

Inference and Learning from Others

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Plenty of errors in reasoning we make

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- Complexity-based bounded rationality

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Today's genre:

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Today's genre:

- Errors in inference from volitional agents, per se

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- Errors in inference from volitional agents, per se
 - How good gleaning information from others?

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 - How good gleaning information from others?
 - What systematic errors?

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- Errors in inference from volitional agents, per se
 - How good gleaning information from others?
 - What systematic errors?
 - What effects of these errors?



Extensive Imitation is Irrational and Harmful

Introduction

Cursed Thinking:

Extensive Imitation is Irrational and Harmful

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Cursed Thinking:

- People under-infer information from others' behavior.

Extensive Imitation is Irrational and Harmful

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 - Winner's curse in auctions, lemons, & financial markets

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 - No no-trade results—directly, patternly, and disciplinedly

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Today: Naive inference in observational learning:

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- naive inference, redundancy neglect \implies
 - ubiquitous imitation
 - overconfidently wrong social beliefs

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Introduction

Plugging my papers on inferring from others:

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Introduction

Plugging my papers on inferring from others:

- Eyster and Rabin (2005), *Econometrica*
- Eyster and Rabin (2010), *AEJ Theory*
- Eyster and Rabin (2012)
- Eyster, Rabin, and Vayanos (2013),
- **Eyster and Rabin (2013),**
- Eyster, Rabin, and Weizsacker (in progress)
- Gagnon-Bartsch and Rabin (in progress)



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Today

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- 1 How Not to Cure Syphilis

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- 1 How Not to Cure Syphilis
- 2 Rational Observational Learning

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 - 1 **Behavioral** implications

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 - 1 Informational, societal consequences of redundancy neglect

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- 1 How Not to Cure Syphilis
- 2 Rational Observational Learning
 - 1 **Behavioral** implications
- 3 Naive Observational Learning
 - 1 Informational, societal consequences of redundancy neglect

Note: Today and virtually all on this topic → Erik Eyster

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Extensive Imitation is Irrational and Harmful

Introduction

Rational-Herding Literature:

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- People infer from actions of those with similar tastes.

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Efficiency facts of rational-herding models:

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- Observing others always helps in expected terms.

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- Not of society (frequently) thinking it knows things it doesn't.

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- Observing others always helps in expected terms.
- High likelihood wrong herds only if those herds are unconfident.
- Rational-herding literature is about failure to aggregate information
- Not of society (frequently) thinking it knows things it doesn't.
- (Debated in literature: is even non-aggregation really likely?)



Extensive Imitation is Irrational and Harmful

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We think:

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- *Limits* to imitation perhaps bigger punchline than imitation itself.

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But:

- We are skeptical people so reluctant to imitate.

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Remainder:

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- Historical example: mercury

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- Historical example: mercury
- Extended illustrative example

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- Formal framework:

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- Formal framework:
 - rationality and anti-imitation

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- Formal framework:
 - rationality and anti-imitation
 - redundancy neglect and mislearning

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Extensive Imitation is Irrational and Harmful

A Night with Venus, A Lifetime with Merury

“A night with venus, and a lifetime with mercury”

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Late 15th to mid-20th century, syphilis wreaked havoc on the world

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- Hyman (1941): as late as 1941, 4.4% of Americans infected, causing 40,000 deaths per year
- Tens of millions had disease, millions died from it



Extensive Imitation is Irrational and Harmful

A Night with Venus, a Lifetime with Mercury

16th to early 20th century, leading treatment for syphilis: mercury.

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- Its use, however, premised on curative properties when taken orally
 - Many, especially military doctors with statistics, had their doubts
 - But continued to be widely used until penicillin
 - Partially superseded by the arsenic derivative salvarsan in 1909
 - (But standard practice was to combine salvarsan with mercury)



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A Night with Venus, a Lifetime with Mercury

Why used so long?

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Why used so long?

- Hard to prove, even now, that it was, on net, a bad idea.

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Why used so long?

- Hard to prove, even now, that it was, on net, a bad idea.
- But it seems very unlikely

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- If so, how could doctors get it wrong for over 400 years

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- *Not* arguing it was a dumb idea

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Note:

- *Not* arguing it was a dumb idea
- Asking why used for 450 years.

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A Night with Venus, a Lifetime with Mercury

Paper: extended example, inspired by medical examples, of issues.

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- Trial and error of drugs.

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Paper: extended example, inspired by medical examples, of issues.

- Trial and error of drugs.
- Fully rational will eventually reject drugs that don't work.

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Paper: extended example, inspired by medical examples, of issues.

- Trial and error of drugs.
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- Trial and error of drugs.
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- But this requires extreme attention to redundancy.

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When most drugs false positives (and docs know this!),

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When most drugs false positives (and docs know this!),

- the way rational herds self-correct: virtually guaranteed that bad drugs get abandoned by doctors with little personal evidence against who have observed massive number of doctors prescribing.

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When most drugs false positives (and docs know this!),

- the way rational herds self-correct: virtually guaranteed that bad drugs get abandoned by doctors with little personal evidence against who have observed massive number of doctors prescribing.
- And even mild redundancy neglect guarantees adoption of a bad drug.

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A Night with Venus, a Lifetime with Mercury

Instead, now: extended example not in paper.

Extensive Imitation is Irrational and Harmful

Dining Out

Modification of the canonical two-state, two signal, two-restaurant model of social learning.

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Modification of the canonical two-state, two signal, two-restaurant model of social learning.

- Two restaurants in town,

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Modification of the canonical two-state, two signal, two-restaurant model of social learning.

- Two restaurants in town,
 - A and B , $p(A \text{ good}, B \text{ bad}) = p(B \text{ good}, A \text{ bad}) = .5$.

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Modification of the canonical two-state, two signal, two-restaurant model of social learning.

- Two restaurants in town,
 - A and B , $p(A \text{ good}, B \text{ bad}) = p(B \text{ good}, A \text{ bad}) = .5$.
 - Two states: $\omega_A \rightarrow A$ is good, $\omega_B \rightarrow B$ is good.
- Each of ∞ diners receives private signals $\in \{\alpha, \beta, \emptyset\}$

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 - α supports ω_A ,

Extensive Imitation is Irrational and Harmful

Dining Out

Modification of the canonical two-state, two signal, two-restaurant model of social learning.

- Two restaurants in town,
 - A and B , $p(A \text{ good}, B \text{ bad}) = p(B \text{ good}, A \text{ bad}) = .5$.
 - Two states: $\omega_A \rightarrow A$ is good, $\omega_B \rightarrow B$ is good.
- Each of ∞ diners receives private signals $\in \{\alpha, \beta, \emptyset\}$
- The signals are *i.i.d.* conditional on the state,
 - α supports ω_A ,
 - β supports ω_B ,

Extensive Imitation is Irrational and Harmful

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Extensive Imitation is Irrational and Harmful

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↗

Extensive Imitation is Irrational and Harmful

Dining Out

- For each Player k ,
 - $\Pr[s_k = \alpha | \omega_A] = \Pr[s_k = \beta | \omega_B] = .7(1 - \eta)$ and

Extensive Imitation is Irrational and Harmful

Dining Out

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Extensive Imitation is Irrational and Harmful

Dining Out

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 - $\eta = 0$, canonical binary-signal information structure.

Extensive Imitation is Irrational and Harmful

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Extensive Imitation is Irrational and Harmful

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 - $\eta = 0$, canonical binary-signal information structure.
 - When $\eta \rightarrow 1$, information is very rare.
 - (Lots results independent of η)

↪

Extensive Imitation is Irrational and Harmful

Dining Out

- Each Player k chooses among nine choices: she can dine in Restaurant A, dine in Restaurant B, or dine at home.

Extensive Imitation is Irrational and Harmful

Dining Out

- Each Player k chooses among nine choices: she can dine in Restaurant A, dine in Restaurant B, or dine at home.
 - Goes to a restaurant if she thinks there is more than 60% chance it is good, and stays at home if that is not true at either restaurant.

Extensive Imitation is Irrational and Harmful

Dining Out

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Extensive Imitation is Irrational and Harmful

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Extensive Imitation is Irrational and Harmful

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- Superscripts for the number of people she takes:

$p(\omega_A)$ $[0,10), [10,20), [20,30), [30,40)$ $[40,60]$ $(60,70], (70,80], (80,90], (90,100]$

Choice B^{+++}, B^{++}, B^+, B H A, A^+, A^{++}, A^{+++}

↗

Extensive Imitation is Irrational and Harmful

Dining Out

Three people choose restaurants each period,

Three people choose restaurants each period,

- Signal conditionally i.i.d. given state

Extensive Imitation is Irrational and Harmful

Dining Out

Three people choose restaurants each period,

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- Each after observing

Three people choose restaurants each period,

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- Each after observing her own signal,

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- Each after observing her own signal, and the full actions (three locations, and party size), in order,

Three people choose restaurants each period,

- Signal conditionally i.i.d. given state
- Each after observing her own signal, and the full actions (three locations, and party size), in order, taken in all previous periods.

↗

Extensive Imitation is Irrational and Harmful

Dining Out

What predictions does full rationality make?

Extensive Imitation is Irrational and Harmful

Dining Out

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- \emptyset signal, observes nothing but $H \rightarrow$ stay home.

Extensive Imitation is Irrational and Harmful

Dining Out

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Extensive Imitation is Irrational and Harmful

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Extensive Imitation is Irrational and Harmful

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Suppose in period 2 observe exactly one A in period 1.

Extensive Imitation is Irrational and Harmful

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- What do as a function of your signal?

Extensive Imitation is Irrational and Harmful

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Extensive Imitation is Irrational and Harmful

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 - $\beta \rightarrow H$.

Extensive Imitation is Irrational and Harmful

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Suppose in period 2 observe exactly one A in period 1.

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 - $\emptyset \rightarrow A$.

Extensive Imitation is Irrational and Harmful

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Suppose in period 2 observe exactly one A in period 1.

- What do as a function of your signal?
- You will realize that the three signals in period 1 were $\{\alpha, \emptyset, \emptyset\}$.
 - $\beta \rightarrow H$.
 - $\emptyset \rightarrow A$.
 - $\alpha \rightarrow A^{++}$



Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A, A, A\}$

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A, A, A\}$

Period 3: $\beta \rightarrow H, \emptyset \rightarrow A, \alpha \rightarrow A^{++}$

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
Period 3:		$\beta \rightarrow H, \emptyset \rightarrow A, \alpha \rightarrow A^{++}$	

Extensive Imitation is Irrational and Harmful

Dining Out

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- Key logic: guys in period 2 did *not* get any additional information.

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
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- Key logic: guys in period 2 did *not* get any additional information.
 - (If did, would not have gone alone.)

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
Period 3:		$\beta \rightarrow H, \emptyset \rightarrow A, \alpha \rightarrow A^{++}$	

- Key logic: guys in period 2 did *not* get any additional information.
 - (If did, would not have gone alone.)
 - Period 3: rationally realize no new information in Period-2 followers.

↗

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A, A, A\}$

Period 3: $\{A, A, A\}$

Period 4: $\{A, A, A\}$

Period 5: $\{A, A, A\}$

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A, A, A\}$

Period 3: $\{A, A, A\}$

Period 4: $\{A, A, A\}$

Period 5: $\{A, A, A\}$

Period 6: $\beta \rightarrow H, \emptyset \rightarrow A, \alpha \rightarrow A^{++}$

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
Period 3:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
Period 4:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
Period 5:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
Period 6:		$\beta \rightarrow H, \emptyset \rightarrow A, \alpha \rightarrow A^{++}$	

- Understanding redundancy information in actions: hard.

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
Period 3:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
Period 4:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$
Period 5:	$\{A, A, A\}$		$\{\emptyset, \emptyset, \emptyset\}$

Period 6: $\beta \rightarrow H, \emptyset \rightarrow A, \alpha \rightarrow A^{++}$

- Understanding redundancy information in actions: hard.
- But it matters a lot.

↷

Extensive Imitation is Irrational and Harmful

Dining Out

Herding without sufficiently increased enthusiasm is a bad sign:

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A, A, H\}$

Extensive Imitation is Irrational and Harmful

Dining Out

Herding without sufficiently increased enthusiasm is a bad sign:

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A, A, H\}$

Period 3: $\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$

Extensive Imitation is Irrational and Harmful

Dining Out

Herding without sufficiently increased enthusiasm is a bad sign:

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, A, H\}$		$\{\emptyset, \emptyset, \beta\}$
Period 3:		$\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$	

Extensive Imitation is Irrational and Harmful

Dining Out

Herding without sufficiently increased enthusiasm is a bad sign:

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, A, H\}$		$\{\emptyset, \emptyset, \beta\}$

Period 3: $\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$

3 A, 3 H $\rightarrow \omega_A, \omega_B$ equally likely!

Extensive Imitation is Irrational and Harmful

Dining Out

Herding without sufficiently increased enthusiasm is a bad sign:

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, A, H\}$		$\{\emptyset, \emptyset, \beta\}$
Period 3:		$\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$	

3 A, 3 H $\rightarrow \omega_A, \omega_B$ equally likely!

- Do we get that?

↯

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A, H, H\}$

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A, H, H\}$

Period 3: $\beta \rightarrow B^{++}, \emptyset \rightarrow B, \alpha \rightarrow H$

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, H, H\}$		$\{\emptyset, \beta, \beta\}$
Period 3:		$\beta \rightarrow B^{++}, \emptyset \rightarrow B, \alpha \rightarrow H$	

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A, H, H\}$		$\{\emptyset, \beta, \beta\}$
Period 3:		$\beta \rightarrow B^{++}, \emptyset \rightarrow B, \alpha \rightarrow H$	

You shouldn't go to A even if get α !

↗

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{H, H, H\}$

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{H, H, H\}$

Period 3: $\beta \rightarrow B^{+++}, \emptyset \rightarrow B^{++}, \alpha \rightarrow B$

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{H, H, H\}$		$\{\beta, \beta, \beta\}$
Period 3:		$\beta \rightarrow B^{+++}, \emptyset \rightarrow B^{++}, \alpha \rightarrow B$	

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{H, H, H\}$		$\{\beta, \beta, \beta\}$
Period 3:		$\beta \rightarrow B^{+++}, \emptyset \rightarrow B^{++}, \alpha \rightarrow B$	

Go to B no matter what!

\Downarrow

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A^{++}, A, A\}$

Period 3: $\{A^{++}, A, A\}$

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{A^{++}, A, A\}$

Period 3: $\{A^{++}, A, A\}$

Period 4: $\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A^{++}, A, A\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 3:	$\{A^{++}, A, A\}$		$\{\emptyset, \beta, \beta\}$

Period 4: $\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$

↪

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1:	$\{A, H, H\}$
Period 2:	$\{A^{++}, A, A\}$
Period 3:	$\{A^{++}, A^{++}, A\}$
Period 4:	$\{A^{++}, A^{++}, A\}$
Period 5:	$\{A^{++}, A^{++}, A^{++}\}$

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$
Period 2: $\{A^{++}, A, A\}$
Period 3: $\{A^{++}, A^{++}, A\}$
Period 4: $\{A^{++}, A^{++}, A\}$
Period 5: $\{A^{++}, A^{++}, A^{++}\}$

Period 6: $\beta \rightarrow H, \emptyset \rightarrow A, \alpha \rightarrow A^{++}$

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A^{++}, A, A\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 3:	$\{A^{++}, A^{++}, A\}$		$\{\emptyset, \emptyset, \beta\}$
Period 4:	$\{A^{++}, A^{++}, A\}$		$\{\alpha, \alpha, \emptyset\}$
Period 5:	$\{A^{++}, A^{++}, A^{++}\}$		$\{\beta, \beta, \beta\}$
Period 6:		$\beta \rightarrow H, \emptyset \rightarrow A, \alpha \rightarrow A^{++}$	

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{A^{++}, A, A\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 3:	$\{A^{++}, A^{++}, A\}$		$\{\emptyset, \emptyset, \beta\}$
Period 4:	$\{A^{++}, A^{++}, A\}$		$\{\alpha, \alpha, \emptyset\}$
Period 5:	$\{A^{++}, A^{++}, A^{++}\}$		$\{\beta, \beta, \beta\}$
Period 6:		$\beta \rightarrow H, \emptyset \rightarrow A, \alpha \rightarrow A^{++}$	

Will a β signal help stop the herd?

↗

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1:

$\{A, A, A\}$

Period 2:

$\{A^{++}, A^{++}, A^{++}\}$

Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1:

$\{A, A, A\}$

Period 2:

$\{A^{++}, A^{++}, A^{++}\}$

Period 3:

$\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, A, A\}$		$\{\alpha, \alpha, \alpha\}$
Period 2:	$\{A^{++}, A^{++}, A^{++}\}$		$\{\beta, \beta, \beta\}$
Period 3:		$\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$	

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, A, A\}$		$\{\alpha, \alpha, \alpha\}$
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- Enough.

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, A, A\}$		$\{\alpha, \alpha, \alpha\}$
Period 2:	$\{A^{++}, A^{++}, A^{++}\}$		$\{\beta, \beta, \beta\}$
Period 3:		$\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$	

- Enough.
- Things fare more complicated if

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, A, A\}$		$\{\alpha, \alpha, \alpha\}$
Period 2:	$\{A^{++}, A^{++}, A^{++}\}$		$\{\beta, \beta, \beta\}$
Period 3:		$\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$	

- Enough.
- Things fare more complicated if don't observe order

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, A, A\}$		$\{\alpha, \alpha, \alpha\}$
Period 2:	$\{A^{++}, A^{++}, A^{++}\}$		$\{\beta, \beta, \beta\}$
Period 3:		$\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$	

- Enough.
- Things fare more complicated if don't observe order don't observe all

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, A, A\}$		$\{\alpha, \alpha, \alpha\}$
Period 2:	$\{A^{++}, A^{++}, A^{++}\}$		$\{\beta, \beta, \beta\}$
Period 3:		$\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$	

- Enough.
- Things fare more complicated if don't observe order don't observe all heterogenous preferences

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, A, A\}$		$\{\alpha, \alpha, \alpha\}$
Period 2:	$\{A^{++}, A^{++}, A^{++}\}$		$\{\beta, \beta, \beta\}$
Period 3:		$\beta \rightarrow B, \emptyset \rightarrow H, \alpha \rightarrow A$	

- Enough.
- Things fare more complicated if don't observe order don't observe all heterogenous preferences
 - But nothing makes the severe limits to imitation go away

↗

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

- Cannot observe order of play.

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

- Cannot observe order of play.
- **Signals rare**

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

- Cannot observe order of play.
- **Signals rare**
- In period 3,

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

- Cannot observe order of play.
- **Signals rare**
- In period 3,
 - If see $\{H, H, H, H, H, H\}$, then believe

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

- Cannot observe order of play.
- **Signals rare**
- In period 3,
 - If see $\{H, H, H, H, H, H\}$, then believe .5

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

- Cannot observe order of play.
- **Signals rare**
- In period 3,
 - If see $\{H, H, H, H, H, H\}$, then believe .5
 - If see $\{A, H, H, H, H, H\}$, then believe

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

- Cannot observe order of play.
- **Signals rare**
- In period 3,
 - If see $\{H, H, H, H, H, H\}$, then believe .5
 - If see $\{A, H, H, H, H, H\}$, then believe .7

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

- Cannot observe order of play.
- **Signals rare**
- In period 3,
 - If see $\{H, H, H, H, H, H\}$, then believe .5
 - If see $\{A, H, H, H, H, H\}$, then believe .7
 - If see $\{A, A, H, H, H, H\}$, then believe

Extensive Imitation is Irrational and Harmful

Dining Out

Same setting (same signals, players per period, etc.) but:

- Cannot observe order of play.
- **Signals rare**
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 - If see $\{H, H, H, H, H, H\}$, then believe .5
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One old and one new example:

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Extensive Imitation is Irrational and Harmful

Dining Out

actions

response

Period 1: $\{A, H, H\}$

Period 2: $\{H, H, H\}$

Period 3: $\beta \rightarrow B^{+++}, \emptyset \rightarrow B^{++}, \alpha \rightarrow B$

Extensive Imitation is Irrational and Harmful

Dining Out

	actions	response	signals
Period 1:	$\{A, H, H\}$		$\{\alpha, \emptyset, \emptyset\}$
Period 2:	$\{H, H, H\}$		$\{\beta, \beta, \beta\}$
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Anti-imitation!



Extensive Imitation is Irrational and Harmful

Dining Out

Harder to see:

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Dining Out

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- Rational observational learning in this case:

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 - Eventually will herd on $\{B^{+++}\}$ or $\{A^{+++}\}$.

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 - Roughly 30% of time herd starts in wrong direction,

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Dining Out

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When signals are rare,

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Now: formal, continuous framework

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Now: formal, continuous framework

- Lots of structure ... simple results



Extensive Imitation is Irrational and Harmful

Impartial Inference and the Limits of Imitation

- Two possible states, $\omega \in \{0, 1\}$, *ex ante* equally likely

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- $F_k^{(0)}$ and $F_k^{(1)}$ mutually absolutely continuous
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↗

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Observation structure:

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- $D(k) \subset \{1, \dots, k-1\} \equiv k$'s predecessors whose actions k observes

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- $\mathcal{N} = \{\{1, 2, \dots\}, \{D(1), D(2), \dots\}\}$ is observation structure

↪

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Impartial Inference and the Limits of Imitation

- Player k chooses action $\alpha_k \in [0, 1]$ to maximize $E\{-(\alpha_k - \omega)^2\}$ given her information, $I_{k\rightleftharpoons}$
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Extensive Imitation is Irrational and Harmful

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- Many of a player's observations may be redundant

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Central definition:

Definition

The quadruple of distinct players (i, j, k, l) in \mathcal{N} forms a *diamond* if $i \in ID(j) \cap ID(k)$, $j \notin ID(k)$, $k \notin ID(j)$, and $\{j, k\} \subset D(l)$

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- Canonical single-file models of Banerjee (1992) and Bikchandani, Hirshleifer, and Welch (1992) do not include diamonds

Extensive Imitation is Irrational and Harmful

Impartial Inference and the Limits of Imitation

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Definition

k imitates j if $a_k(a_j, a_{-j}^k; s_k)$ is weakly increasing (but not constant) in $a_j \rightleftharpoons$

Definition

k anti-imitates j if $a_k(a_j, a_{-j}^k; s_k)$ weakly decreasing (not constant) in $a_j \rightleftharpoons$

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Extensive Imitation is Irrational and Harmful

Impartial Inference and the Limits of Imitation

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Assume the observation structure \mathcal{N} generates impartial inference. Then some player anti-imitates another if and only if \mathcal{N} contains a shield_≡

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- Proof does some accounting based on simple single-shield correlation-subtraction intuition.



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- Single-file: each person imitates only her immediate predecessor
- More generally: if no player anti-imitates, then no player imitates two predecessors who both observe an earlier, common predecessor
- But sharing no common observation excludes virtually all social learners (except at the beginning) in almost all settings of interest

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- Rational social learning also may lead some players to form beliefs on the opposite side of their priors than all their information

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Definition

Player k 's action a_k is *contrarian* given signal s_k and history a^{k-1} iff $a_k \neq 0$ and $\text{sgn}(a_k) = -\text{sgn}(s_k) = -\text{sgn}(a_j)$ for every $j \in D(k)$

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Proposition

Assume \mathcal{N} generates impartial inference \Rightarrow

- ① If some player's action is contrarian, then \mathcal{N} contains a shield \Rightarrow
- ② If \mathcal{N} contains a shield and players' private signals are drawn from the density $f^{(\omega)}$ that is everywhere positive on $[\underline{s}, \bar{s}]$, then with positive probability some player's action is contrarian \Rightarrow



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- and $S_t = \sum_{k=1}^n s_t^k$, the sum of round- t signals
- Then:

$$A_t = S_t + n \sum_{i=1}^{t-1} (-1)^{i-1} (n-1)^{i-1} A_{t-i}$$

↪

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- When $n = 1$, $A_t = S_t + A_{t-1} \Leftrightarrow$
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- Leading to
 - $A_1 = S_1$, $A_2 = S_2 + 3A_1$
 - $A_3 = S_3 + 3A_2 - 6A_1$
 - $A_4 = S_4 + 3S_3 - 6A_2 + 12A_1$

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Redundancy Neglect

What happens if people do not anti-imitate, and imitate more broadly than predicted by full rationality?

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Definition

Social learning is *strictly and boundedly increasing in private signals* if

- 1 (strictly increasing) for each Player t , and each $a^{t-1} \in \mathbb{R}^{t-1}$,

$$\hat{s}^t > s^t \Rightarrow a_t(a^{t-1}, \hat{s}_t) > a_t(a^{t-1}, s_t)$$

- 2 (boundedly increasing) there exists $K \in \mathbb{R}_{++}$ such that for each Player t , each $a^{t-1} \in \mathbb{R}^{t-1}$, and each $s^t, \hat{s}^t \in \mathbb{R}$,

$$|a_t(a^{t-1}, \hat{s}_t) - a_t(a^{t-1}, s_t)| \leq K |\hat{s}_t - s_t|$$

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Definition

Players use social-learning rules that *neglect redundancy* if there exist an integer N and a constant $c > 0$ with the property that for each Player $t \geq N + 1$, each $a^{t-N-1} \in \mathbb{R}^{t-N-1}$, each $s_t \in \mathbb{R}$, and each $z' > z \geq 0$,

$$a_t(a^{t-N-1}, \underbrace{z', z', \dots, z'}_{N \text{ times}}, s_t) - a_t(a^{t-N-1}, \underbrace{z, z, \dots, z}_{N \text{ times}}, s_t) \geq (1 + c)(z' - z)$$

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- But generally this will not be the case—redundancy neglect embodies the error of reading more than one conditionally independent piece of information into recent predecessors' actions
- RN is joint assumption about observation structure and imitation
 - encompasses all sorts of combinations of assumptions about whom people observe and whom they imitate



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Redundancy Neglect

- Also allows people to under-infer from their predecessors, as in partially-cursed equilibrium (Eyster and Rabin (2005)), so long as they neglect redundancy:

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- Also allows people to under-infer from their predecessors, as in partially-cursed equilibrium (Eyster and Rabin (2005)), so long as they neglect redundancy:
- someone can treat all predecessors' actions as half as informative as they are at the same time as she mistakenly imitates many predecessors instead of just one.
- The condition is, intuitively, that the sum total of influence from underweighting individuals and overcounting predecessors is greater than the influence of one person, correctly interpreted.



Extensive Imitation is Irrational and Harmful

Redundancy Neglect

Proposition

Suppose players social-learning rules are strictly and boundedly increasing in private signals as well as neglect redundancy, and that no player anti-imitates any other. Then, with positive probability, society converges to the action that corresponds to certain beliefs in the wrong state.

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- but instead cause it to mislearn

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- Redundancy neglect and the absence of anti-imitation do not *merely* prevent society from learning
- but instead cause it to mislearn
- redundancy-neglecting doctors can converge with near certainty to a bad medicine ... and believe it works with near certainty



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Redundancy Neglect

- When players move single-file and observe all predecessors, BRTNI players (Eyster and Rabin, 2010), who interpret each predecessor's action as her private signal, satisfy redundancy neglect with $c = N - 1$ for each N and mislearn with positive probability

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- BRTNI players give the past 100 players 100 times the weight that they should get
- Proposition says that far milder over-imitation leads society astray
- If everyone treats their predecessors' actions as embodying just two conditionally independent signals, instead of one, then society sometimes converges to complete confidence in the wrong state.



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Conclusion

- Reminder: results do not depend upon details of our environment

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- Reminder: results do not depend upon details of our environment
- When observed recent actors provide independent information, they should all be imitated
- But when those recent players themselves imitate earlier actions, those earlier actions should be subtracted

