State Pooling and Belief Polarization

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Columbia University - Experimental Lunch

October 4, 2019

State Pooling and Belief Polarization

Puzzle

- Society today is more polarized (McCarty et al. 2006)
- Information is more easily accessible (lower cost)
- If a "true state" exists, beliefs should converge, right?
- Not necessarily true if information collection is endogenous

Summary

- **Setup**: the action space is smaller than the state space (e.g. 2 actions safe/risky and 3 states), the agents collect evidence before choosing an action
- **State pooling**: agents avoid redundant information and "pool together" states associated with the same action
- **Belief polarization**: posterior beliefs are more distant (extreme) than prior beliefs

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Today's Presentation

- **Motivating Example**
- **Research Question**
- **Laboratory Experiment**
  - Design
  - Preliminary results
- Appendix A: Related Literature
- Appendix B: More about the State Pooling Model
- Appendix C: Alternative Hypothesis

Motivating Example

Motivating Example

Setting

- Alice and Bob face a choice: go to the Theater or stay Home
  - Theater: uncertainty about the quality of the movie [state s]
  - Home: "safe" choice [status quo]

	Theater	Home	
s	$v_i^T(s)$	$v_A^H(s)$	$v_B^H(s)$
bad	0	0.45	0.55
medium	0.5	0.45	0.55
good	1	0.45	0.55

- Assume uniform prior $p_s = \frac{1}{3}$ and risk neutrality

Motivating Example

Scenario 1

- Alice and Bob have the same beliefs over s and $EV(\text{Theater})$
  - $EV(\text{Theater}) = 0.5$
- Alice and Bob make different choices
  - A chooses Theater as $0.5 = EV(\text{Theater}) > EV(\text{Home}) = 0.45$
  - B chooses Home as $0.5 = EV(\text{Theater}) < EV(\text{Home}) = 0.55$

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Motivating Example

Scenario 2

- Same problem as before, but now A and B can collect “some” information about the movie quality
- Note that we have 2 actions (T/H) and 3 states (b/m/g)
  - For Alice it is *sufficient* to know if the movie is b or (m/g)

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Motivating Example

Scenario 2

- Same problem as before, but now A and B can collect “some” information about the movie quality
- Note that we have 2 actions (T/H) and 3 states (b/m/g)
  - For Bob it is *sufficient* to know if the movie is (b/m) or g

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Motivating Example

Scenario 2

- If the movie is good (bad) they agree about the action Theater (Home)
- But they do not agree about the expected quality of the movie
  - Good movie: $EV_A(T|g) = 0.75 < EV_B(T|g) = 1$
  - Bad movie: $EV_A(T|b) = 0 < EV_B(T|b) = 0.25$
- If the movie is medium they still disagree about the action
- But they also disagree about the expected quality of the movie
  - Alice chooses Theater: $EV_A(T|m) = 0.75$
  - Bob chooses Home: $EV_B(T|m) = 0.25$

Motivating Example

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Motivating Example

Summary

- Alice and Bob have the same prior beliefs
- But they have different preferences (outside option)
- The introduction of **endogenous information collection** created disagreement about movie quality
- Stock/bond investment, Referendum vote (e.g. Brexit), etc.

Definitions (again)

- **State pooling**: agents avoid redundant information and "pool together" states associated with the same action
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Research Question

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Can we observe belief polarization and identify its drivers in a lab experiment?

This question can be divided into three smaller ones:

1. **How do agents evaluate and choose information sources?**
   We replicate well-known results (compression of WTP wrt optimal value, preference for certainty)
2. **Do we observe (preference for) state pooling?**
   Yes, we report new evidence of preference for "state pooling" and "extreme" information
3. **Do we observe belief polarization (by changing Safe)?**
   Yes, a change in the safe option generates "information switch" as predicted, and creates belief polarization

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Laboratory Experiment

Laboratory Experiment

- **How do agents evaluate and choose information sources?**
- **Do we observe (preference for) state pooling?**
- **Do we observe belief polarization (by changing Safe)?**

- Stage 1: choose or “hire” an advisor (experiment)
- Observe signal realization
- Stage 2: select an action [risky/safe]

- We collect separately
  - Choices over sources of information (advisors)
  - Action (conditional on realized signals)
  - Elicited beliefs (signal probability and posterior)
  - Willingness to pay for signal structures

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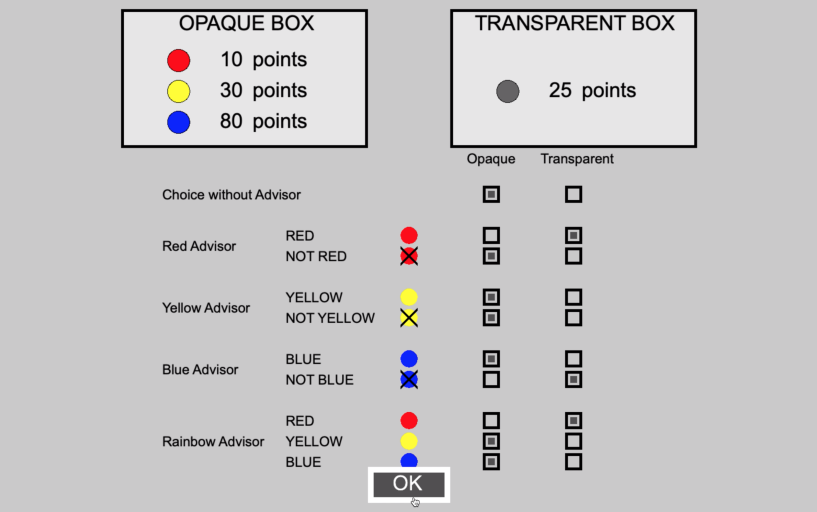
Laboratory Experiment

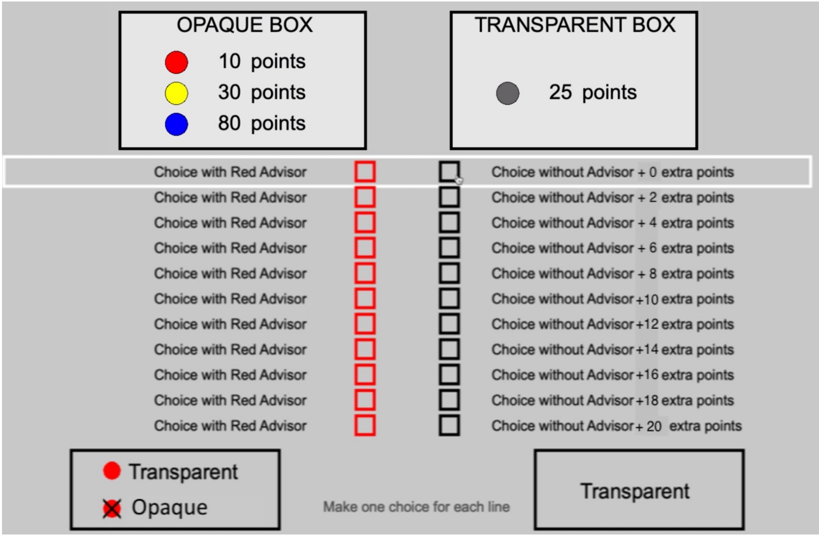
- Experiment conducted at Columbia in August-September 2019
- 85 participants (undergraduate and graduate students)
- Average time 80 minutes, Average payment ∼$25
  - Show-up fee ($10)
  - Main experiment, 4 parts (probability points, $15 prize)
  - Risk attitude (Holt-Laury, $0.10-$4.00)
  - Intelligence (Raven's Progressive Matrices, 5 x $0.50)
  - Unrewarded questionnaire (strategy, LOT-R, demographics)

Task 1

Task 1 - Choice screen

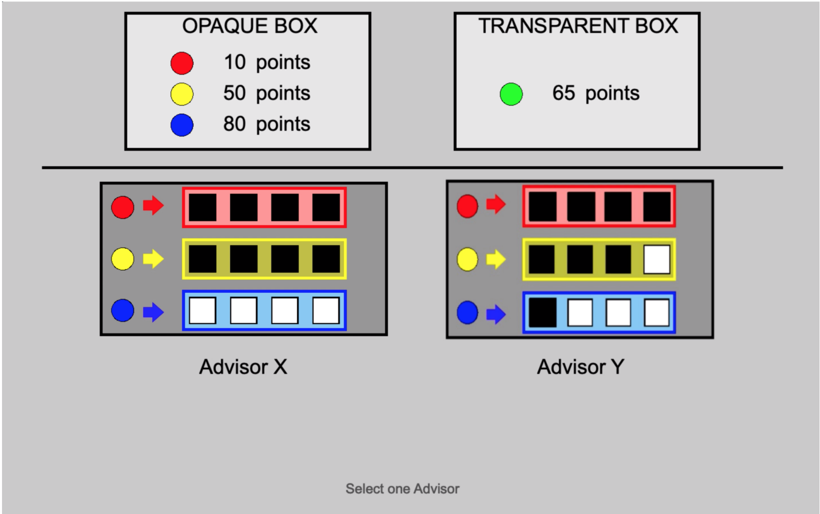


Task 1 - Hiring screen

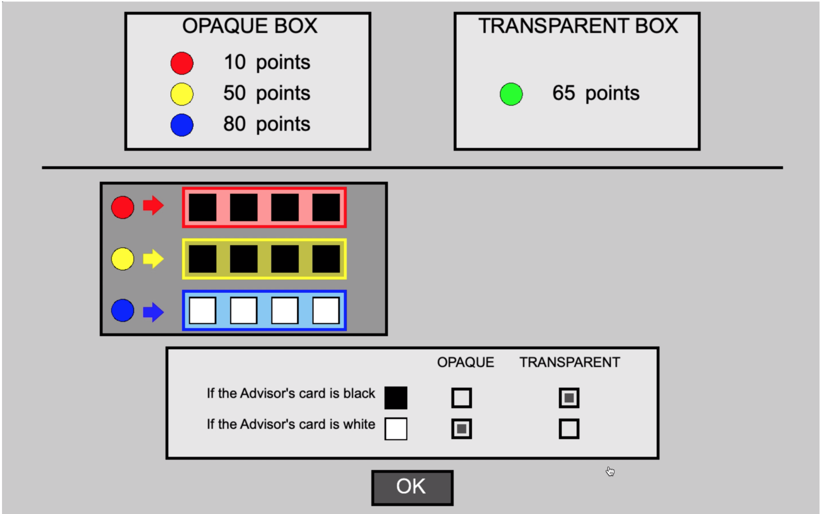


Task 2

Task 2 - Hiring screen

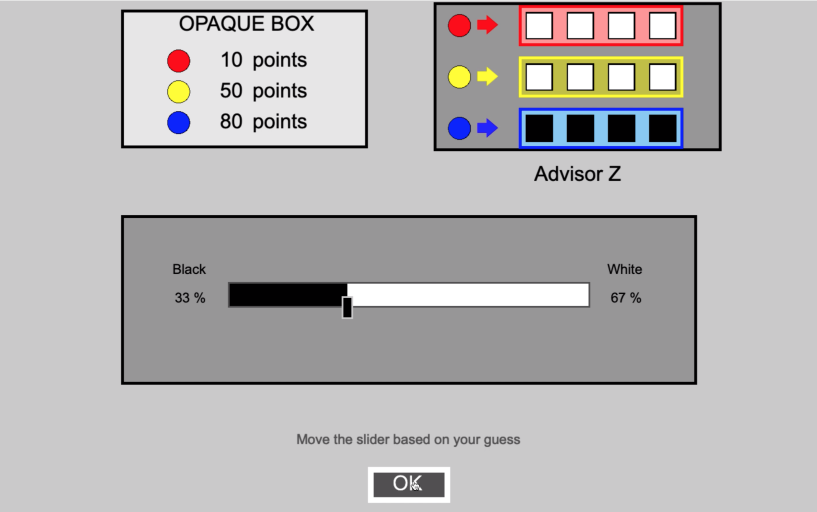


Task 2 - Choice screen



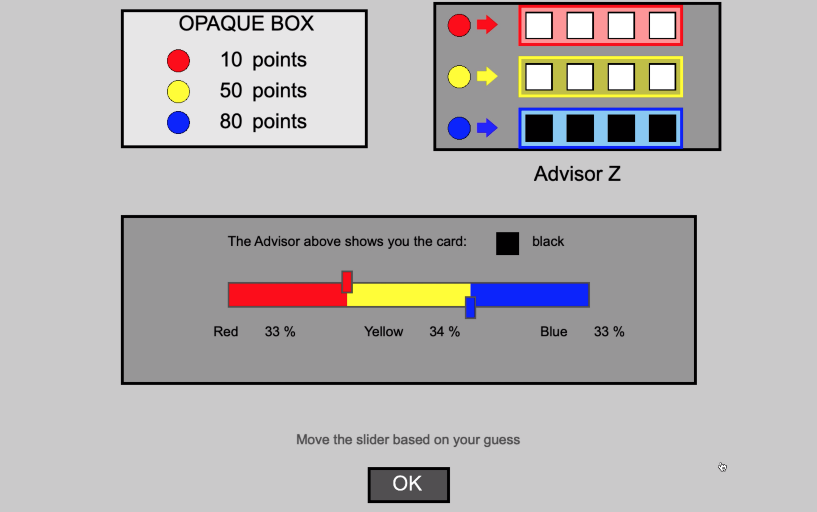
Task 3

Task 3 - Belief elicitation



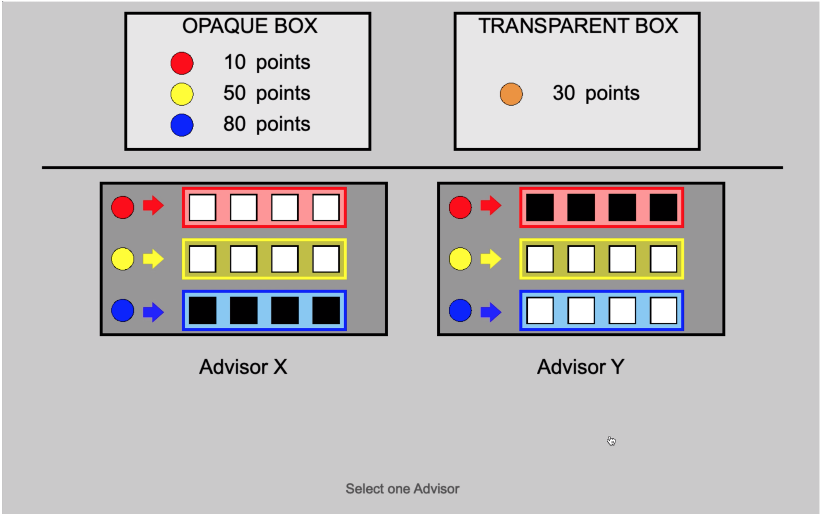
Task 4

Task 4 - Belief elicitation

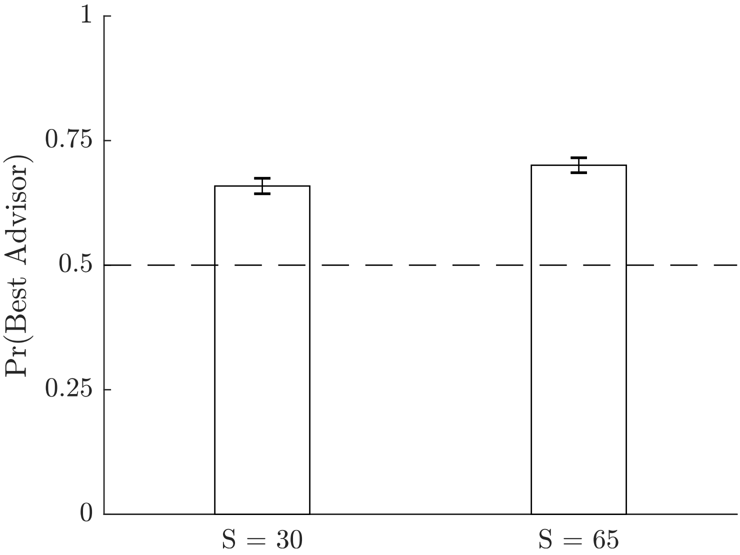


Preliminary Results

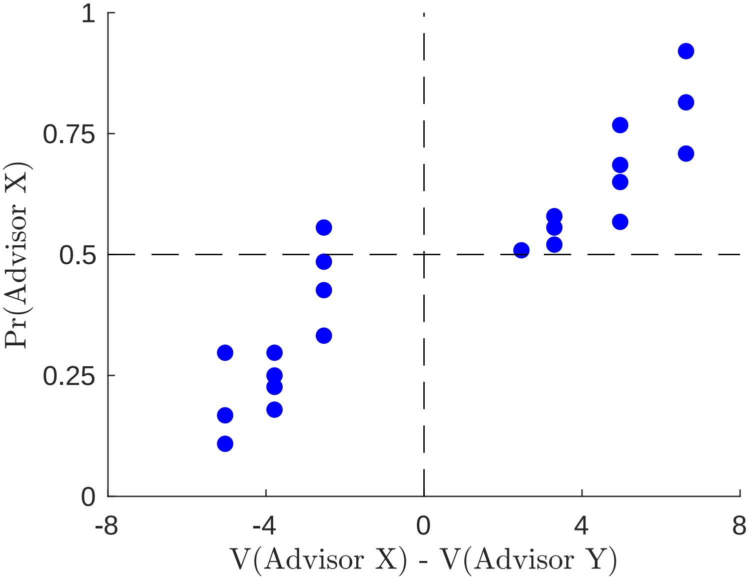
Task 2 - How did we design the pairs of advisor?



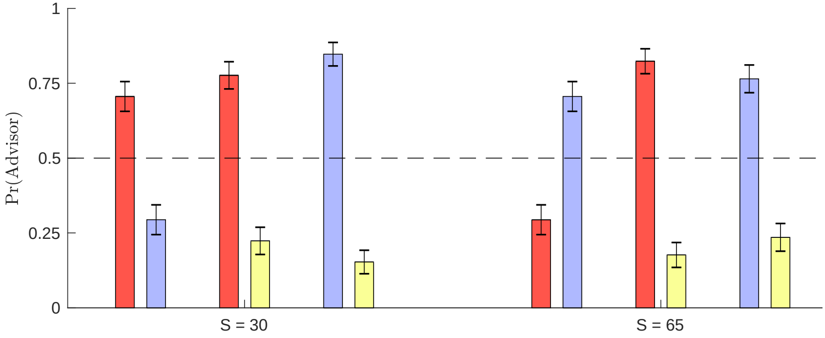
Most of participants “switch” advisor optimally



Accuracy depends on the stakes

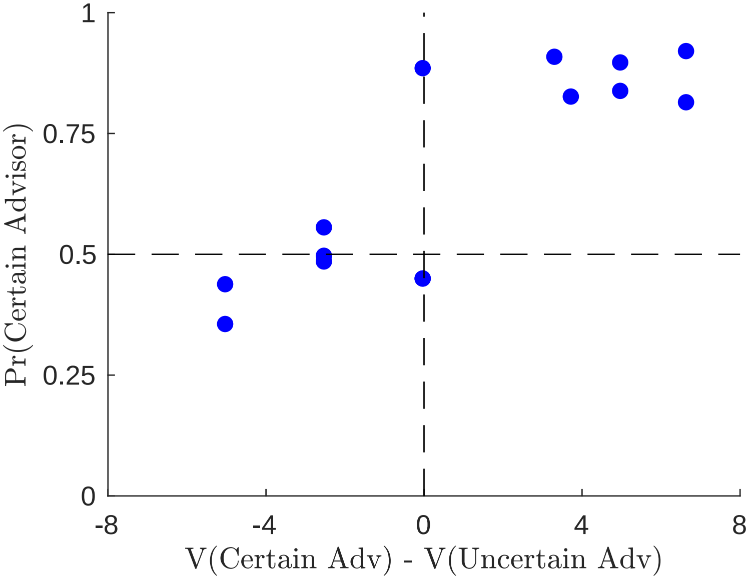


Simple Advisors: Certainty vs Certainty



- Each advisor “pools” two states out of three
- These trials are easy to interpret
- Participants switch in the red/blue choice...
- ...but they switch only when it is valuable to do so

Certainty vs Uncertainty



Aggregate Valuation of Advisors - Logit Regression

	(1)
v_I^{Bayes}	0.210***
	(0.0346)
Best Advisor	0.106
	(0.143)
Certainty	
State Pooling	
Certainty $\times$ SP	
Trials	All
Observations	3,400

The significance levels concern the hypothesis that the coefficient is 0.
Notation: *** p<0.01, ** p<0.05, * p<0.1

Aggregate Valuation of Advisors - Logit Regression

	(1)	(2)
v_I^{Bayes}	0.210***	0.236***
	(0.0346)	(0.0110)
Best Advisor	0.106	
	(0.143)	
Certainty		0.1876***
		(0.0708)
State Pooling		
Certainty $\times$ SP		
Trials	All	All
Observations	3,400	3,400

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Aggregate Valuation of Advisors - Logit Regression

	(1)	(2)	(3)
v_I^{Bayes}	0.210***	0.236***	0.2108***
	(0.0346)	(0.0110)	(0.0113)
Best Advisor	0.106		
	(0.143)		
Certainty		0.1876***	
		(0.0708)	
State Pooling			0.742***
			(0.0757)
Certainty $\times$ SP			0.488***
			(0.0825)
Trials	All	All	All
Observations	3,400	3,400	3,400

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Aggregate Valuation of Advisors - Logit Regression

	(1)	(2)	(3)	(4)
v_I^{Bayes}	0.210***	0.236***	0.2108***	0.253***
	(0.0346)	(0.0110)	(0.0113)	(0.0358)
Best Advisor	0.106			-0.186
	(0.143)			(0.149)
Certainty		0.1876***		0.596***
		(0.0708)		(0.154)
State Pooling			0.742***	1.041***
			(0.0757)	(0.111)
Certainty $\times$ SP			0.488***	-0.0601
			(0.0825)	(0.164)
Trials	All	All	All	All
Observations	3,400	3,400	3,400	3,400

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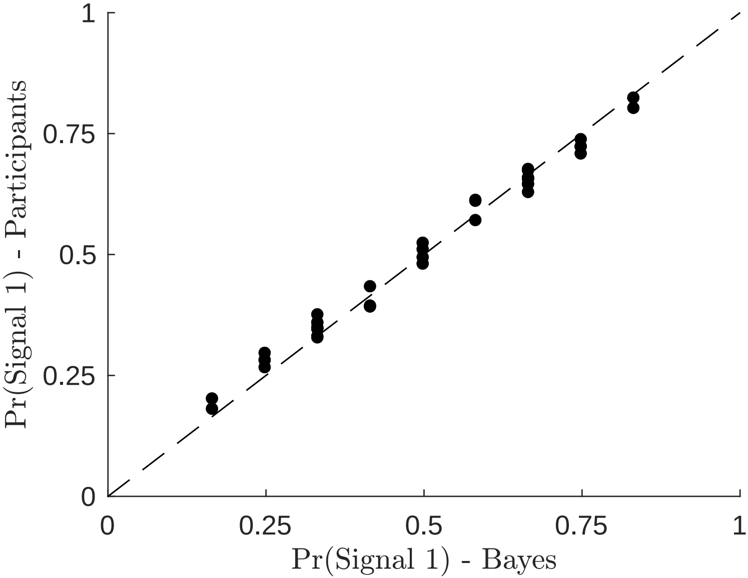
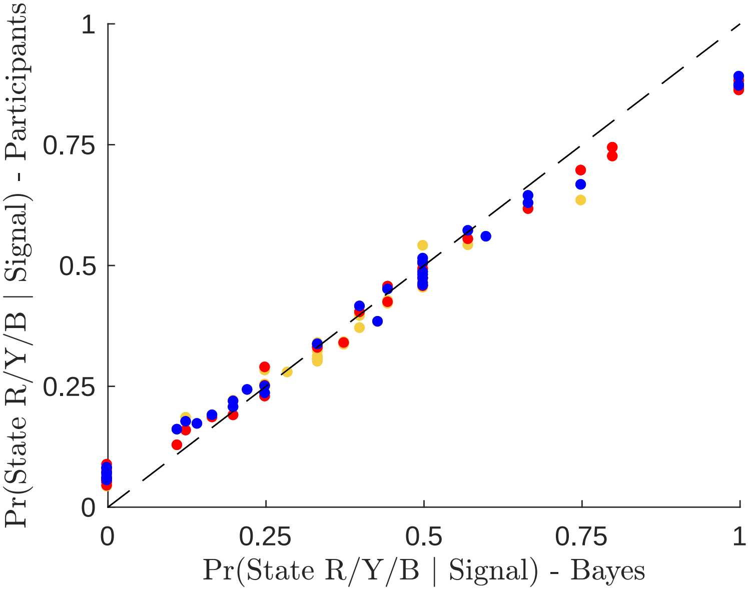
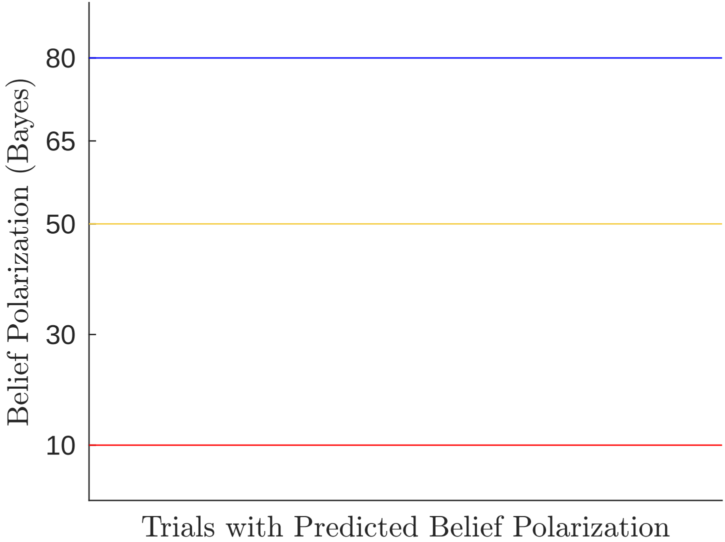
Elicited Beliefs - Card color



Elicited Beliefs - Ball color



Beliefs Polarization - Predictions



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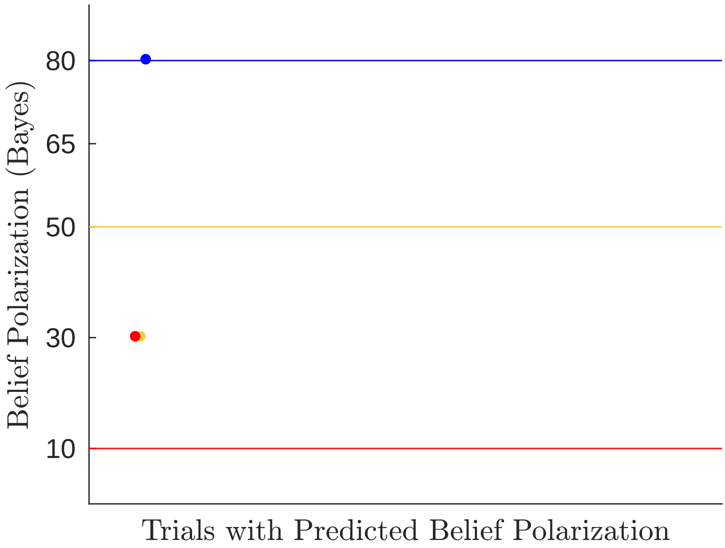

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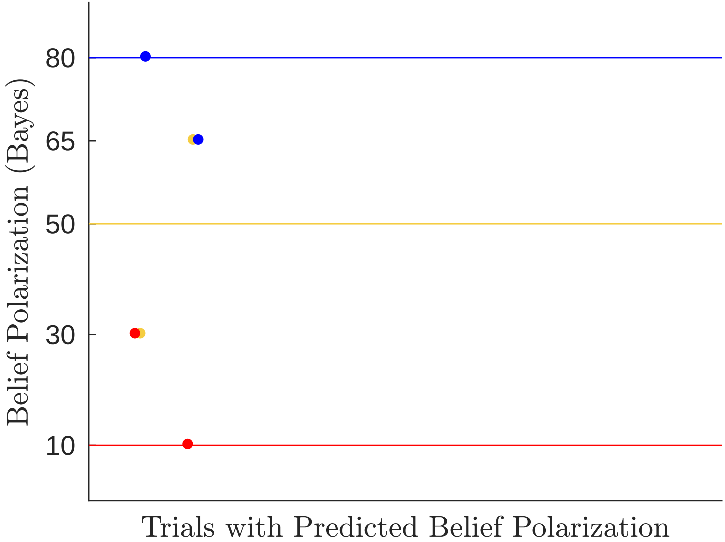

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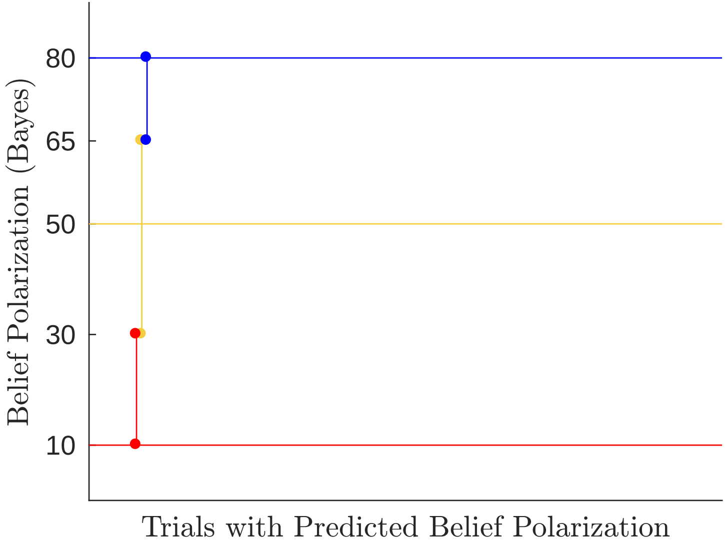

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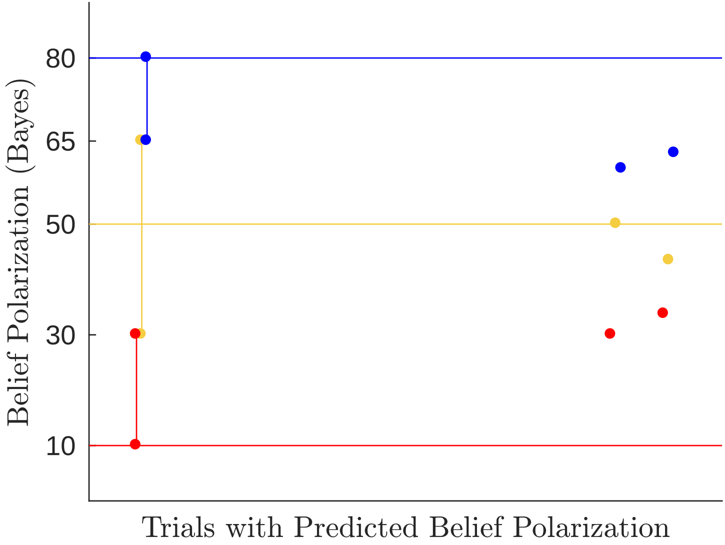

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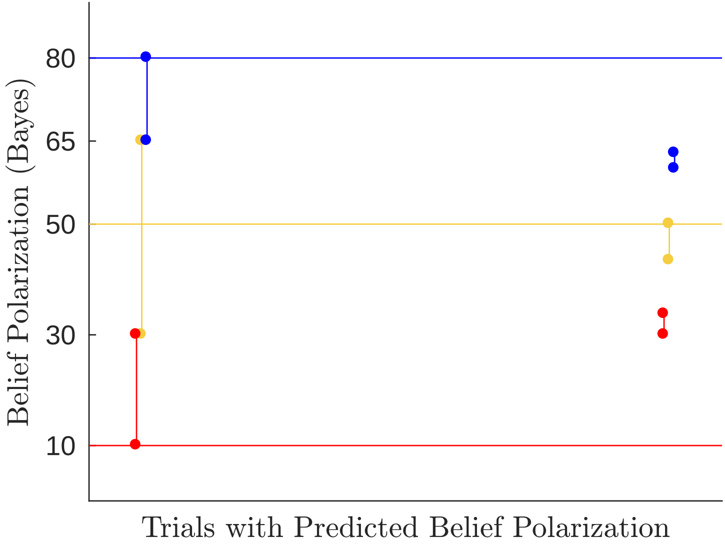

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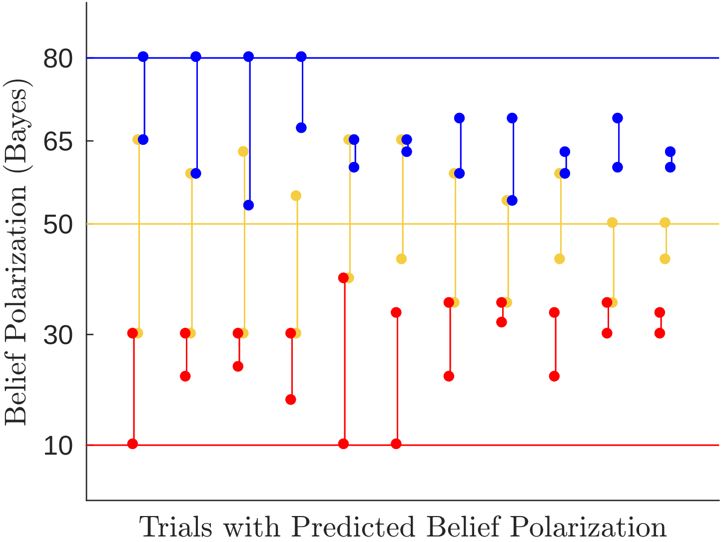
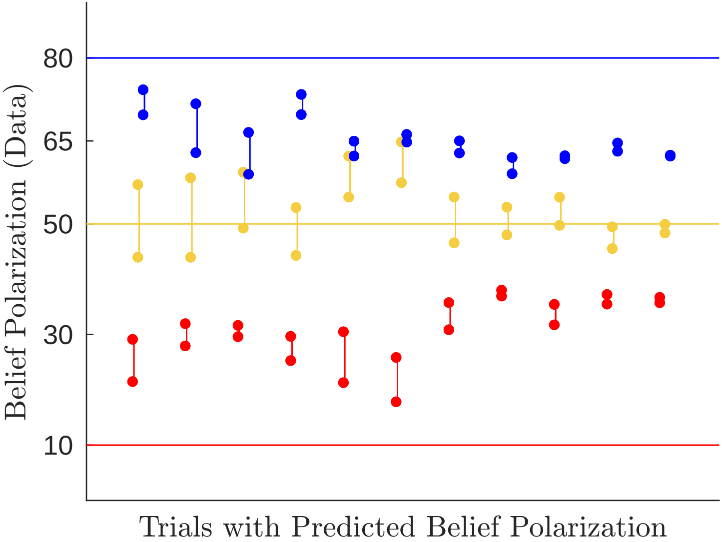
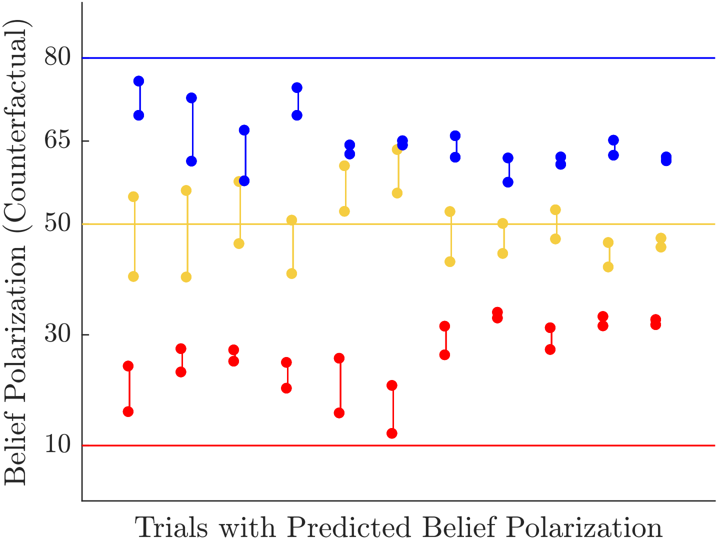


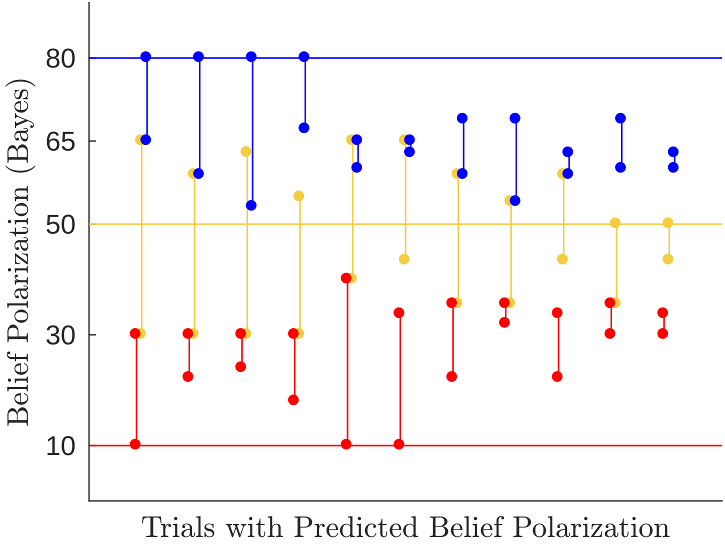
Beliefs Polarization - Data



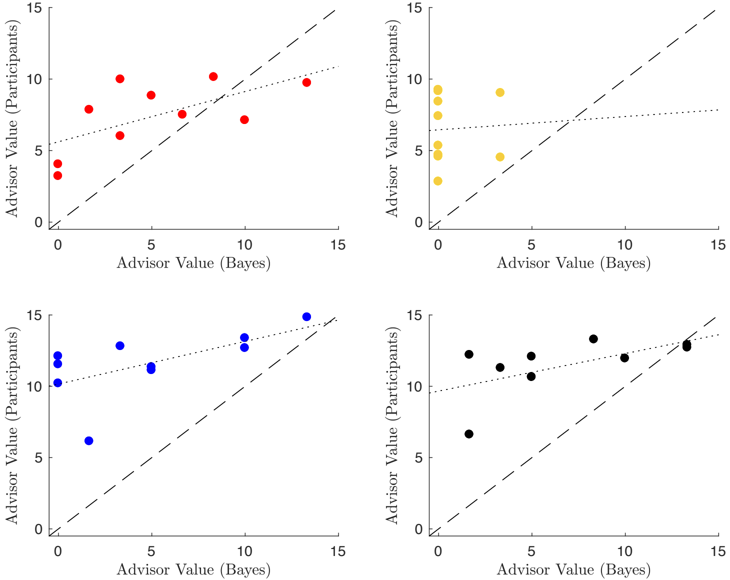
Beliefs Polarization - Counterfactual



Beliefs Polarization - Predictions



Compression in the WTP for Advisors in Task 1



Questionnaire - Strategies

State Pooling

- If low ball in transparent box, pick advisor most likely to reveal blue or yellow, vice versa
- I chose based on whichever advisor's information could tell me more about the single ball I either really did or did not want to pick

Other strategies

- CERTAINTY - I would choose the advisor which had the same color of cards for each color ball
- BLUE - To make sure if it is blue
- RED - I chose the advisor of the ball I didn't want to get on the opaque box, and if that was the color that was on the box, I went with the transparent box
- TALKATIVE - Probability

Summary

- **Motivation**: Empirical evidence of belief polarization (BP)
- **Setup**: 3 states and 2 actions (safe/risky)
- Endogenous information acquisition generates BP
- **Lab experiment**:
  - A change in the safe option generates "advisor switches" as predicted...
  - ... and creates (mitigated) belief polarization.
  - We replicate well-known results (compression, preference for certainty) in a new setup with 3 states...
  - ... and we report novel evidence: preference for "state pooling" and "extreme states" advisors.

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Appendix Slides

Appendix A - The Model

Appendix A

Appendix B - Related Literature

Appendix B

Appendix C - Confounding Factors

Appendix C

Appendix A - The Model

Full Model (Matveenko and Novak)

- DM is rationally inattentive (Sims, 2003, 2006)
  - Information costly - Shannon cost
  - λ - marginal cost of information
  - $\kappa(P, G)$ - **expected reduction in entropy**
  - $G(v)$ prior distribution
  - $P(i|v)$ probability of choosing action i conditional on v

- Main result: possible "wrong direction" updating of beliefs dependent on respective position of prior beliefs and safe option. It leads to polarization (more extreme posterior beliefs).

Agent's problem

Denote: $\mathbf{v} = (v_1, \ldots, v_n)$, $G(\mathbf{v})$ - prior joint distribution
Find an information strategy maximizing:

$$\max_{P(i|v)} \left\{ \sum_{i=1}^{2} \int_{\mathbf{v}} v_i P(i|\mathbf{v}) G(d\mathbf{v}) - \lambda \kappa(P, G) \right\},$$

where

$$\kappa(P, G) = -\sum_{i=1}^{2} P_i^0 \ln P_i^0 + \int_{\mathbf{v}} \left(\sum_{i=1}^{2} P(i|\mathbf{v}) \ln P(i|\mathbf{v}) \right) G(d\mathbf{v}).$$

$P(i|v)$ is the conditional on the realized value of v, the probability of choosing option i and

$$P_i^0 = \int_{\mathbf{v}} P(i|\mathbf{v}) G(d\mathbf{v}), \; i = 1, 2$$

where P_i^0 is the unconditional probability of option i to be chosen.

Lemma 1 (Matějka, McKay, 2015)

Conditional on the realized state of the world s^* probability of choosing risky option is

$$P(\text{picking risky}|\text{state is } s^*) = \frac{P_1^0 e^{\frac{v_s^*}{\lambda}}}{P_1^0 e^{\frac{v_s^*}{\lambda}} + (1 - P_1^0) e^{\frac{R}{\lambda}}}$$

of choosing safe option is:

$$P(\text{picking safe}|\text{state is } s^*) = \frac{(1 - P_1^0) e^{\frac{R}{\lambda}}}{P_1^0 e^{\frac{v_s^*}{\lambda}} + (1 - P_1^0) e^{\frac{R}{\lambda}}}$$

here P_1^0 is unconditional probability of choosing risky option.

Beliefs

- Agent's prior expected value of the risky option is:

$$\mathbb{E}v = \sum_{s=1}^{n} v_s g_s$$

we **fix the state** of the nature: it is s^*

- Observer sees agent's updated belief about the average of v:

$$\begin{aligned}\mathbb{E}_i[\mathbb{E}(v|i)|s^*] = P(i = 1|s^*)&\mathbb{E}(v|\text{picking option 1})+ \\ &+ (1 - P(i = 1|s^*))\mathbb{E}(v|\text{picking option 2})\end{aligned}$$

where for option $i \in \{1, 2\}$

$$\mathbb{E}(v|\text{picking option i}) = \sum_{j=1}^{n} v_i P(\text{state is j}|\text{picking option i})$$

Beliefs

Theorem

Expected posterior value of the risky option for a rationally inattentive decision maker is

$$\mathbb{E}_i[\mathbb{E}(v|i)|s^*] = \sum_{i=1}^{n} v_i g_i \frac{\alpha_{s^*} e^{\frac{v_i}{\lambda}} + (1-\alpha_{s^*})e^{\frac{R}{\lambda}}}{P_1^0 e^{\frac{v_i}{\lambda}} + (1-P_1^0)e^{\frac{R}{\lambda}}} \tag{1}$$

where

$$\alpha_{s^*} = \frac{P_1^0 e^{\frac{v_{s^*}}{\lambda}}}{P_1^0 e^{\frac{v_{s^*}}{\lambda}} + (1-P_1^0)e^{\frac{R}{\lambda}}}$$

Updating of beliefs

We are interested in

$$\Delta = \mathbb{E}_i[\mathbb{E}(v|i)|s^*] - \mathbb{E}v$$

Theorem

The sign of Δ is the same as the sign of $(v_{s^*} - R)$.

Proof.

Straightforward and we use:

Lemma 2

Relations $\alpha_{s^*} \gtrless P_1^0$ under $P_1^0 > 0$ are equivalent to $v_{s^*} \gtrless R$

$\square$

Example 3 states, 2 actions

- 3 possible states of the world - indexed by s
- 2 options/actions - indexed by a
  - Option 1 - Risky with values: $v_1 < v_2 < v_3$
  - Option 2 - Safe option with value R in all states
- Prior belief about the states: g_1, g_2, g_3
- Marginal cost of information: λ

Assumption 1: to rule out uninteresting cases

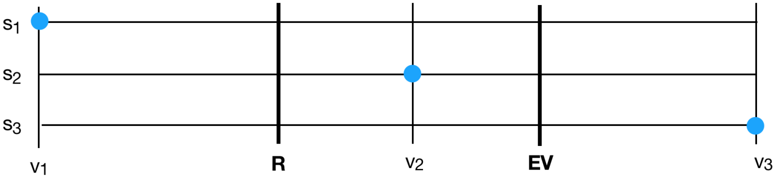
$$v_1 < R < v_3$$

Updating in "wrong" direction

We are interested when the conditional expectation moves in the **"wrong" direction**

Example for $s^* = 1$ the expectation "should" go down, so the agent is biased when

$$\mathbb{E}_a[\mathbb{E}(v|a)|s^*] > \mathbb{E}v > 0$$



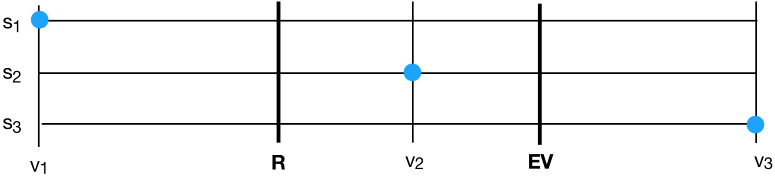
Updating in "wrong" direction

Let's denote $\Delta = \mathbb{E}_a[\mathbb{E}(v|a)|s^*] - \mathbb{E}v$.

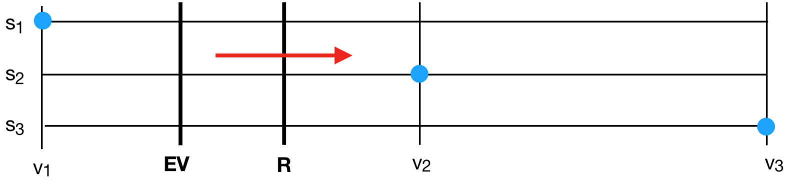
If

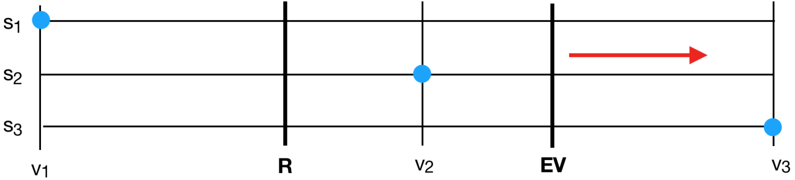
$$(\mathbb{E}v - v_{s^*}) \cdot \Delta > 0$$

then the agent is updating belief in the wrong direction



Result





Back to Model slides

Appendix B - Literature

Information and Belief Polarization

- Polarization is an ubiquitous phenomenon
- Mixed evidence of how information contributes to polarization
  - Politicians and voters more polarized despite increased availability of information
    McCarty, Poole and Rosenthal (2006)
  - Greater Internet use is not associated with faster growth in political polarization among US demographic groups
    Boxell, Gentzkow and Shapiro (2017)

Back to Literature slides

Multiple Explanations for Polarization

1. **Confirmation bias**
   - Misreading ambiguous signals: Rabin, Schrag (1999); Fryer, Harms, Jackson (2017)
   - Limited memory: Wilson (2014)
   - Experiments: Lord, Ross, Lepper (1979)

2. **Overconfidence and correlation neglect**
   - Ortoleva and Snowberg (2015)

3. **Positive test strategy**
   - Klayman and Ha (1987), Nickerson (1998)

Results mostly based on exogeneous information and/or exogeneously imposed biases.

▸ Back to Literature slides

Confirmation Bias and Rational Inattention

1. **Su (2014)**
   - Gaussian signal + quadratic loss function
   - Attention proportional to observation window
   - Results: conformism in learning

2. **Nimark and Sundaresan (2018)**
   - Mainly focus on polarization persistence
   - Agent pays more attention to the states which are more likely

3. **Dixit and Weibull (2007)** - not RI
   - Learning about policy in place (signal bimodal)
   - Agents agree on loss function, disagree on probabilities of states
   - Status quo vs. new reform - Divergence of opinions

Back to Literature slides

Experimental Literature

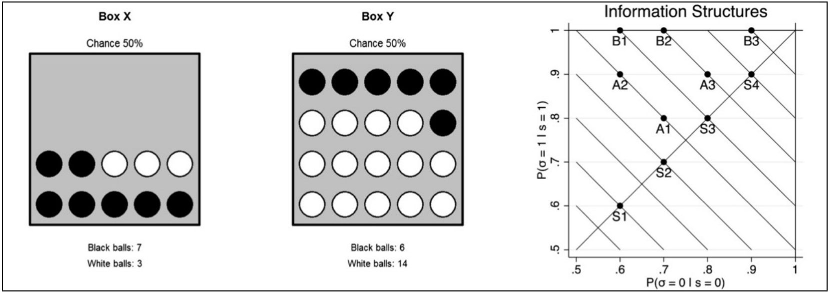
1. **Ambuehl and Li (2018)**
   - Systematic analysis of belief updating and demand for information
   - Compression effect: subjective valuation of useful information underreacts to increased informativeness
   - Biases mainly due to non-standard belief updating rather than risk preferences

2. **Charness, Oprea, and Yuksel (2018)**
   - Study how people choose between biased information sources
   - Evidence of confirmation-seeking rule
   - Mistakes are driven by errors in reasoning about informativeness

Back to Literature slides

Ambuehl and Li (2018)

- Prediction game
- **Information valuation task**
- Belief updating task
- Eliciting signal probabilities
- Gradual information task



Back to Literature slides

Charness, Oprea, and Yuksel (2018)

Back to Literature slides

Appendix C
Confounding Factors

Who killed BP in the lab? A list of usual suspects

- Risk attitude
- Noise/randomness
- Inertia
- Status quo effect
- Wrong updating (base-rate neglect, conservatism)
- Updating strength affected by irrelevant variables
- Confirmatory strategy (positive test)
- Preference over non-instrumental information
- Signal avoidance (ostrich effect)
- Biased information cost/value function (compression)

Back to Experiment slides