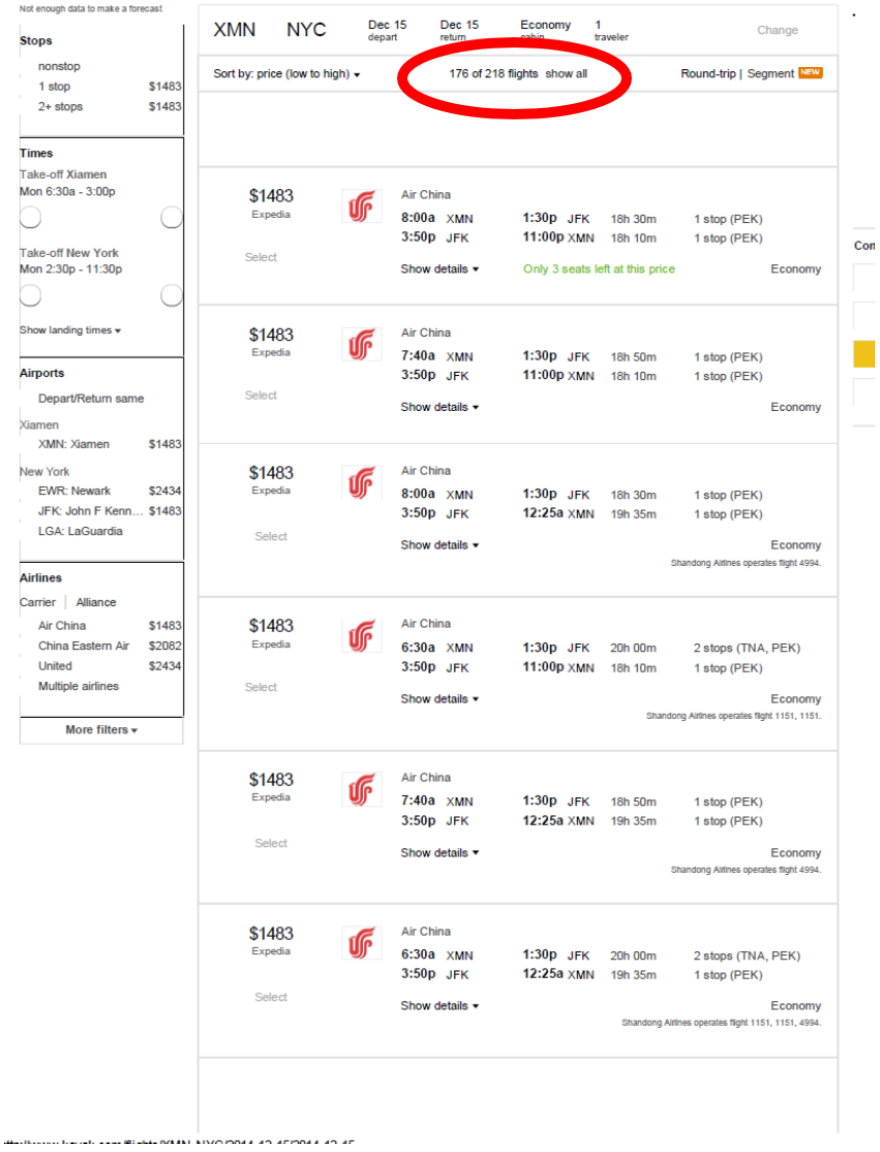
Attention is a Scarce Resource

- Attention: Actively processing specific information in our environment
- **Claim:** Attention is a scarce resource in economic choice
    - People may not make use of all available information when making a choice

Attention is a Scarce Resource

- This is
  - **Intuitively extremely plausible**
  - Clear in empirical studies
  - Replicable in the laboratory

Attention is a Scarce Resource



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Salience and Taxation: Chetty et al. [2009]

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- Adding tax to the posted price reduces sales by about 8%
- Despite the fact people can accurately report tax rate if asked

Other Examples

- Changes in alcohol taxes included in posted prices have more effect than those applied at the register
  - Chetty et al. [2009]
- People fail to choose efficient plans in Medicare Part D
  - Abaluck and Gruber [2011]
- People make suboptimal choices in 401k retirement plans
  - Choi et al. [2011]
- Limited information search during internet purchases
  - De Los Santos et al. [2012]

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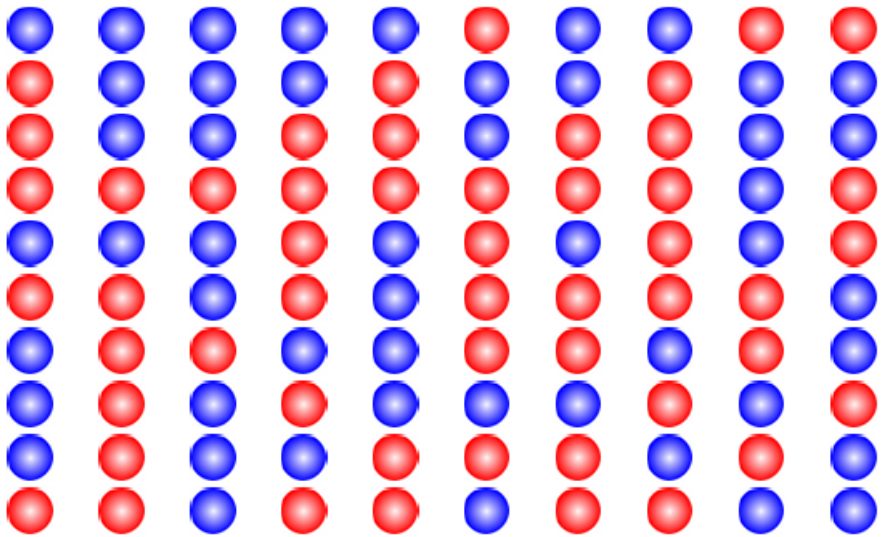
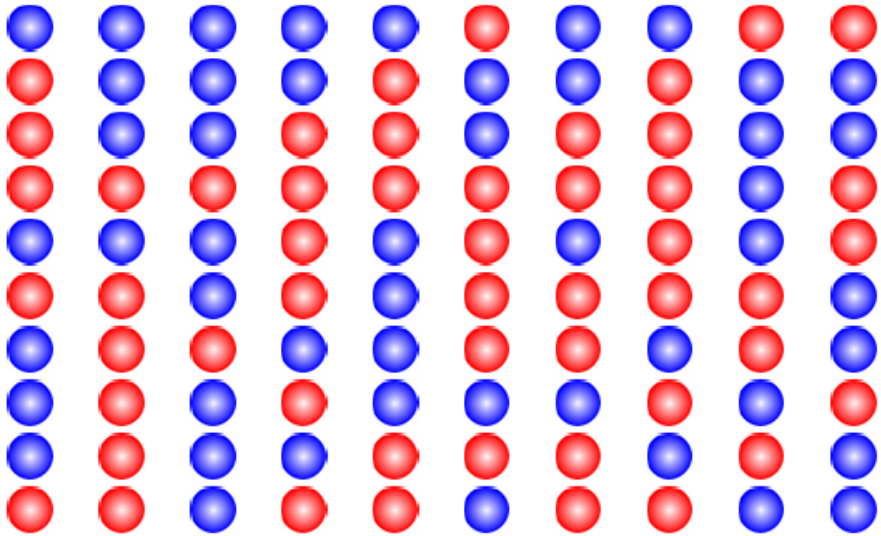
An Experimental Example



- Subjects presented with 100 balls
- State is determined by the number of red balls
- Prior distribution of red balls known to subject

An Experimental Example



Action	Payoff 49 red balls	Payoff 51 red balls
a	10	0
b	0	10

- No time limit: trade off between effort and financial rewards
- Probability of choosing the correct action c. 70%

Outline

Attention and Incentives

- People display limited attention when making economic choices
- But will **adjust** what they pay attention to in response to perceived incentives

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- **Example 1: Discrimination** [Bartos et al. 2016]
  - Sent housing applications to landlords and job applications to employers
  - Randomized names to be traditionally white majority or Roma minority
  - Tracked whether applicant's CV was viewed
  - Roma CVs significantly more likely than 'White' CVs to be viewed in the housing case
  - Not so in the employment case

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- **Example 2: Inflation forecasting**
  - Inflation is much more volatile in Iran than New Zealand, making it more important for firms to keep track of
  - Firms have more precise inflation expectations in Iran than in New Zealand [Afrouzi 2017]

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  - Professional forecasters in Brazil make more accurate forecasts when taking part in a contest [Gaglianone et al. 2017]

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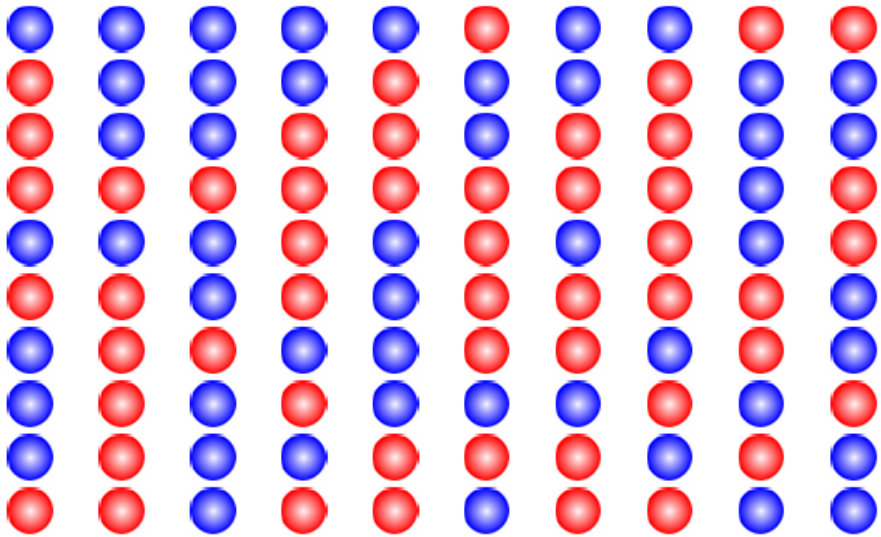
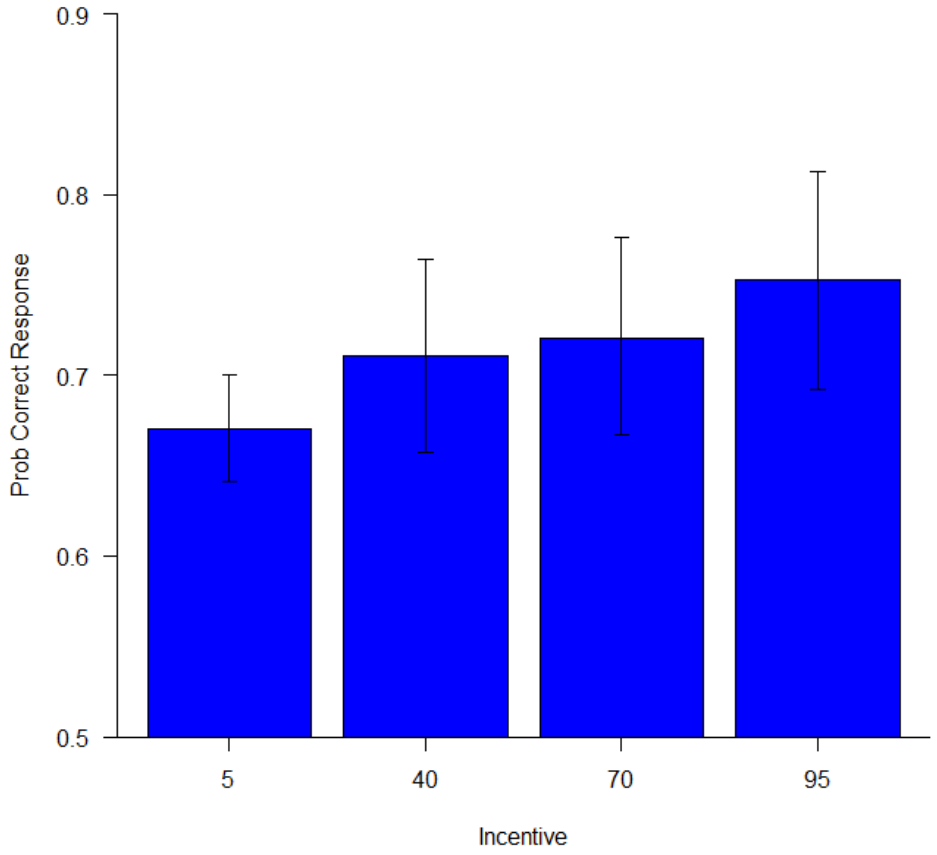


Action	Payoff 49 red balls	Payoff 51 red balls
a	x	0
b	0	x

Experiment				
Decision Problem	Payoffs			
	$U(a,1)$	$U(a,2)$	$U(b,1)$	$U(b,2)$
1	5	0	0	5
2	40	0	0	40
3	70	0	0	70
4	95	0	0	95

Attention and Incentives



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- In order to capture this behavior, we want a model that
  - Recognizes attentional limits
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The Rational Inattention Model

- In order to capture this behavior, we want a model that
  - Recognizes attentional limits
  - Allows attention to respond endogenously to incentives
- Rational inattention is one such model
- Attention allocation modelled as optimal choice
- Consumers choose information in order to maximize benefits net of costs
  - Benefits: better subsequent choices
  - Costs: cognitive resources, time costs, etc.

The Rational Inattention Model

- The decision maker wants to learn about the state of the world
  - Quality of a flight
  - Price of an item
  - Inflation rate
  - Number of red balls on the screen
- Because they will subsequently have to choose an alternative
  - Buy a flight
  - Set prices of their own good
  - Make a forecast
  - Pick an experimental option
- Incentives to learn because the utility of different options depends on the state of the world
  - Different sets of options leads to different incentives

- The specifics of the process of information acquisition may be very complex

The Rational Inattention Model

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- Rational Inattention models the choice of information in an *abstract* way
- The decision maker chooses an *information structure*
  - Set of signals to receive
  - Probability of receiving each signal in each state of the world

The Rational Inattention Model

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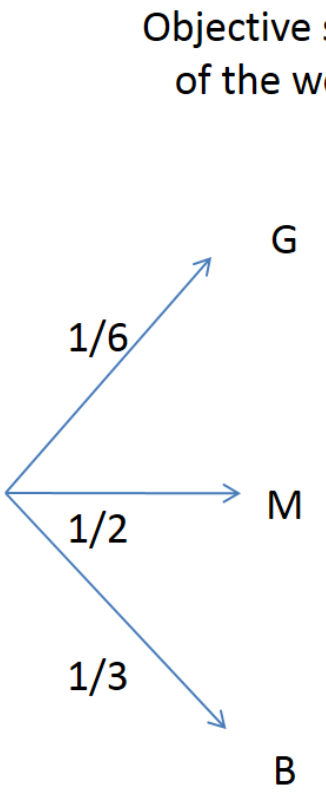
- Rational Inattention models the choice of information in an *abstract* way
- The decision maker chooses an *information structure*
  - Set of signals to receive
  - Probability of receiving each signal in each state of the world
- While this appears abstract
  - Specific information gathering strategies give rise to information structures
  - Can be thought of as a special case of this model

The Choice Problem



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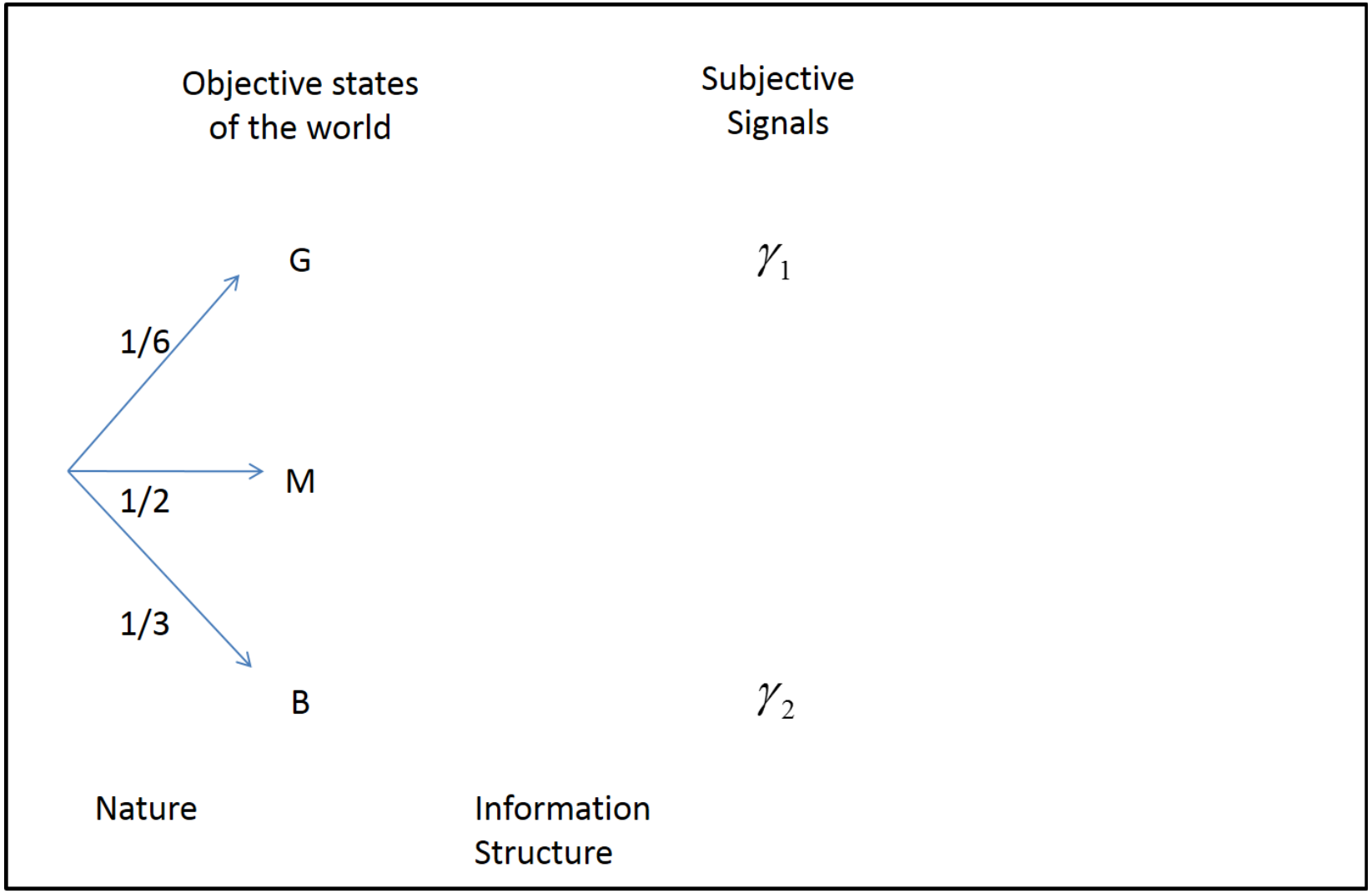

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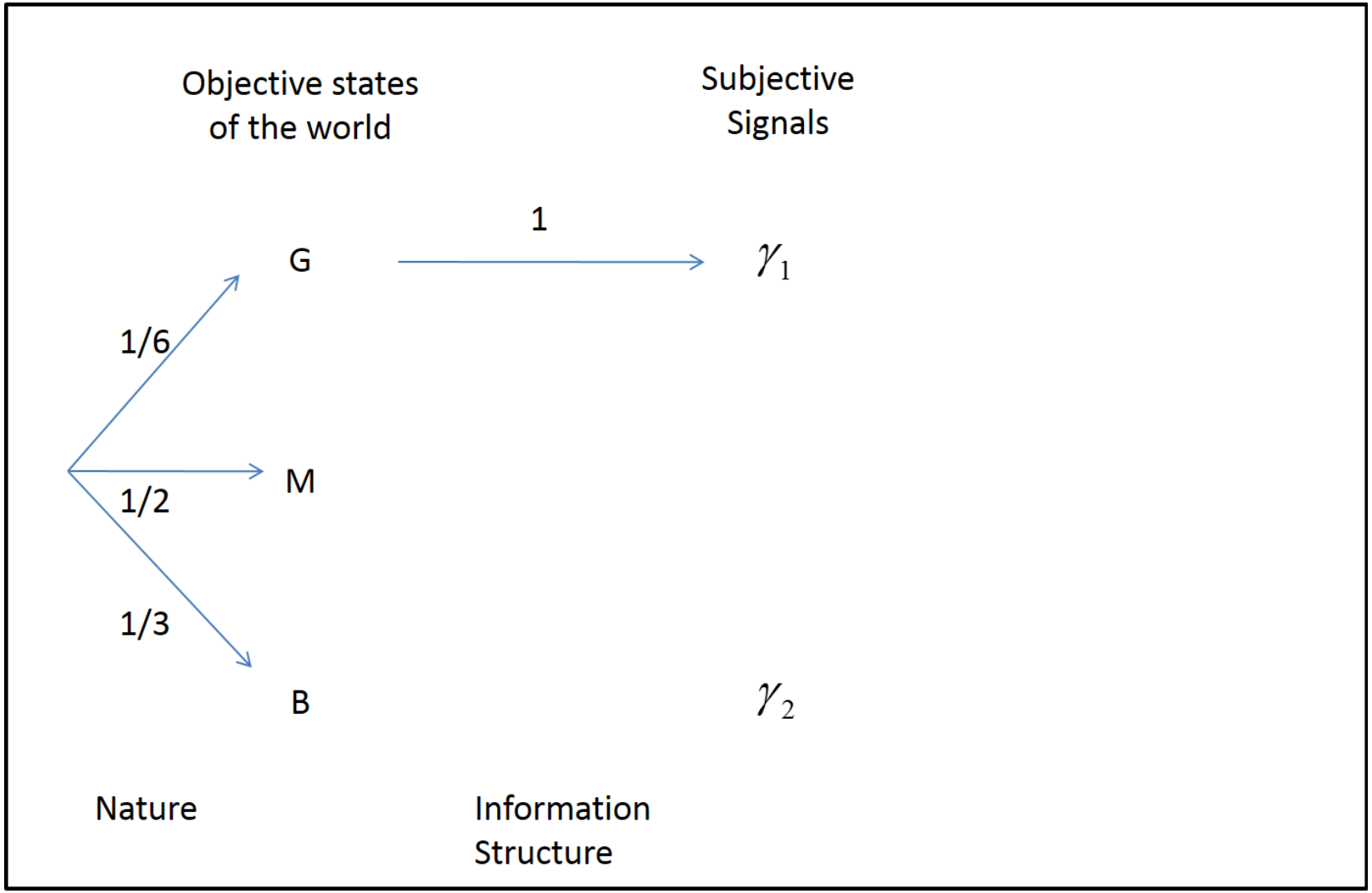

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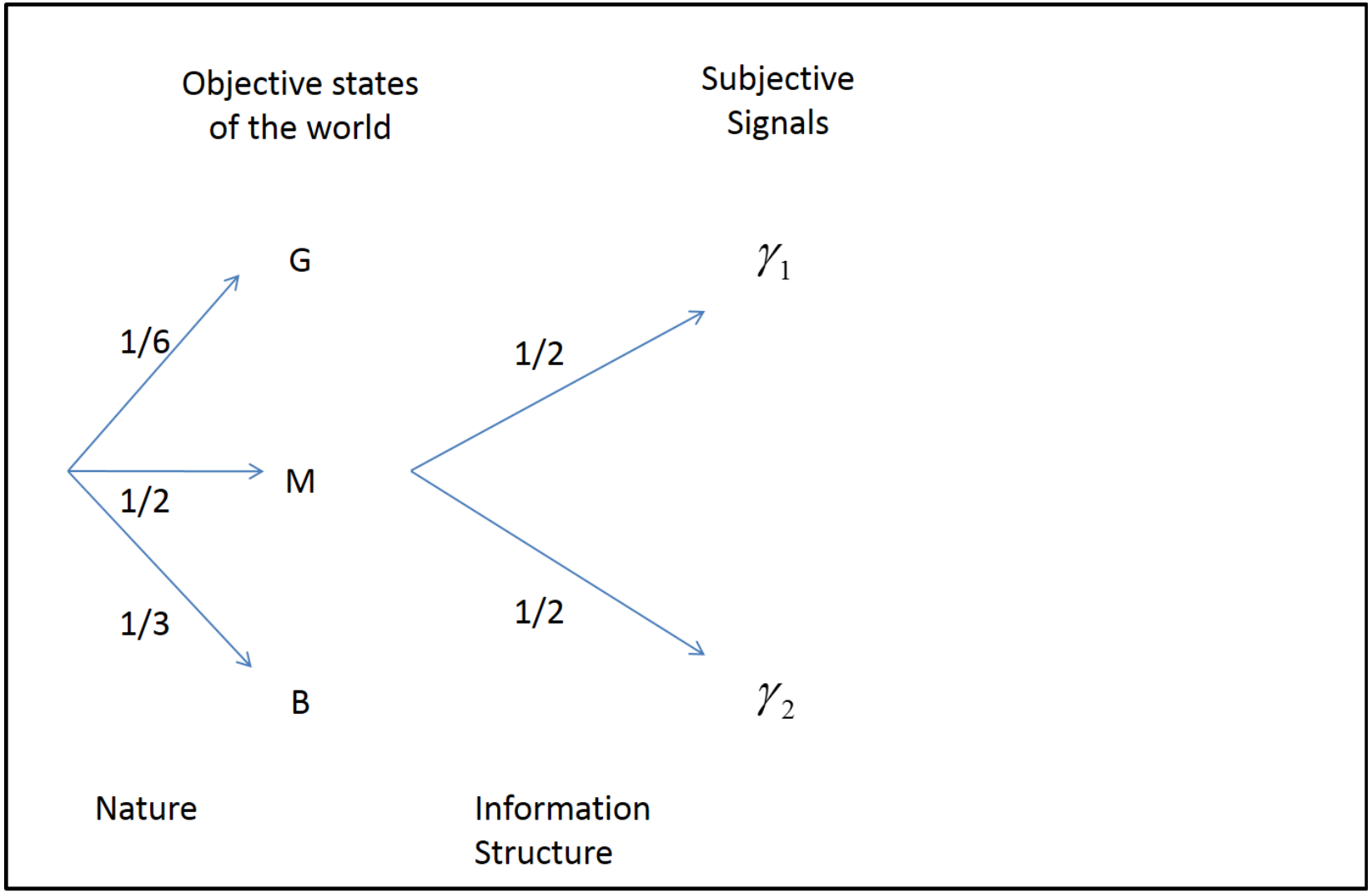

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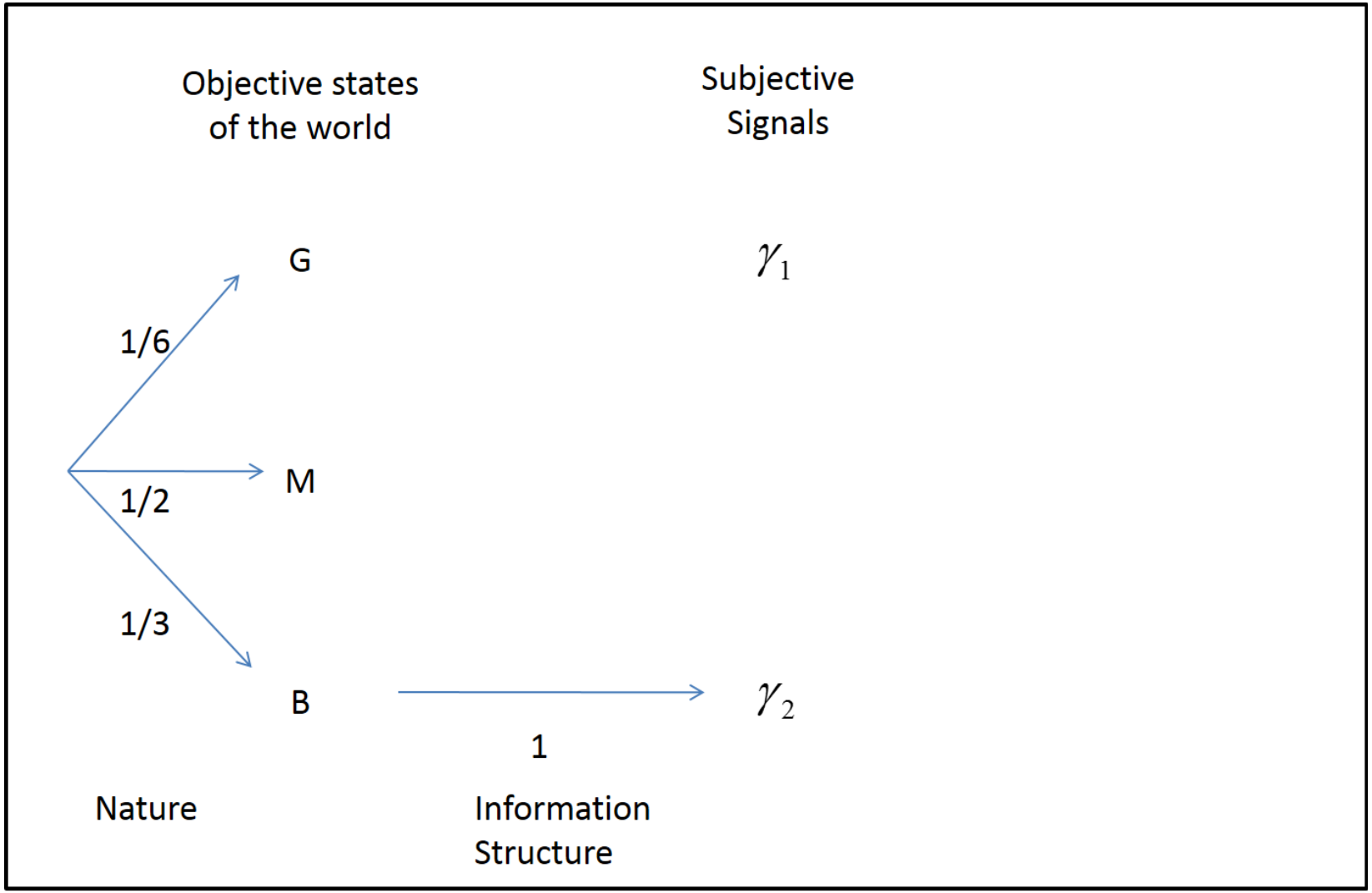

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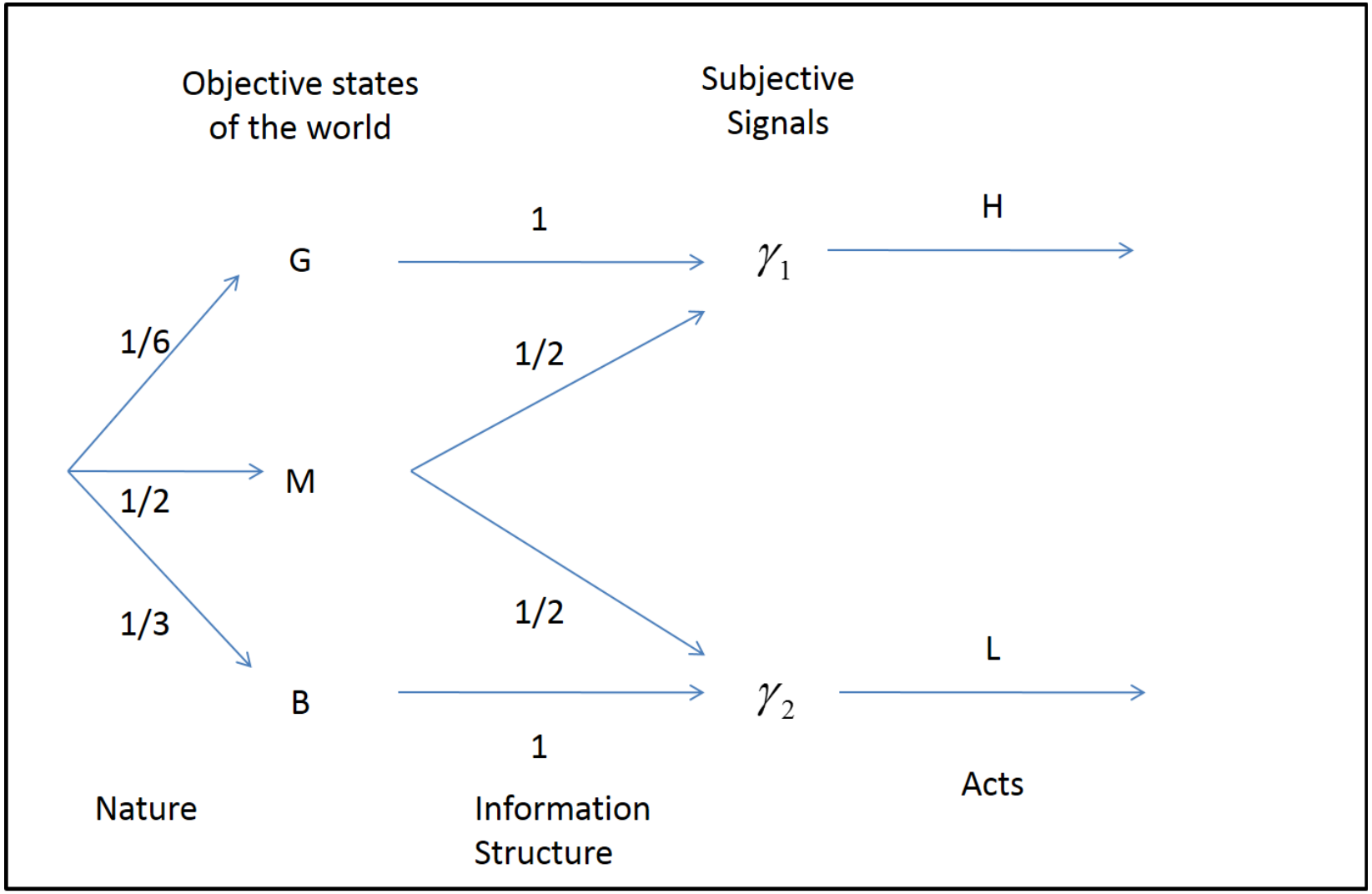


Outline

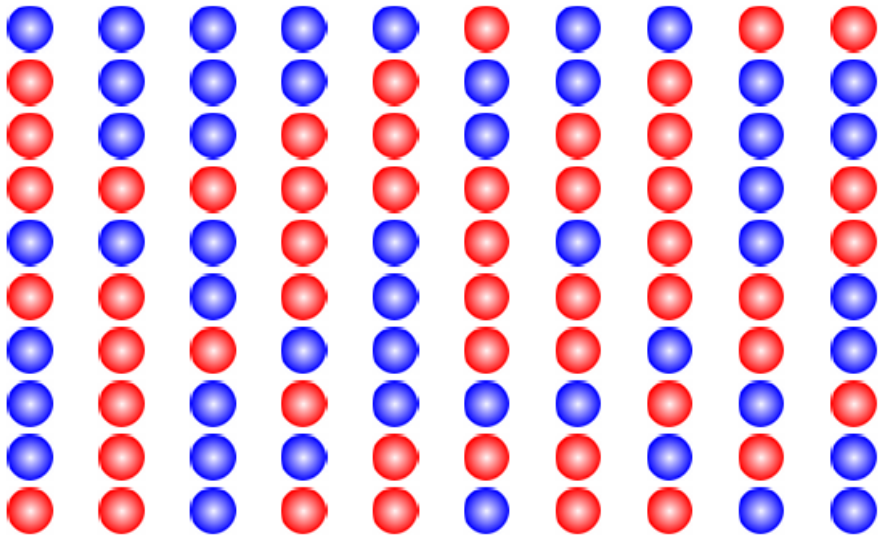
State Dependent Stochastic Choice Data

- What does the rational inattention model buy us?
  - What predictions can we make?
  - How can we test it?

State Dependent Stochastic Choice Data

- What does the rational inattention model buy us?
  - What predictions can we make?
  - How can we test it?
- Depends on the data you use
- Our work suggests (to us) a particularly useful type of data
- State Dependent Stochastic Choice data
  - Regularly used in psychology/psychometrics
  - Less commonly used in economics

State Dependent Stochastic Choice



Action	Payoff 49 red balls	Payoff 51 red balls
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- What could we observe in this experiment?

An Experimental Example

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  - Which action is chosen in one repetition

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Action	**State = 49 red balls**	**State = 51 red balls**
Prob choose a	$P(a\|49)$	$P(a\|51)$
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An Experimental Example

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Prob choose a	$P(a\|49)$	$P(a\|51)$
Prob choose b	$P(b\|49)$	$P(b\|51)$

- Easy to collect in the lab
  - Possible outside?

Why State Dependent Stochastic Choice Data

- Key observation: State dependent stochastic choice data tells us a lot about the information structure a decision maker has used

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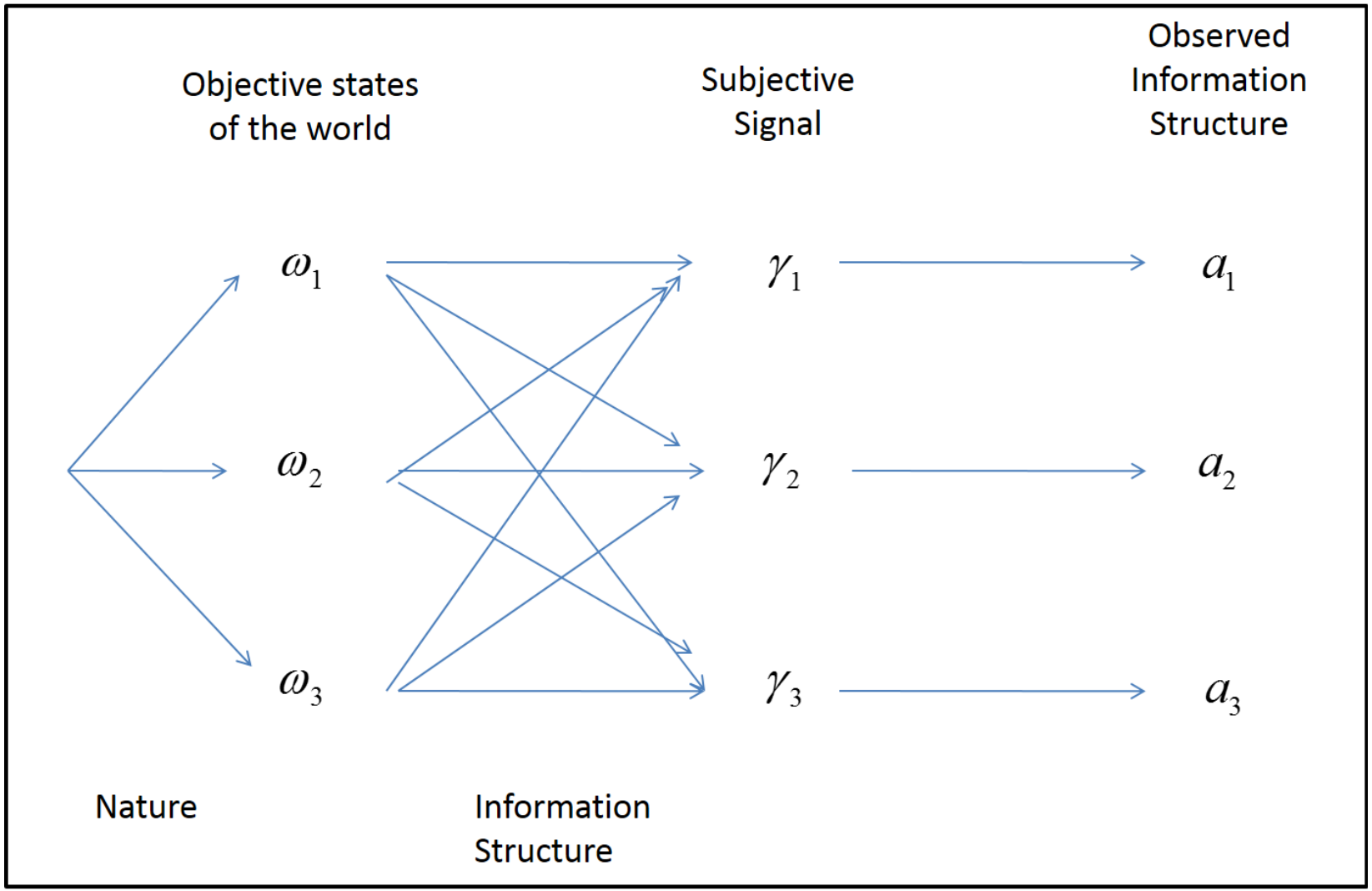
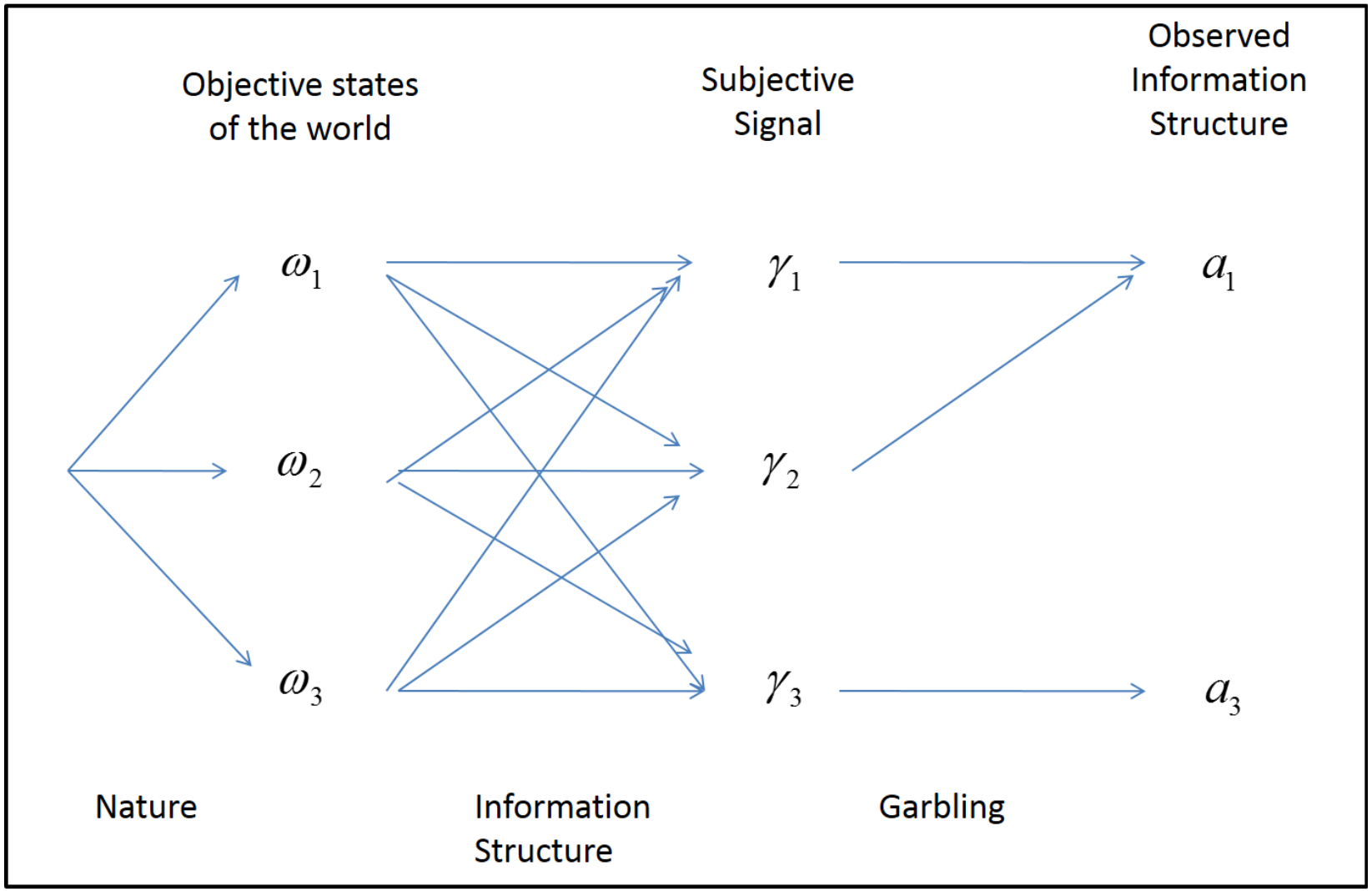
- Key observation: State dependent stochastic choice data tells us a lot about the information structure a decision maker has used
- Assume that decision maker is 'well behaved'
  - Chooses each action in response to at most one signal
  - No mixed strategies - one action per signal
- Information structure can be observed directly from state dependent stochastic choice
  - For each chosen action a there is an associated signal $\bar{\gamma}^a$
  - Probability of signal $\bar{\gamma}^a$ in any state is the same as the probability of choosing action in that state
- This is the 'revealed information structure'

Recovering Information Structures

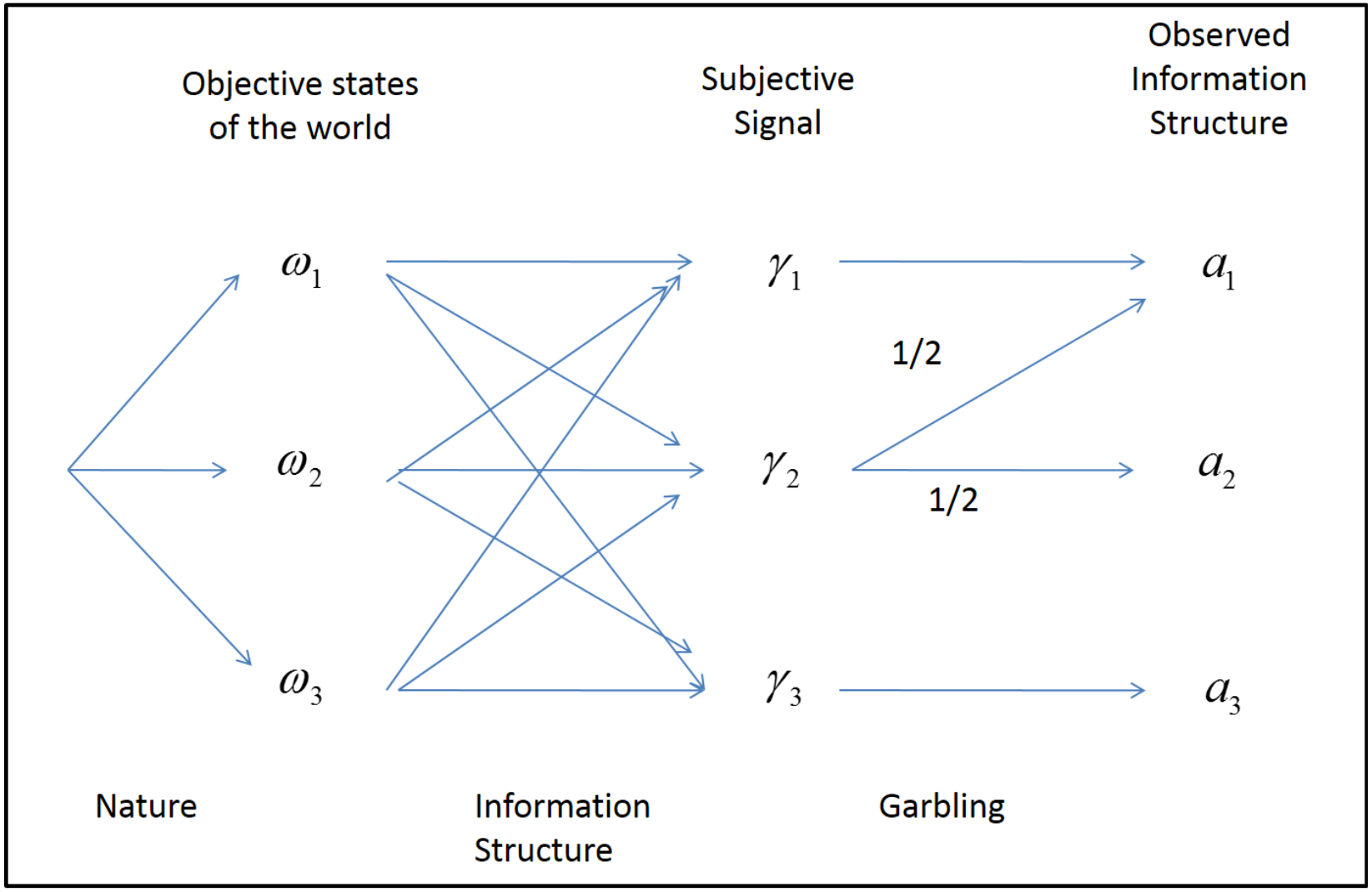


- What if decision maker is not well behaved?

Same Action in Different States



Mixing


Objective states of the world
Subjective Signal
Observed Information Structure
ω_1
ω_2
ω_3
γ_1
γ_2
γ_3
a_1
a_2
a_3
1/2
1/2
Nature
Information Structure
Garbling

Observing Information Structures

- What if decision maker is not well behaved?
- Can still construct the revealed information structure, but may not be the same as the 'true' information structure
- But we can put a lower bound on the amount of information gathered
    - Choices cannot be more informative about the state than the information structure
- Turns out that this is still very useful
- Allows us to identify necessary and sufficient conditions for various classes of model

Outline

Theoretical Progress

- In recent papers we have used this insight to establish the testable implications of rational inattention
- Key question: what is the cost function?

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- Key question: what is the cost function?
- We take two approaches
  - In each case provide a complete axiomatic characterization

1. **Agnostic:** Make no assumption about costs
   - Caplin and Dean [2015]
   - Pros: results do not depend on assumptions on the cost function
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Theoretical Progress

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1. **Agnostic:** Make no assumption about costs
   - Caplin and Dean [2015]
   - Pros: results do not depend on assumptions on the cost function
   - Cons: weak predictions (?), hard to use
2. **Specific**: Assume a specific functional form for costs
   - Based on Shannon mutual information between signal and states
     - Sims [2003]
     - Caplin, Dean and Leahy [2016, 2017]
   - Pros: relatively easy to use
   - Cons: might be the wrong cost function

Testable Implications

- Example of a testable prediction from the 'agonistic' model
- No Improving Attention Cycles (NIAC)
- Guarantees the existence of a rationalizing cost function

Optimal Choice of Attention Strategy

Decision Problem 1

Action	**Payoff 49 red balls**	**Payoff 51 red balls**
$\mathbf{a}^1$	10	0
$\mathbf{b}^1$	0	10

Prior: $\{0.5, 0.5\}$

Action	**State = 49 red balls**	**State = 51 red balls**
Prob choose *a*	$\frac{3}{4}$	$\frac{1}{4}$
Prob choose *b*	$\frac{1}{4}$	$\frac{3}{4}$

Optimal Choice of Attention Strategy

Decision Problem 2

Action	**Payoff 49 red balls**	**Payoff 51 red balls**
$\mathbf{a}^2$	20	0
$\mathbf{b}^2$	0	20

Prior: $\{0.5, 0.5\}$

Action	**State = 49 red balls**	**State = 51 red balls**
Prob choose *a*	$\frac{2}{3}$	$\frac{1}{3}$
Prob choose *b*	$\frac{1}{3}$	$\frac{2}{3}$

Optimal Choice of Attention Strategy

- $G(A, \pi)$ is the gross value of using information structure π in decision problem A

G	$\bar{\pi}^1$	$\bar{\pi}^2$
$\{a^1, b^1\}$	$7\frac{1}{2}$	$6\frac{2}{3}$
$\{a^2, b^2\}$	15	$13\frac{1}{3}$

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- Cost function must satisfy

$$\begin{aligned} G(\{a^1, b^1\}, \pi^1) - K(\pi^1) &\geq G(\{a^1, b^1\}, \pi^2) - K(\pi^2) \\ G(\{a^2, b^2\}, \pi^2) - K(\pi^2) &\geq G(\{a^2, b^2\}, \pi^1) - K(\pi^1) \end{aligned}$$

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- Which implies

$$\frac{5}{6} = G(\{a^1, b^1\}, \pi^1) - G(\{a^1, b^1\}, \pi^2) \geq$$

$$K(\pi^1) - K(\pi^2) \geq$$

$$G(\{a^2, b^2\}, \pi^1) - G(\{a^2, b^2\}, \pi^2) = 1\frac{2}{3}$$

Optimal Choice of Attention Strategy

- Surplus must be maximized by observed assignments

$$\begin{aligned} & G(\{a^1, b^1\}, \pi^1) + G(\{a^2, b^2\}, \pi^2) \\ \geq \quad & G(\{a^1, b^1\}, \pi^2) + G(\{a^2, b^2\}, \pi^1) \end{aligned}$$

- This has to be true if decision maker is rationally inattentive **regardless** of cost function

Testable Implications

- Example of a testable prediction from the Shannon model
  - Costs based on Shannon mutual information
- Invariance Under Compression
- Identifies Shannon within the broader class of 'posterior separable' models

Invariance Under Compression - An Example

- Consider decision problem (i)

	ω_1	ω_2
Prior Probability	0.5	0.5
Payoff Action A	10	0
Payoff Action B	0	10

Invariance Under Compression - An Example

- Consider decision problem (i)

	ω_1	ω_2
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Payoff Action B	0	10

- And now decision problem (ii) which splits ω_2

State	ω_1	ω_2	ω_3
Prior Probability	0.5	0.2	0.3
Payoff Action A	10	0	0
Payoff Action B	0	10	10

Invariance Under Compression - An Example

- How should behavior change between the two decision problems?
- In principle, many things could happen
  - Could be harder to learn about two states that one, so less accurate in (ii) than (i)
  - Could be easier to learn about two states that one, so more accurate in (ii) than (i)

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  - Could be harder to learn about two states that one, so less accurate in (ii) than (i)
  - Could be easier to learn about two states that one, so more accurate in (ii) than (i)
- Shannon model says that behavior should not change
  - $P_i(a|\omega_2) = P_{ii}(a|\omega_2) = P_{ii}(a|\omega_3)$

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What are the Open Questions

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- Now we know what rationally inattentive behavior looks like, when is it appropriate model of behavior?
- What are the appropriate costs for inattention
  - Can we develop a parsimonious usable model which is fit for purpose?
- Can models of inattention be used to 'microfound' and unify other behavioral phenomena
  - Reference dependence [Woodford 2012]

What are the Open Questions

- How does rational inattention compare to other models of attention
  - Salience [Bordalo, Gennaioli, and Shleifer, 2012]
  - Focussing [Koszegi and Szeidl, 2013]
  - Relative thinking [Bushong et al 2015]

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- How does instrumental demand for information relate to other motivators?
  - Curiosity/fear
  - Preference for early resolution of uncertainty
- For which economic problems is this really important?
  - All of them?
  - Expectations in macroeconomic models?
  - Mechanism design?

Expansion

- How does information gathering change with incentives?
- Simplest possible design: two states and two acts
- Change the value of choosing the correct act

Experiment 2				
Decision Problem	Payoffs			
	$U(a,1)$	$U(a,2)$	$U(b,1)$	$U(b,2)$
1	5	0	0	5
2	40	0	0	40
3	70	0	0	70
4	95	0	0	95

- States equally likely
- Increase the value of making the correct choice
  - Payment in probability points
- 52 subjects

Questions

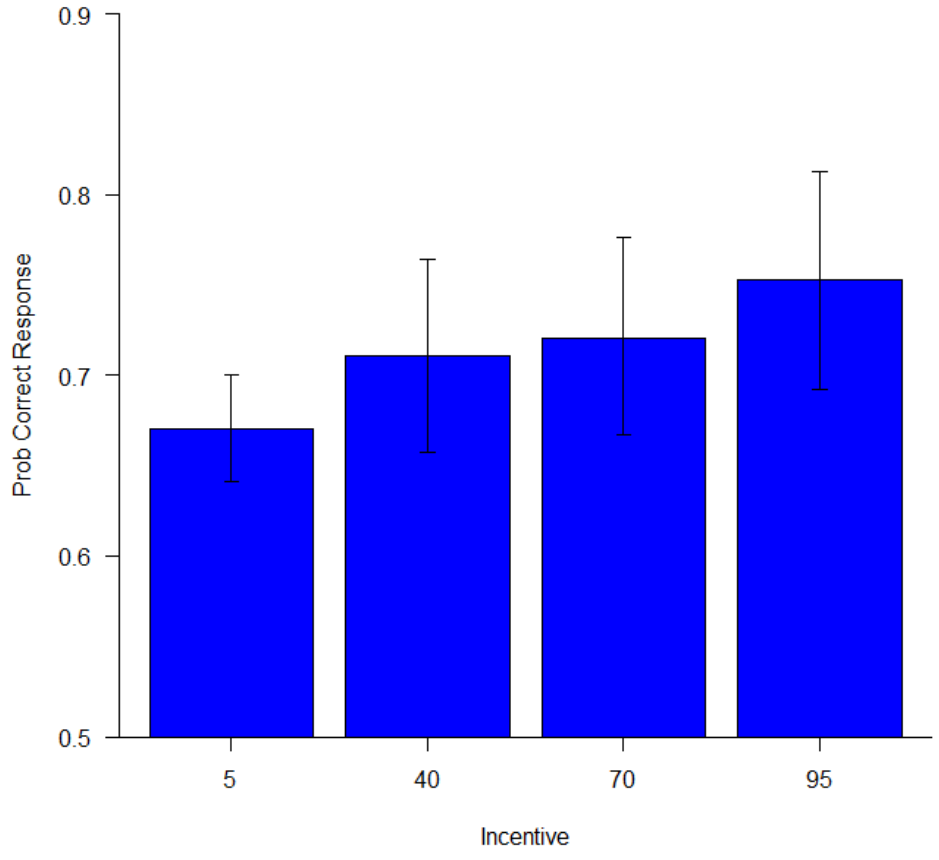
1. Are people rationally inattentive?
    - NIAC: choose information optimally relative to some cost function
2. What do information costs look like?
3. Do they look like Shannon Costs?
    - ILR: implies an 'expansion path' for information

Testing NIAC

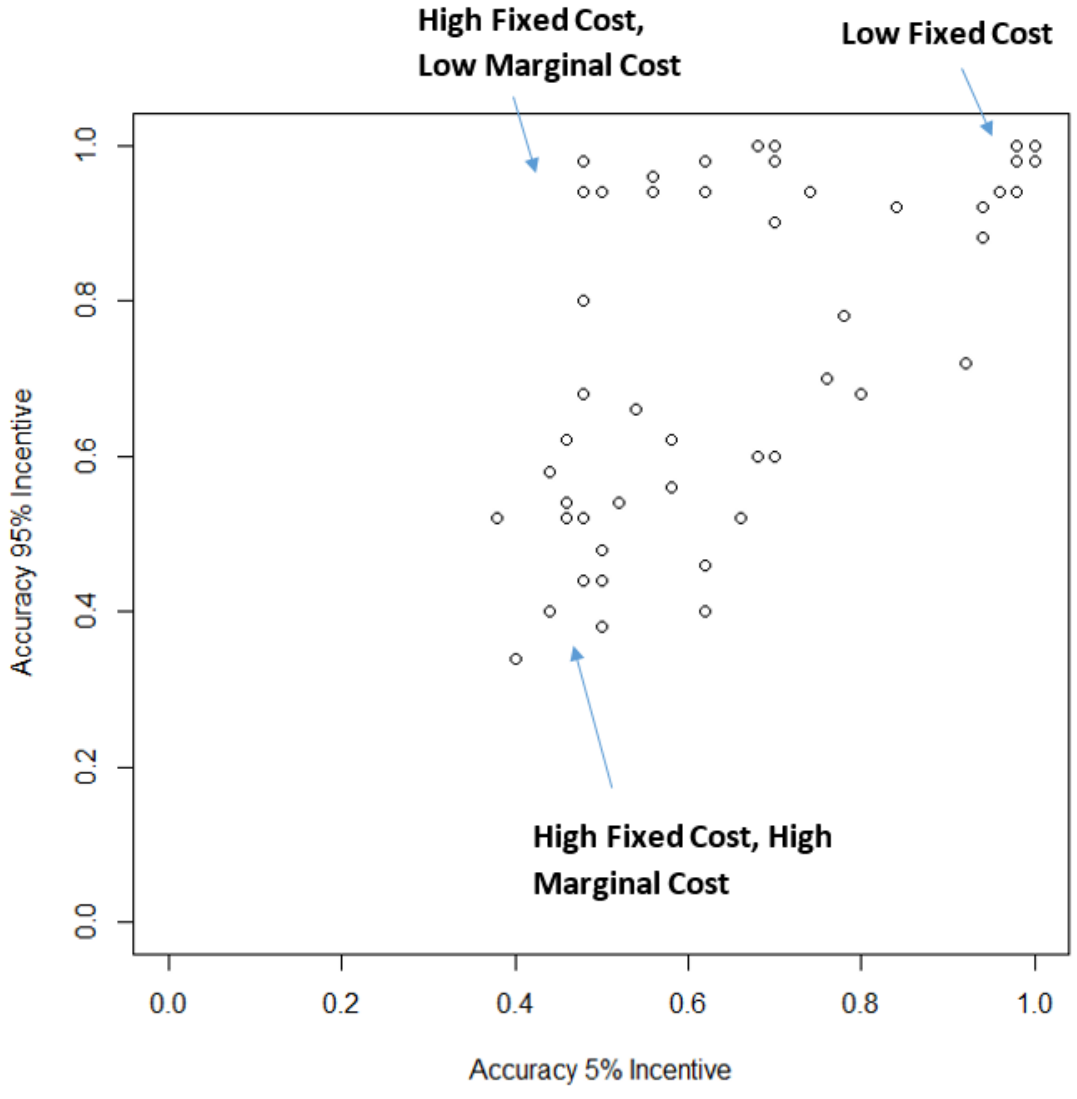
- NIAC: Ensures data is rationalizable according to some cost function
- Requires that surplus cannot be increased by reassigning information structures to decision problems

Testing NIAC

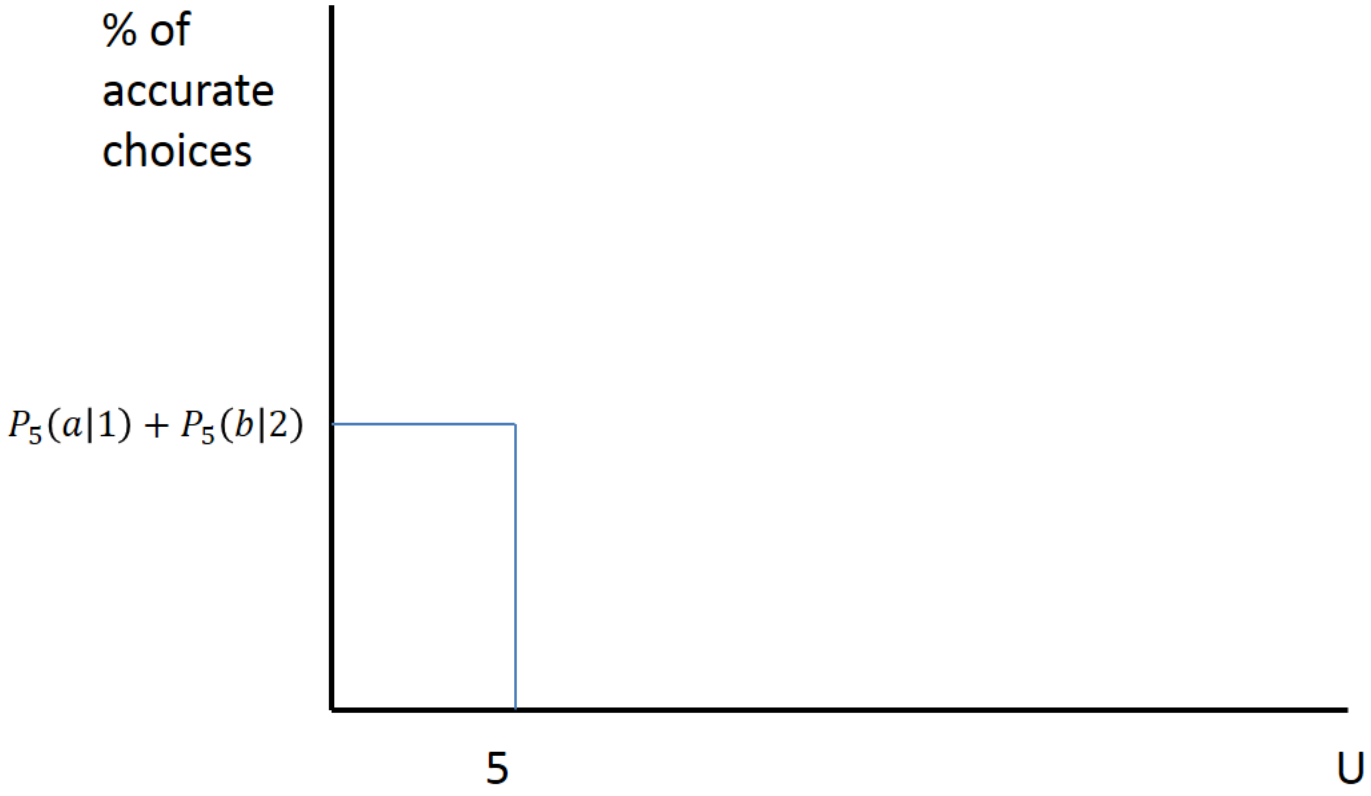
- In this experiment: Proportion of correct choices **weakly increasing** with incentives
- From the aggregate data



Recovering Costs - Individual Level

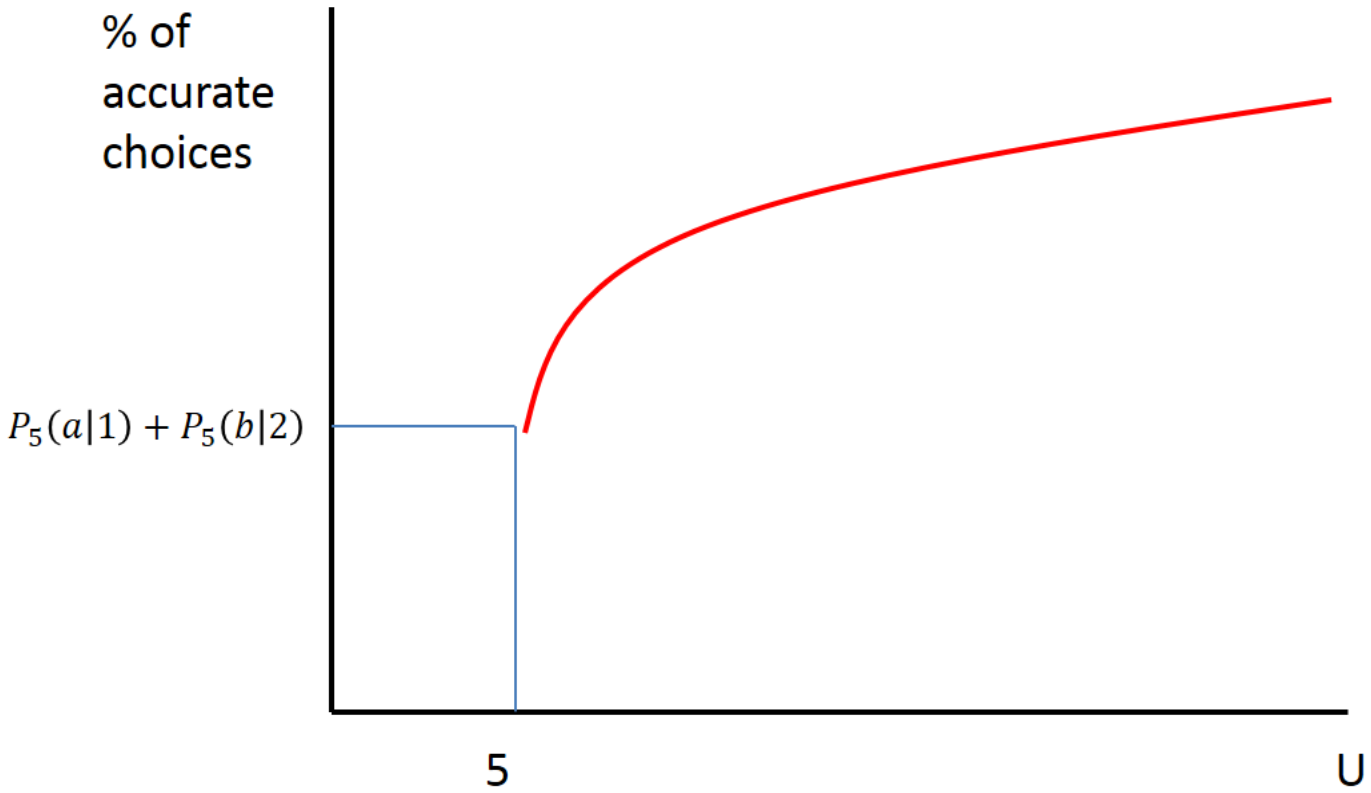


Shannon Mutual Information Costs



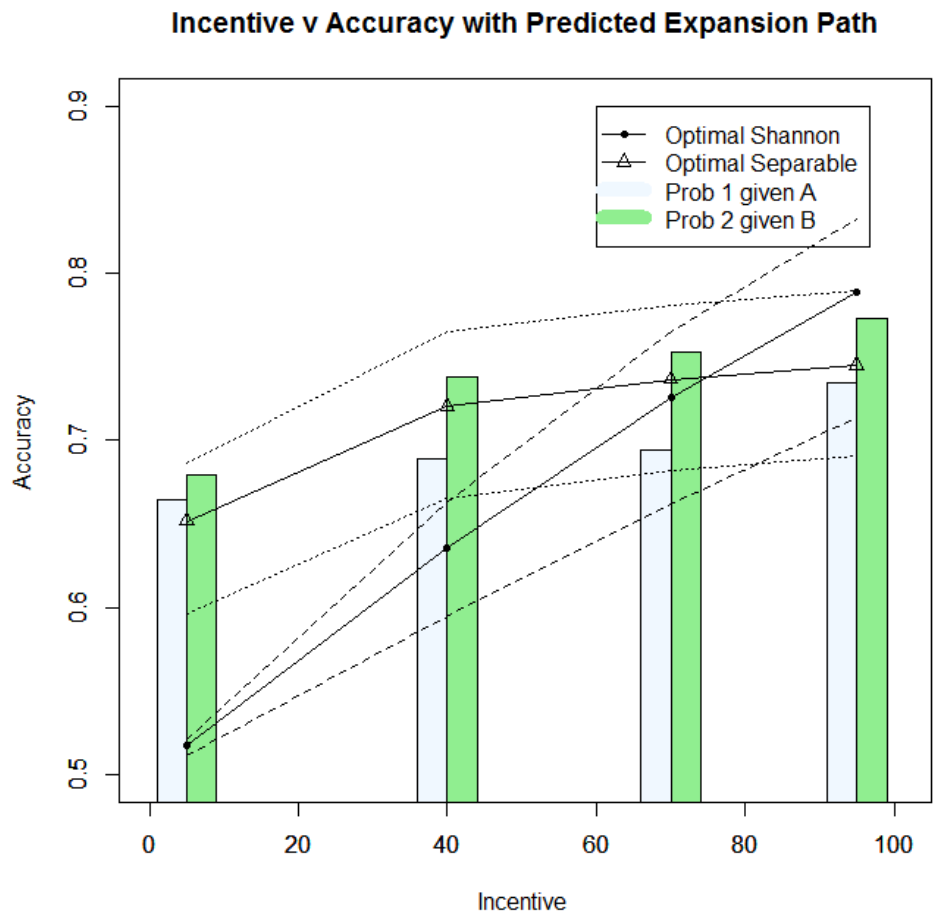
- Observation of choice accuracy for $x = 2$ pins down λ

Shannon Mutual Information Costs



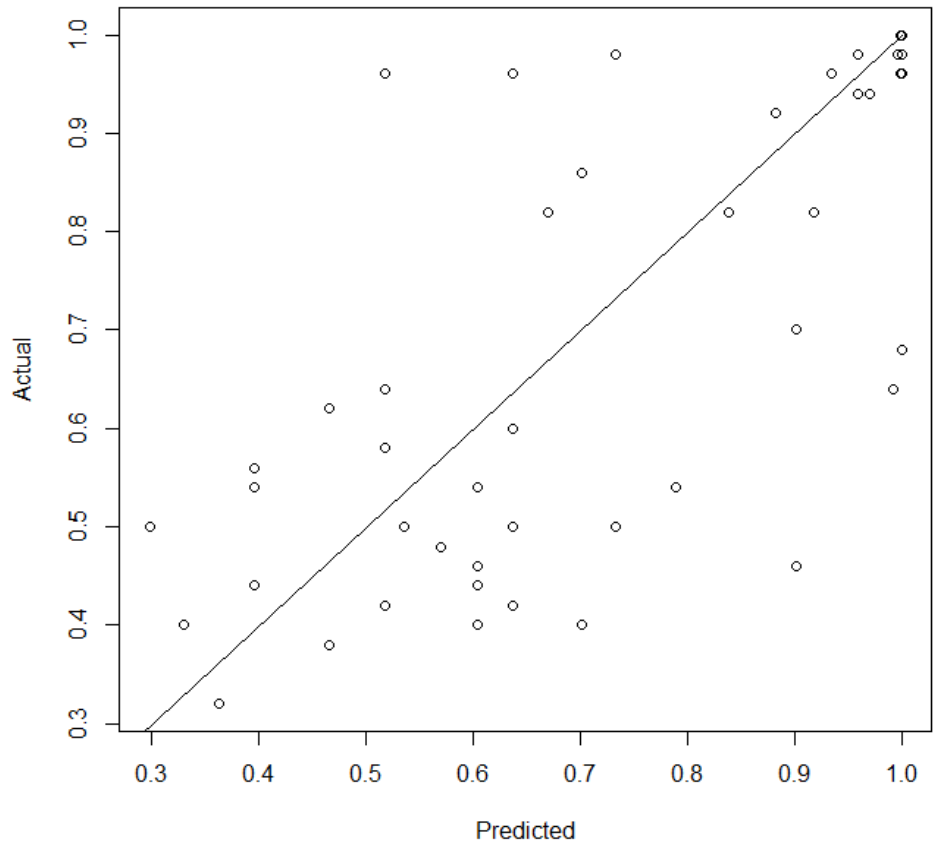
- Implies expansion path for all other values of x

Aggregate Data



- In aggregate, subjects respond less slowly than Shannon predicts

Individual Level Data



- Predicted vs Actual behavior in DP 4 given behavior in DP 1
- 44% of subjects adjust significantly more slowly than Shannon
- 19% significantly more quickly