WHEN CHOICES ARE MISTAKES

Kirby Nielsen (CALTECH)
John Rehbeck (THE OHIO STATE UNIVERSITY)

BACKGROUND

- Decades of empirical evidence has documented deviations from expected utility (EU) maximization

BACKGROUND

- Decades of empirical evidence has documented deviations from expected utility (EU) maximization
- Behavioral economics approach:
  - Descriptive models to capture violations
  - Often implicit: violation $\Rightarrow$ individuals do not want to satisfy EU in this particular decision

BACKGROUND

- Decades of empirical evidence has documented deviations from expected utility (EU) maximization
- Behavioral economics approach:
  - Descriptive models to capture violations
  - Often implicit: violation $\Rightarrow$ individuals do not want to satisfy EU in this particular decision
- Alternative interpretation:
  - Violations are mistakes
  - Individuals would prefer to maximize EU even if choices don't always reflect this

EXAMPLE: ALLAIS PARADOX

	Option A:	Option B:
Q1:		
Q2:		

EXAMPLE: ALLAIS PARADOX

	Option A:	Option B:
Q1:	100% chance of $10	
Q2:		

EXAMPLE: ALLAIS PARADOX

	Option A:		Option B:
Q1:	100% chance of $10	vs.	80% chance of $13 20% chance of $0
Q2:			

EXAMPLE: ALLAIS PARADOX

	Option A:		Option B:
Q1:	100% chance of $10	vs.	80% chance of $13 20% chance of $0
Q2:	25% chance of $10 75% chance of $0		

EXAMPLE: ALLAIS PARADOX

	Option A:		Option B:
Q1:	100% chance of $10	vs.	80% chance of $13 20% chance of $0
Q2:	25% chance of $10 75% chance of $0	vs.	20% chance of $13 80% chance of $0

EXAMPLE: ALLAIS PARADOX

	Option A:		Option B:
Q1:	100% chance of \$10	vs.	80% chance of \$13 20% chance of \$0
Q2:	25% chance of \$10 75% chance of \$0	vs.	20% chance of \$13 80% chance of \$0

Many choose Option A in Q1 and Option B in Q2, which violates expected utility theory

EXAMPLE: ALLAIS PARADOX

		Option A:		Option B:	
	Q1:	100% chance of \$10	vs.	80% chance of \$13 20% chance of \$0	
$0.25 \cdot Q1 +$ $0.75 \cdot 0$	Q2:	25% chance of \$10 75% chance of \$0	vs.	20% chance of \$13 80% chance of \$0	$0.25 \cdot Q1 +$ $0.75 \cdot 0$

EXAMPLE: ALLAIS PARADOX

	Option A:		Option B:
Q1:	100% chance of $10	vs.	80% chance of $13 20% chance of $0
Q2:	25% chance of $10 75% chance of $0	vs.	20% chance of $13 80% chance of $0

Behavioral explanations:

- Certainty effect
- Regret aversion
- Etc.

EXAMPLE: ALLAIS PARADOX

	Option A:		Option B:
Q1:	100% chance of \$10	vs.	80% chance of \$13 20% chance of \$0
Q2:	25% chance of \$10 75% chance of \$0	vs.	20% chance of \$13 80% chance of \$0

Behavioral explanations:

- Certainty effect
- Regret aversion
- Etc.
- $\Rightarrow$ Behavioral non-EU models, e.g., prospect theory (Kahneman and Tversky, 1979)

ALLAIS PARADOX

- Choosing Option A in Q1 and Option B in Q2 does **not** imply that the decision maker *wants* to violate expected utility MacCrimmon (1968); Slovic and Tversky (1974); MacCrimmon and Larsson (1979)

ALLAIS PARADOX

- Choosing Option A in Q1 and Option B in Q2 does **not** imply that the decision maker *wants* to violate expected utility MacCrimmon (1968); Slovic and Tversky (1974); MacCrimmon and Larsson (1979)
- Case Study: Savage vs. Allais (1950s)

ALLAIS PARADOX

- Choosing Option A in Q1 and Option B in Q2 does **not** imply that the decision maker *wants* to violate expected utility MacCrimmon (1968); Slovic and Tversky (1974); MacCrimmon and Larsson (1979)
- Case Study: Savage vs. Allais (1950s)
  - Allais introduced the Allais Paradox

ALLAIS PARADOX

- Choosing Option A in Q1 and Option B in Q2 does **not** imply that the decision maker *wants* to violate expected utility MacCrimmon (1968); Slovic and Tversky (1974); MacCrimmon and Larsson (1979)
- Case Study: Savage vs. Allais (1950s)
  - Allais introduced the Allais Paradox
  - Savage's decisions violated expected utility

ALLAIS PARADOX

- Choosing Option A in Q1 and Option B in Q2 does **not** imply that the decision maker *wants* to violate expected utility MacCrimmon (1968); Slovic and Tversky (1974); MacCrimmon and Larsson (1979)
- Case Study: Savage vs. Allais (1950s)
  - Allais introduced the Allais Paradox
  - Savage's decisions violated expected utility
  - Savage *changed his decisions* to be consistent with EU

ALLAIS PARADOX

- Choosing Option A in Q1 and Option B in Q2 does **not** imply that the decision maker *wants* to violate expected utility MacCrimmon (1968); Slovic and Tversky (1974); MacCrimmon and Larsson (1979)
- Case Study: Savage vs. Allais (1950s)
  - Allais introduced the Allais Paradox
  - Savage's decisions violated expected utility
  - Savage *changed his decisions* to be consistent with EU
  - **Savage made a mistake**

“In reversing my preference... I have corrected an error. There is, of course, an important sense in which preferences, being entirely subjective, cannot be in error; but in a different, more subtle sense they can be.”

— Leonard Savage (1954)

OUR PAPER

What we do: Develop an experimental framework by which to identify mistakes separate from intentional deviations

OUR PAPER

What we do: Develop an experimental framework by which to identify mistakes separate from intentional deviations

- Are people "Savages" who change their decisions after departing from predictions of our model?

OUR PAPER

What we do: Develop an experimental framework by which to identify mistakes separate from intentional deviations

- Are people "Savages" who change their decisions after departing from predictions of our model?
- Or, do violations lead to renouncing the model?
  - E.g., cautious expected utility (Cerreia-Vioglio, Dillenberger, Ortoleva; 2015)

OUR PAPER

What we do: Develop an experimental framework by which to identify mistakes separate from intentional deviations

- Are people "Savages" who change their decisions after departing from predictions of our model?
- Or, do violations lead to renouncing the model?
  - E.g., cautious expected utility (Cerreia-Vioglio, Dillenberger, Ortoleva; 2015)

Why?

- Interpretation of descriptive models
- Additional challenges for behavioral welfare

WHAT WE DO

- To test this in a clean way, we focus on simple *axioms*
  - E.g., Savage violated the *independence* axiom of EU
  - When individuals violate an axiom, is it a mistake?

WHAT WE DO

- To test this in a clean way, we focus on simple *axioms*
  - E.g., Savage violated the *independence* axiom of EU
  - When individuals violate an axiom, is it a mistake?
- Need three pieces of information to detect mistakes

WHAT WE DO

- To test this in a clean way, we focus on simple *axioms*
  - E.g., Savage violated the *independence* axiom of EU
  - When individuals violate an axiom, is it a mistake?
- Need three pieces of information to detect mistakes
  1. "Ex-ante" preferences over axioms

WHAT WE DO

- To test this in a clean way, we focus on simple *axioms*
  - E.g., Savage violated the *independence* axiom of EU
  - When individuals violate an axiom, is it a mistake?
- Need three pieces of information to detect mistakes
  1. "Ex-ante" preferences over axioms
  2. Violations of axioms

WHAT WE DO

- To test this in a clean way, we focus on simple *axioms*
  - E.g., Savage violated the *independence* axiom of EU
  - When individuals violate an axiom, is it a mistake?
- Need three pieces of information to detect mistakes
  1. "Ex-ante" preferences over axioms
  2. Violations of axioms
  3. Revised choices when presented with inconsistencies

MAIN RESEARCH QUESTIONS

We elicit this in an experiment and ask

MAIN RESEARCH QUESTIONS

We elicit this in an experiment and ask

1. Do individuals prefer these axioms ex-ante?

MAIN RESEARCH QUESTIONS

We elicit this in an experiment and ask

1. Do individuals prefer these axioms ex-ante?

2. Do individuals who prefer an axiom violate it less often?

MAIN RESEARCH QUESTIONS

We elicit this in an experiment and ask

1. Do individuals prefer these axioms ex-ante?

2. Do individuals who prefer an axiom violate it less often?

3. **Main Question**: When an individual prefers an axiom but violates it, how do they reconcile this?
   - Change choices to agree with axiom? (à la Savage)
   - Keep choices and renounce axiom?

MAIN RESEARCH QUESTIONS

We elicit this in an experiment and ask

1. Do individuals prefer these axioms ex-ante?
   - **Yes,** $\sim 85\%$ **select axioms**
2. Do individuals who prefer an axiom violate it less often?

3. **Main Question**: When an individual prefers an axiom but violates it, how do they reconcile this?
   - Change choices to agree with axiom? (à la Savage)
   - Keep choices and renounce axiom?

MAIN RESEARCH QUESTIONS

We elicit this in an experiment and ask

1. Do individuals prefer these axioms ex-ante?
   - **Yes,** ~ 85% **select axioms**
2. Do individuals who prefer an axiom violate it less often?
   - **No**
3. **Main Question**: When an individual prefers an axiom but violates it, how do they reconcile this?
   - Change choices to agree with axiom? (à la Savage)
   - Keep choices and renounce axiom?

MAIN RESEARCH QUESTIONS

We elicit this in an experiment and ask

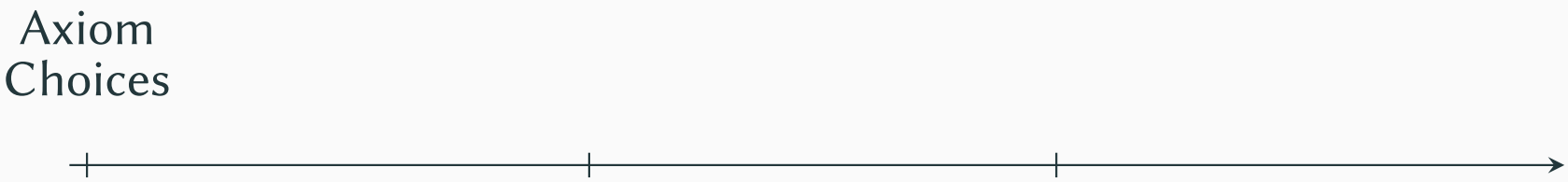
1. Do individuals prefer these axioms ex-ante?
   - **Yes,** ~ 85% **select axioms**
2. Do individuals who prefer an axiom violate it less often?
   - **No**
3. **Main Question**: When an individual prefers an axiom but violates it, how do they reconcile this?
   - **Change choices to agree with axiom? (à la Savage)**
   - Keep choices and renounce axiom?

QUESTIONS ABOUT
WHAT WE ARE TRYING TO DO?

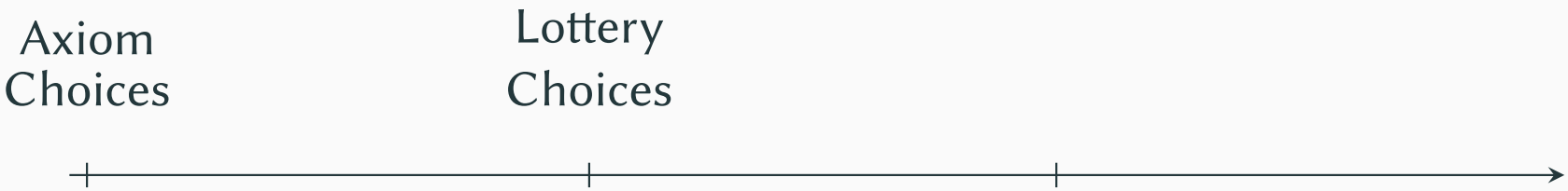
DESIGN

EXPERIMENT TIMELINE

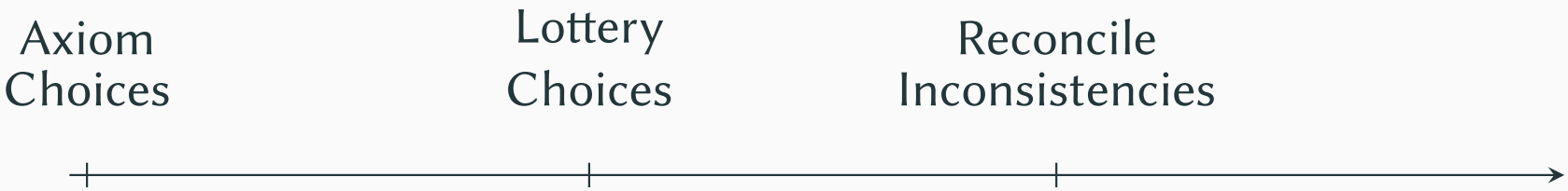
EXPERIMENT TIMELINE



EXPERIMENT TIMELINE



EXPERIMENT TIMELINE



EXPERIMENT TIMELINE

EXPERIMENT TIMELINE

Do individuals *want* to satisfy these axioms?

HOW WE INCENTIVIZE

- We incentivize the choice of an axiom by using the axiom to *automatically* implement choices on a subject's behalf
- For example:
  - Independence of Irrelevant Alternatives (IIA):

$$p = C(\{p, q, r\}) \Rightarrow p = C(\{p, q\})$$

HOW WE INCENTIVIZE

- We incentivize the choice of an axiom by using the axiom to *automatically* implement choices on a subject's behalf
- For example:
  - Independence of Irrelevant Alternatives (IIA):

$$p = C(\{p, q, r\}) \Rightarrow p = C(\{p, q\})$$

  - If a subject "chooses" IIA:
    - We automatically choose p over q for them

HOW WE INCENTIVIZE

- We incentivize the choice of an axiom by using the axiom to *automatically* implement choices on a subject's behalf
- For example:
  - Independence of Irrelevant Alternatives (IIA):

$$p = C(\{p, q, r\}) \Rightarrow p = C(\{p, q\})$$

  - If a subject "chooses" IIA:
    - We automatically choose p over q for them
  - If they do not choose IIA:
    - They choose between p and q themselves

TURN AXIOM INTO AN "ALGORITHM"

$$p = C(\{p, q, r\}) \Rightarrow p = C(\{p, q\})$$

TURN AXIOM INTO AN "ALGORITHM"

$$C(\{p, q, r\})$$

TURN AXIOM INTO AN "ALGORITHM"

$$C(\{p, q, r\})$$

Options:

p vs. q vs. r

TURN AXIOM INTO AN "ALGORITHM"

$$p = C(\{p, q, r\})$$

Options:

p vs. q vs. r

TURN AXIOM INTO AN "ALGORITHM"

$$p = C(\{p, q, r\})$$

Options:

p vs. q vs. r

If You Pick:

p

TURN AXIOM INTO AN "ALGORITHM"

$$p = C(\{p, q, r\}) \Rightarrow p = C(\{p, q\})$$

Options:

p vs. q vs. r

If You Pick:

p

TURN AXIOM INTO AN "ALGORITHM"

$$p = C(\{p, q, r\}) \Rightarrow p = C(\{p, q\})$$

Options:

p vs. q vs. r

p vs. q

If You Pick:

p

TURN AXIOM INTO AN "ALGORITHM"

$$p = C(\{p, q, r\}) \Rightarrow p = C(\{p, q\})$$

Options:	If You Pick:	Then We Pick:
p vs. q vs. r	p	
p vs. q		p

TURN AXIOM INTO AN "ALGORITHM"

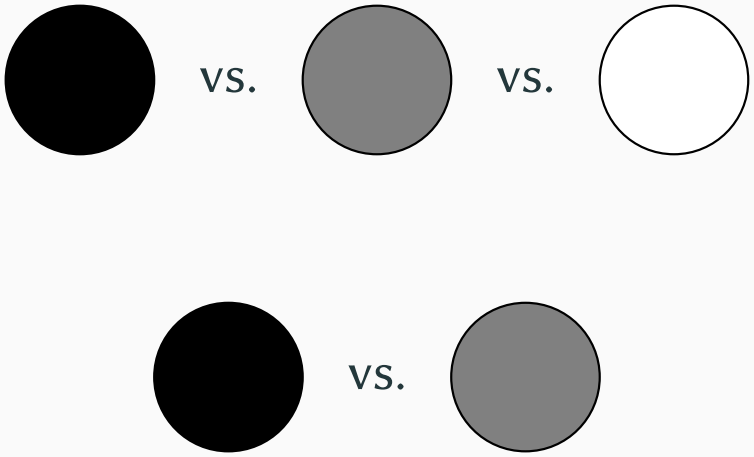
Options:	If You Pick:	Then We Pick:
p vs. q vs. r	p	
p vs. q		p

Yes, I want to use this rule

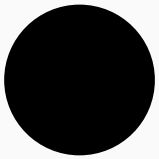
No, I will decide myself

THIS IS WHAT SUBJECTS SEE

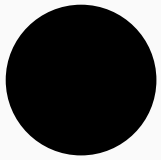
Options:



If You Pick:



Then We Pick:

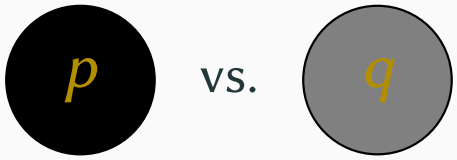


Yes, I want to use this rule

No, I will decide myself

THIS IS WHAT SUBJECTS SEE

Options:



If You Pick:

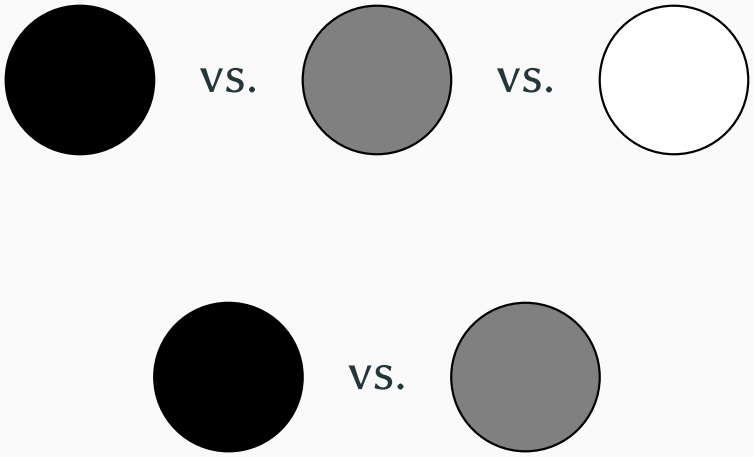
Then We Pick:

Yes, I want to use this rule

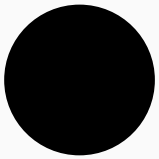
No, I will decide myself

THIS IS WHAT SUBJECTS SEE

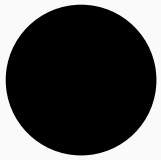
Options:



If You Pick:



Then We Pick:



Yes, I want to use this rule

No, I will decide myself

THE DOMAIN

We fix subjects' beliefs about the domain of lotteries

THE DOMAIN

We fix subjects' beliefs about the domain of lotteries

- Domain:
  - Colors represent weakly-positive money lotteries
  - Payoffs from \$0–\$30
  - Probabilities from 0–100%
  - Colors don't have any inherent meaning
    - E.g., grey is not "in between" black and white

THE DOMAIN

We fix subjects' beliefs about the domain of lotteries

- Domain:
  - Colors represent weakly-positive money lotteries
  - Payoffs from \$0–\$30
  - Probabilities from 0–100%
  - Colors don't have any inherent meaning
    - E.g., grey is not "in between" black and white
- Subjects know the domain but not specific lotteries
  - Eliciting a preference for the *axiom*, not just specific instances of it

INCENTIVES

- Don't think it *always* should be true $\Rightarrow$ don't select it

INCENTIVES

- Don't think it *always* should be true ⇒ don't select it
  - Payment lotteries could be *any* lotteries in the domain
  - If there are any instances where it wouldn't be true, shouldn't select it
    - Caveat: decision-making costs

INCENTIVES

- Don't think it *always* should be true ⇒ don't select it
  - Payment lotteries could be *any* lotteries in the domain
  - If there are any instances where it wouldn't be true, shouldn't select it
    - Caveat: decision-making costs
- Think it always should be true ⇒ select it (weakly)

INCENTIVES

- Don't think it *always* should be true ⇒ don't select it
  - Payment lotteries could be *any* lotteries in the domain
  - If there are any instances where it wouldn't be true, shouldn't select it
    - Caveat: decision-making costs
- Think it always should be true ⇒ select it (weakly)
  - Rule will automatically implement preferred choices
  - In another treatment, strict $1 cost to decide on their own

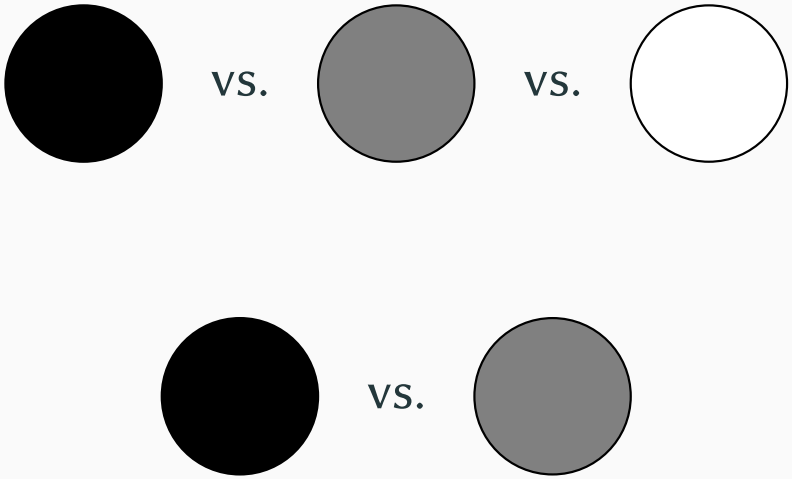
AXIOMS

- We study 3 “simple” axioms:
  1. Independence of Irrelevant Alternatives
  2. Transitivity
  3. Consistency
- And 3 “mixture” axioms:
  1. First-Order Stochastic Dominance
  2. (Mixture) Independence
  3. Branch Independence

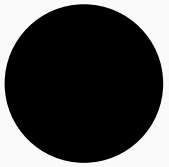
SIMPLE AXIOMS

RULE REPRESENTATION: IIA

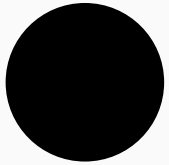
Options:



You Picked:

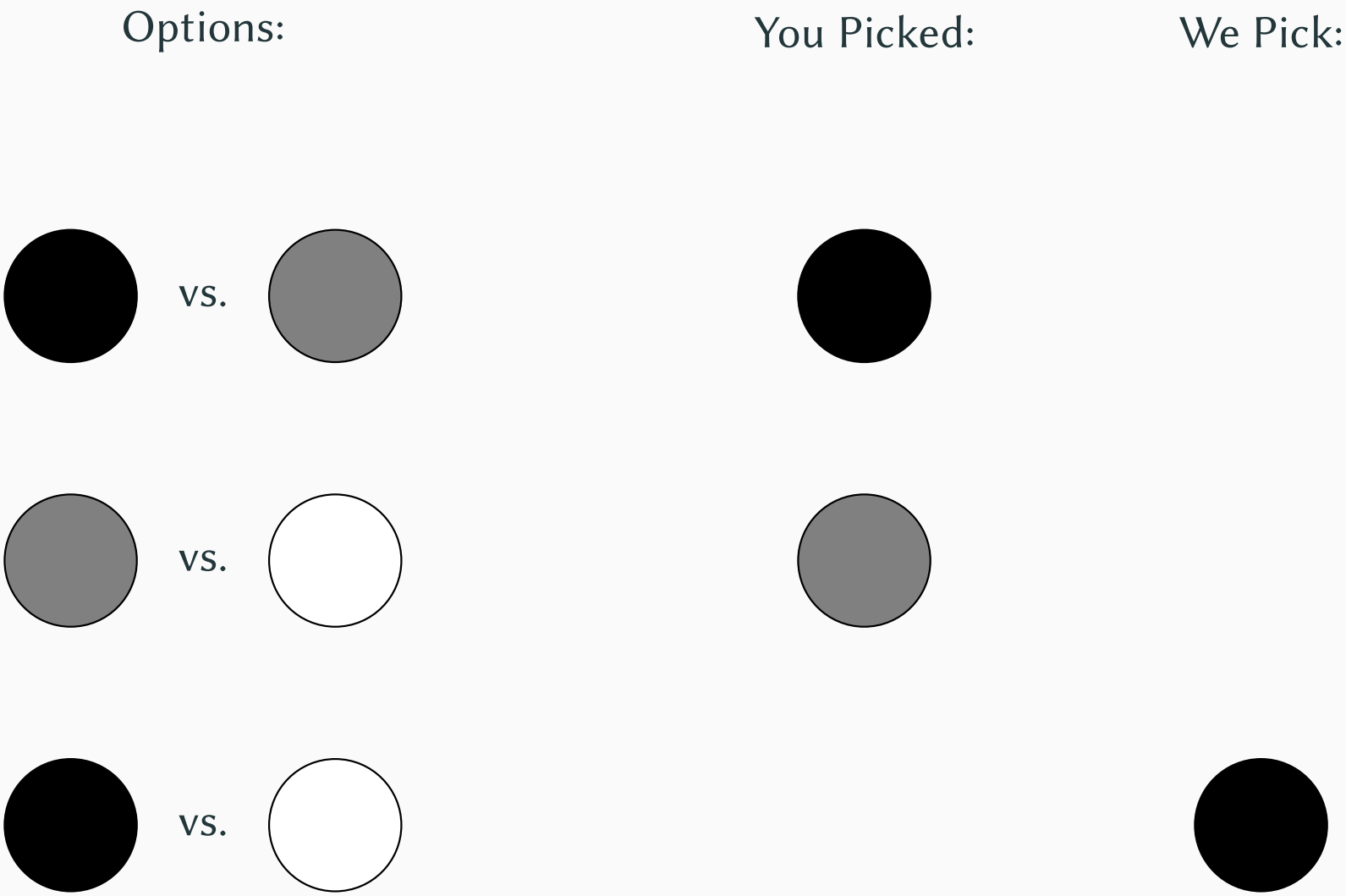


We Pick:



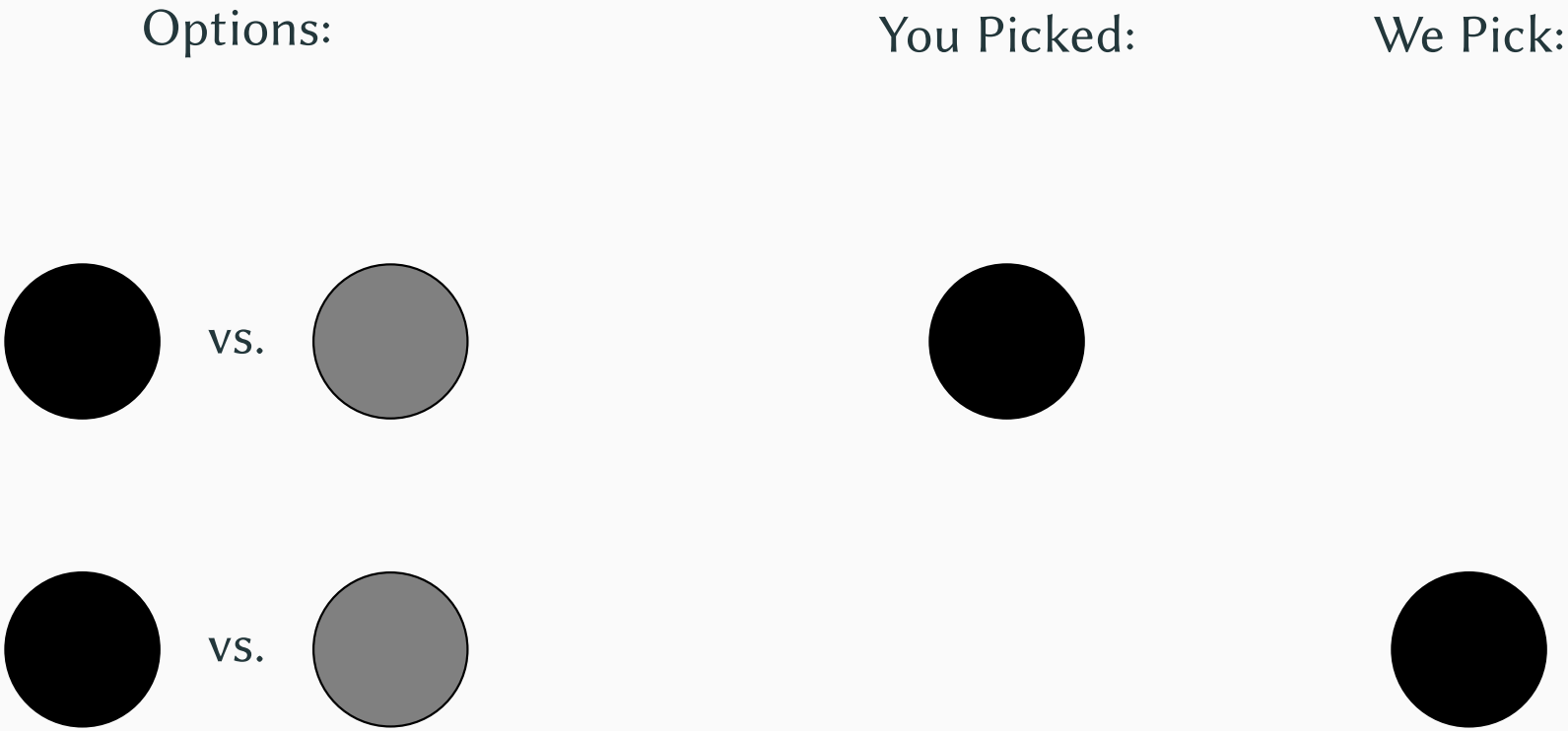
Behavioral violation: salience/rational inattention (BORDALO ET AL., 2012)

RULE REPRESENTATION: TRANSITIVITY



Behavioral violation: regret aversion (LOOMES AND SUGDEN, 1982)

RULE REPRESENTATION: CONSISTENCY

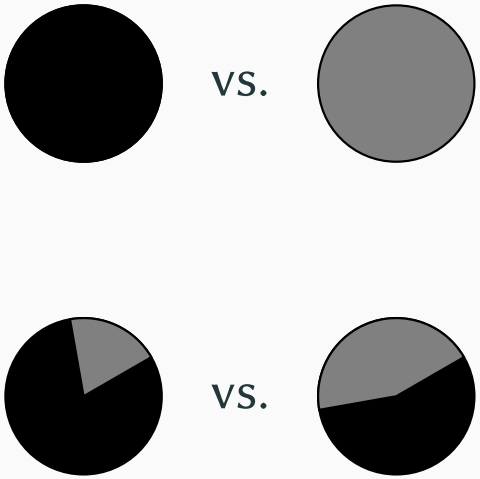


Behavioral violation: deliberate randomization (AGRANOV AND ORTOLEVA, 2017)

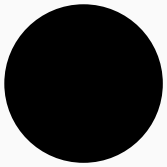
MIXTURE AXIOMS

RULE REPRESENTATION: FOSD

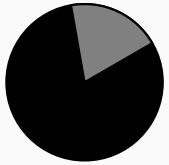
Options:



You Picked:



We Pick:



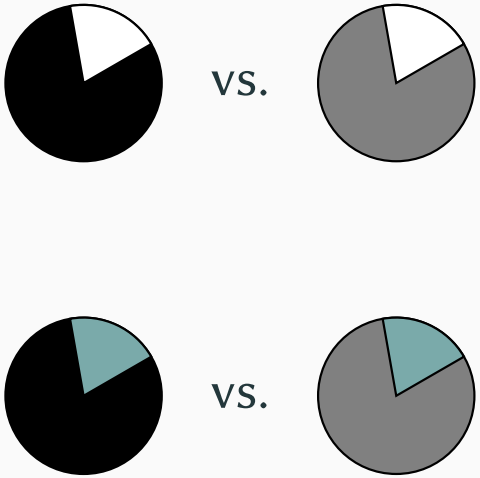
Behavioral violation: diversification (RUBINSTEIN, 2001)

RULE REPRESENTATION: INDEPENDENCE

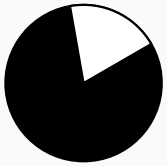
Behavioral violation: prospect theory (KAHNEMAN AND TVERSKY, 1979)

RULE REPRESENTATION: BRANCH INDEPENDENCE

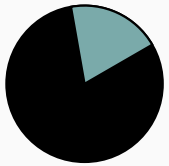
Options:



You Picked:



We Pick:



Behavioral violation: rank-dependent probability weighting (QUIGGIN, 1982)

BENCHMARK

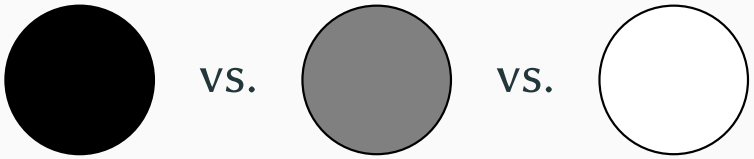
- What if people
  - just like to follow rules?
  - think they *should* follow these rules (demand effect)?
  - follow rules because it's easier than making their own choices?
  - have a preference for control and don't like to follow rules?
  - are responsibility averse?
  - ...

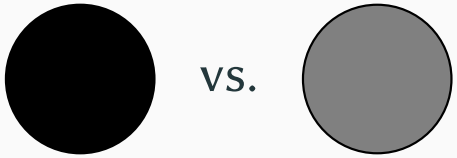
BENCHMARK

- What if people
  - just like to follow rules?
  - think they *should* follow these rules (demand effect)?
  - follow rules because it's easier than making their own choices?
  - have a preference for control and don't like to follow rules?
  - are responsibility averse?
  - ...
- We also present rules that are *intentionally bad* (**c-axioms**)
  - Opposite of each main axiom

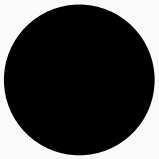
IIA:

Options:

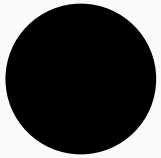




If You Pick:

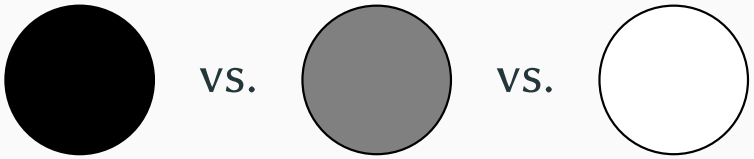


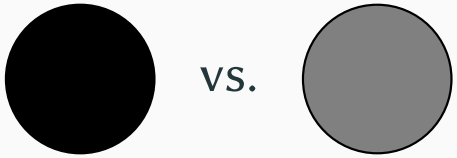
Then We Pick:



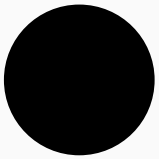
IIA:

Options:

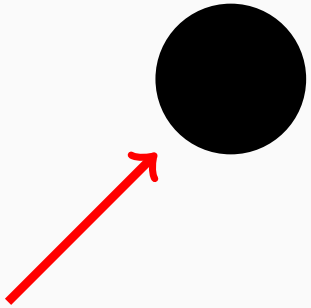




If You Pick:

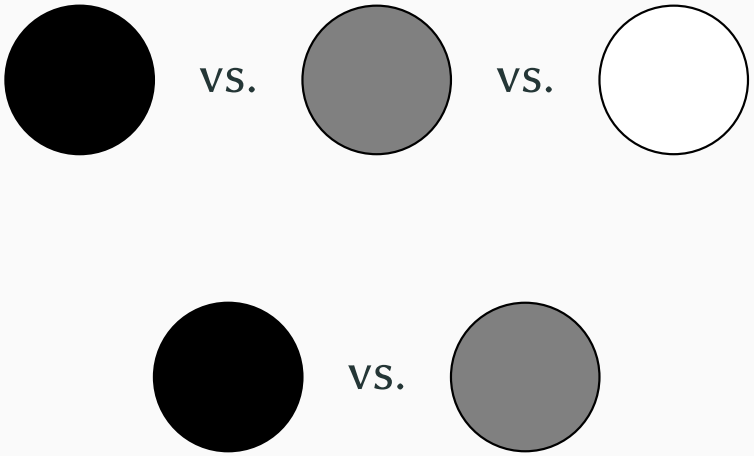


Then We Pick:

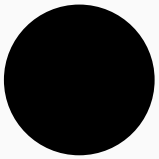


c-IIA:

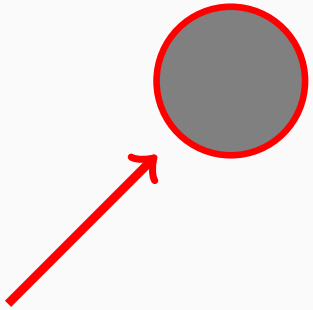
Options:



If You Pick:



Then We Pick:



LOGISTICS

- Subjects made *independent* choices across axiom and c-axiom
- Axiom and $c-$axiom presented on different screens, randomized order
  - Also included six "decoy" rules
- Use c-axiom selection rate as our benchmark for
  - Experimenter demand
  - Confusion
  - Blind rule-following
  - Etc.

C–AXIOMS

- Interpretation:
  - Select axiom and don't select c–axiom: ☺

C–AXIOMS

- Interpretation:
  - Select axiom and don't select c–axiom: ☺
  - Select c–axiom and don't select axiom: ☹

C–AXIOMS

- Interpretation:
  - Select axiom and don't select c–axiom: ☺
  - Select c–axiom and don't select axiom: ☹
  - Select both: Preference for rules, decisions are costly, etc...

C–AXIOMS

- Interpretation:
  - Select axiom and don't select c–axiom: ☺
  - Select c–axiom and don't select axiom: ☹
  - Select both: Preference for rules, decisions are costly, etc...
  - Select neither: "it depends," preference for control...

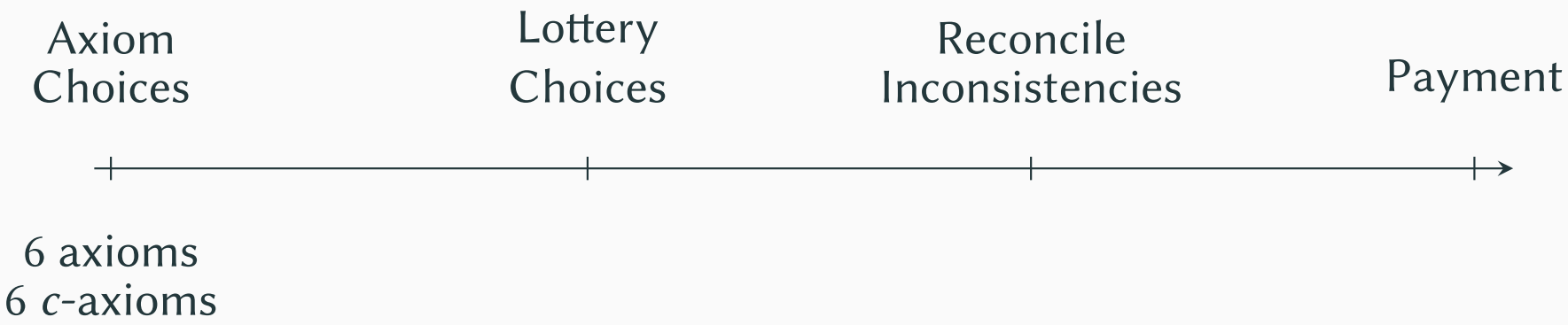
C–AXIOMS

- Interpretation:
  - Select axiom and don't select c–axiom: ☺
  - Select c–axiom and don't select axiom: ☹
  - Select both: Preference for rules, decisions are costly, etc...
  - Select neither: "it depends," preference for control...
- Why the c-axiom benchmark?
  - Deliberately anti-normative
  - Same benchmark across all axioms
  - c–axiom takes same form as corresponding axiom
  - c–axiom takes same input questions as corresponding axioms

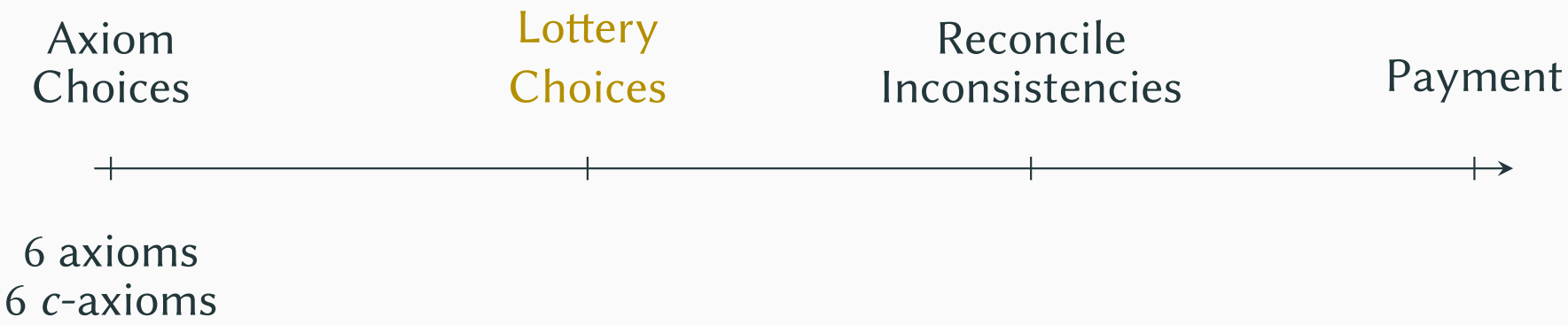
QUESTIONS ABOUT
ELICITING PREFERENCES OVER RULES?

EXPERIMENT TIMELINE

EXPERIMENT TIMELINE



EXPERIMENT TIMELINE



Do individuals still *violate* these axioms?

LOTTERY CHOICES

- Subjects made 33 choices over lotteries
- Designed to detect violations of each of our six axioms
- E.g., to detect a violation of IIA:
  - Choice from $\{p, q, r\}$
  - Choice from $\{p, q\}$

LOTTERY CHOICES

- Picked questions based on “classic” violations in the literature
  - IND: certainty effect
  - IIA: decoy effect
  - TRANS: regret aversion
  - Etc.

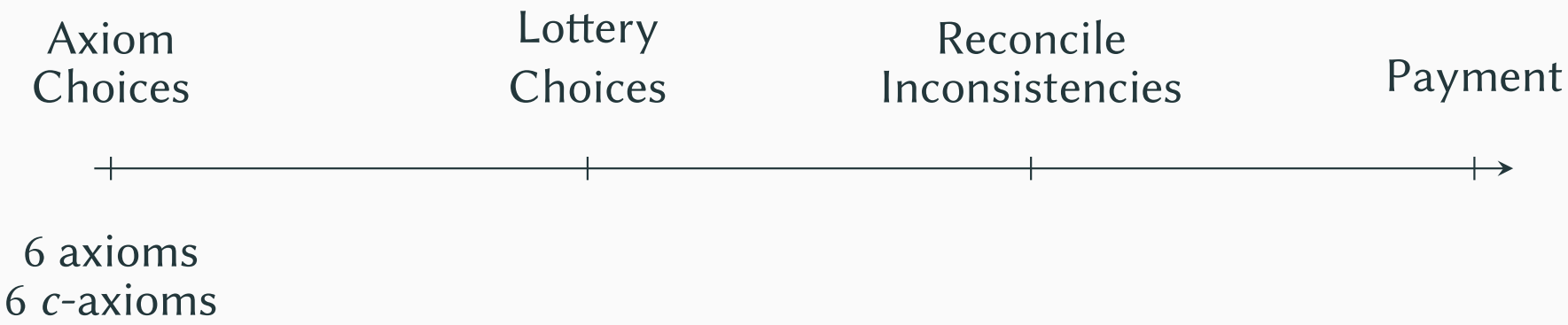
LOTTERY CHOICES

- Picked questions based on “classic” violations in the literature
  - IND: certainty effect
  - IIA: decoy effect
  - TRANS: regret aversion
  - Etc.
- Independently optimized to detect violations of a single axiom
  - Not designed to compare across axioms

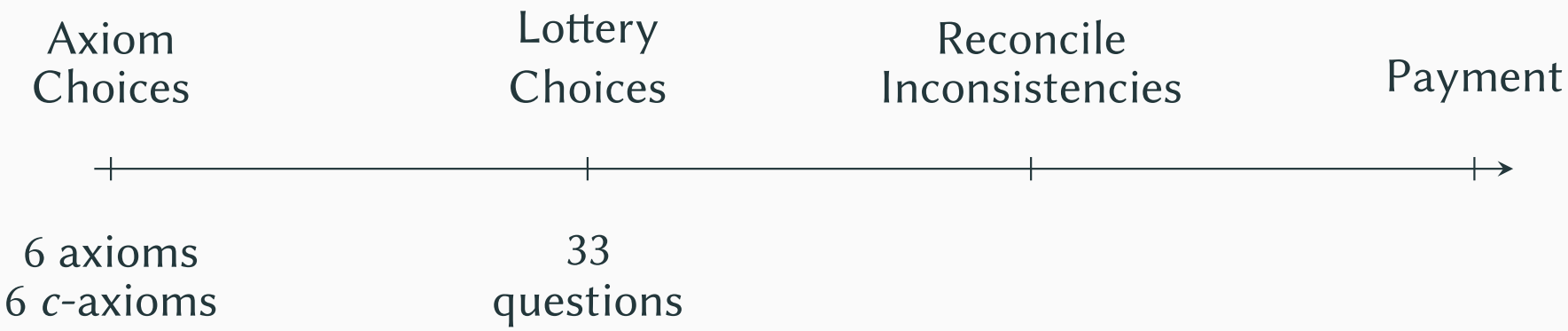
LOTTERY CHOICES

- Picked questions based on “classic” violations in the literature
  - IND: certainty effect
  - IIA: decoy effect
  - TRANS: regret aversion
  - Etc.
- Independently optimized to detect violations of a single axiom
  - Not designed to compare across axioms
- These lotteries are different from the lotteries that incentivize the axiom choices
- Note: All subjects made these decisions, regardless of axiom selection

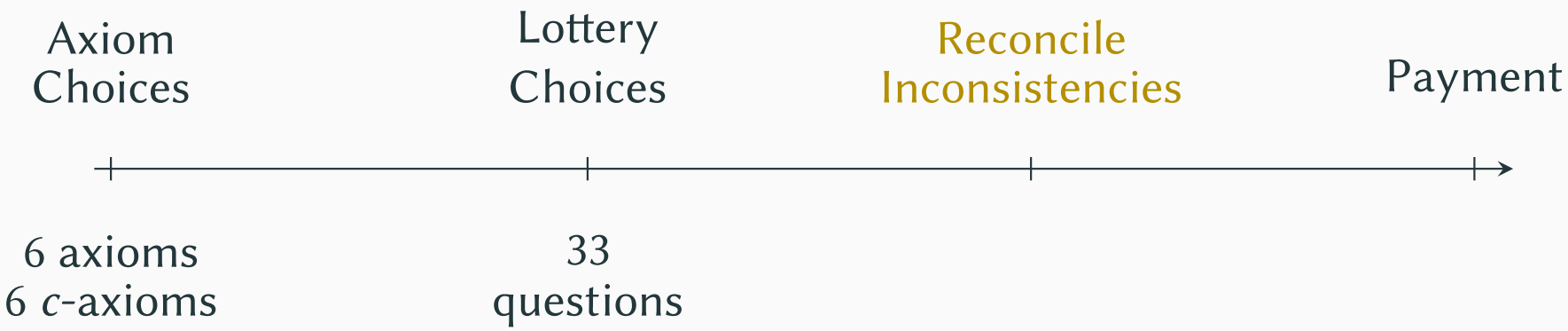
EXPERIMENT TIMELINE



EXPERIMENT TIMELINE



EXPERIMENT TIMELINE



How do individuals *reconcile* these inconsistencies?

RECONCILIATION MOTIVATION

- For example, a subject who endorsed but violated IIA
  - Chose IIA as an axiom
  - $p = C(\{p, q, r\})$
  - $q = C(\{p, q\})$

RECONCILIATION MOTIVATION

- For example, a subject who endorsed but violated IIA
  - Chose IIA as an axiom
  - $p = C(\{p, q, r\})$
  - $q = C(\{p, q\})$
- **Main Question**: How do they respond when confronted with this inconsistency?

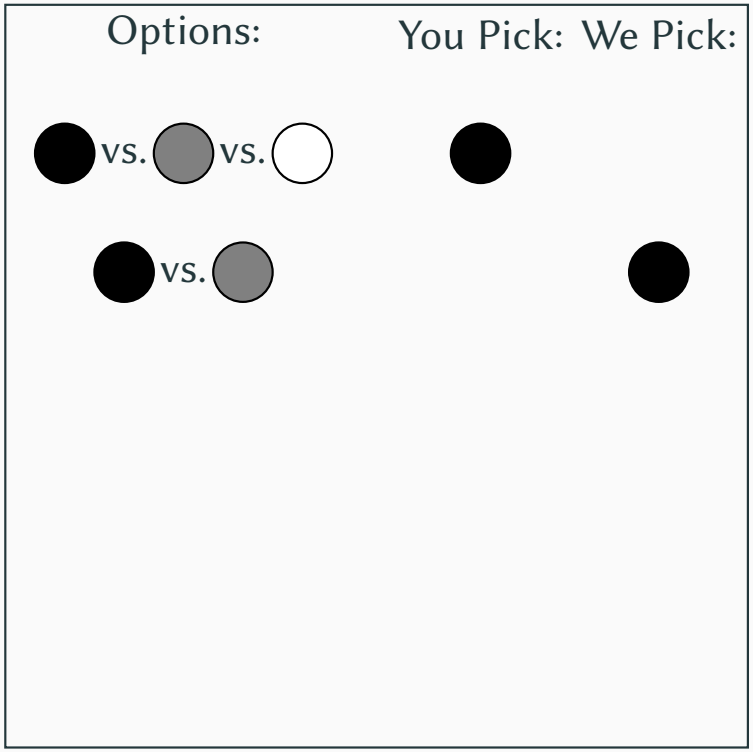
RECONCILIATION MOTIVATION

- For example, a subject who endorsed but violated IIA
  - Chose IIA as an axiom
  - $p = C(\{p, q, r\})$
  - $q = C(\{p, q\})$
- **Main Question**: How do they respond when confronted with this inconsistency?
  - Change decisions to conform to IIA
    - E.g., Savage
    - We interpret this as a mistake

RECONCILIATION MOTIVATION

- For example, a subject who endorsed but violated IIA
  - Chose IIA as an axiom
  - $p = C(\{p, q, r\})$
  - $q = C(\{p, q\})$
- **Main Question**: How do they respond when confronted with this inconsistency?
  - Change decisions to conform to IIA
    - E.g., Savage
    - We interpret this as a mistake
  - Unselect IIA
    - We interpret this as an intentional violation

RECONCILIATION



80% chance of $0
20% chance of $10

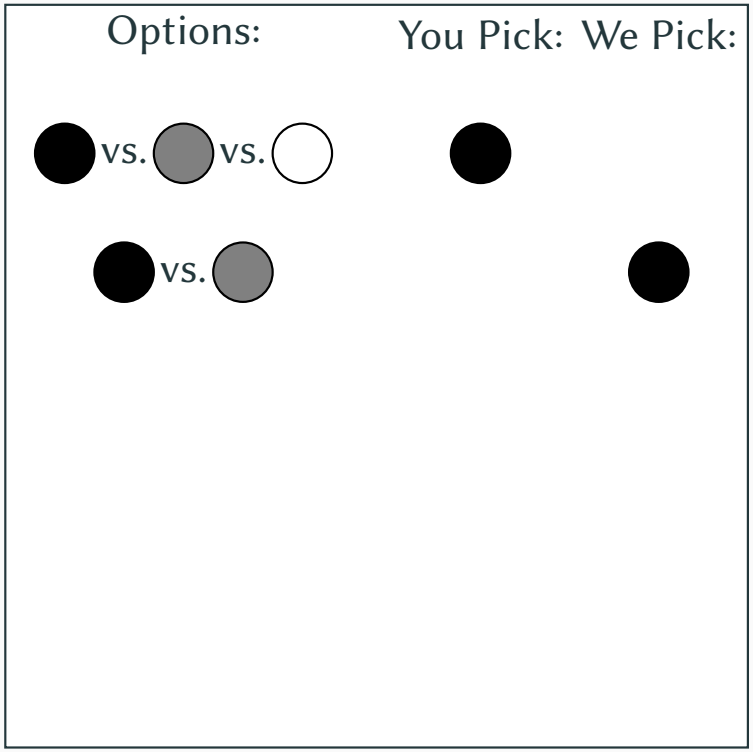
60% chance of $0
40% chance of $6

80% chance of $0
20% chance of $7

80% chance of $0
20% chance of $10

60% chance of $0
40% chance of $6

RECONCILIATION



Black:
80% chance of $0
20% chance of $10

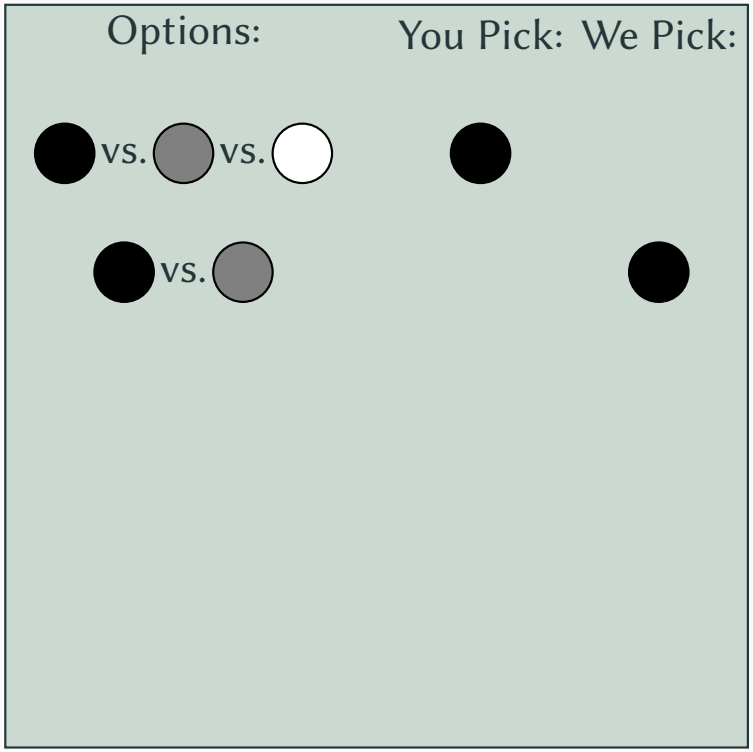
Grey:
60% chance of $0
40% chance of $6

White:
80% chance of $0
20% chance of $7

Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

RECONCILIATION



Black:
80% chance of $0
20% chance of $10

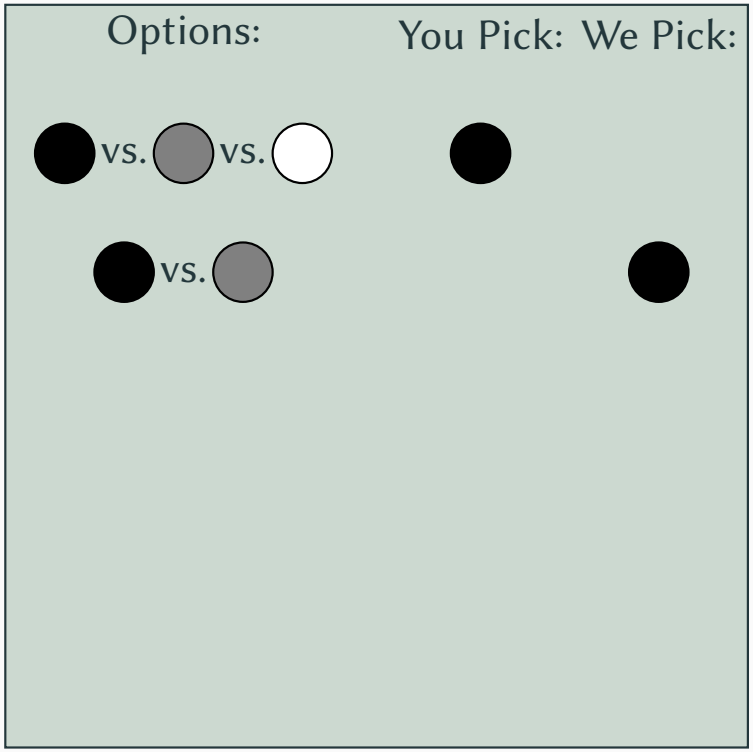
Grey:
60% chance of $0
40% chance of $6

White:
80% chance of $0
20% chance of $7

Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

RECONCILIATION

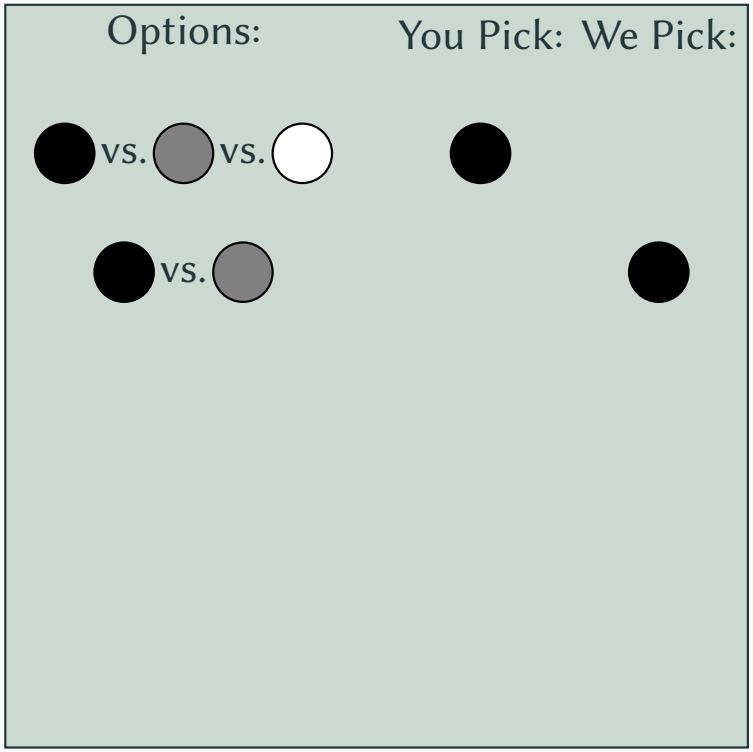


Black:	**Grey**:	**White**:
80% chance of $0	60% chance of $0	80% chance of $0
20% chance of $10	40% chance of $6	20% chance of $7

Black:	**Grey**:
80% chance of $0	60% chance of $0
20% chance of $10	40% chance of $6

In the first row, you chose **Black**. In the second row, you chose **Grey**. **Black** and **Grey** are the same in these two decisions, so the rule would make the same choice between Options **Black** and **Grey** in the two choices.

CORRECTING A MISTAKE

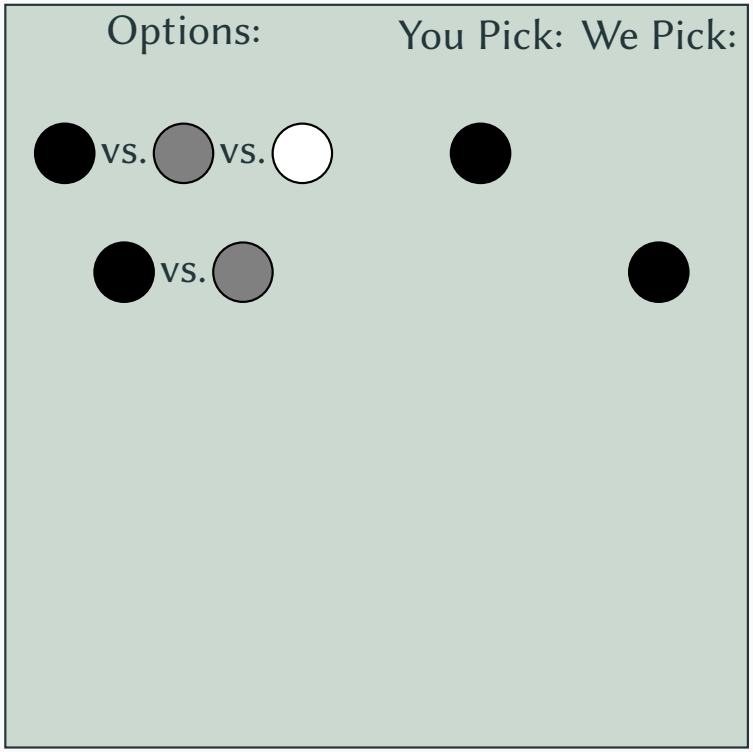


Black:	**Grey**:	**White**:
80% chance of $0	60% chance of $0	80% chance of $0
20% chance of $10	40% chance of $6	20% chance of $7

Black:	**Grey**:
80% chance of $0	60% chance of $0
20% chance of $10	40% chance of $6

In the first row, you chose **Black**. In the second row, you chose **Grey**. **Black** and **Grey** are the same in these two decisions, so the rule would make the same choice between Options **Black** and **Grey** in the two choices.

CORRECTING A MISTAKE

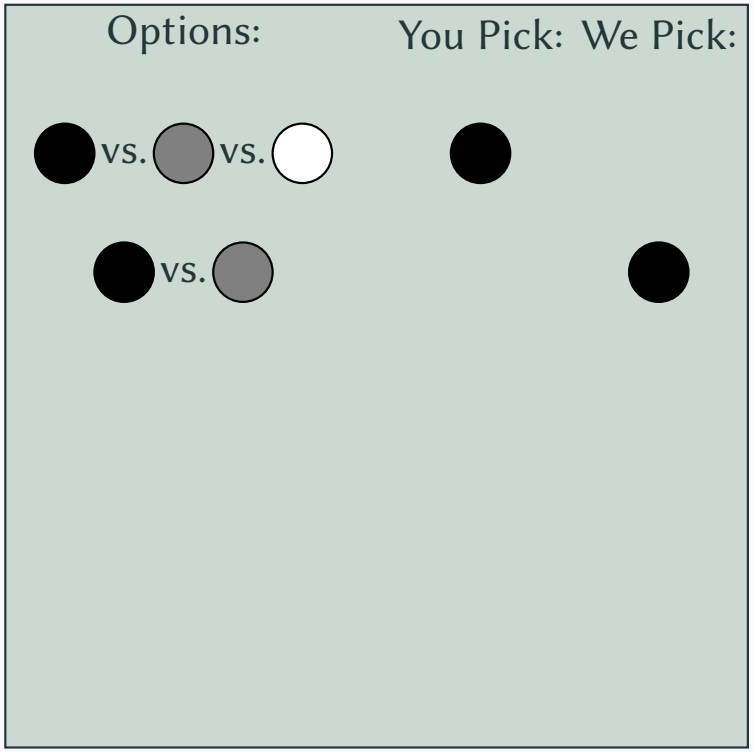


Black:	**Grey**:	**White**:
80% chance of $0	60% chance of $0	80% chance of $0
20% chance of $10	40% chance of $6	20% chance of $7

Black:	**Grey**:
80% chance of $0	60% chance of $0
20% chance of $10	40% chance of $6

In the first row, you chose **Black**. In the second row, you chose **Grey**. **Black** and **Grey** are the same in these two decisions, so the rule would make the same choice between Options **Black** and **Grey** in the two choices.

CORRECTING A MISTAKE



Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

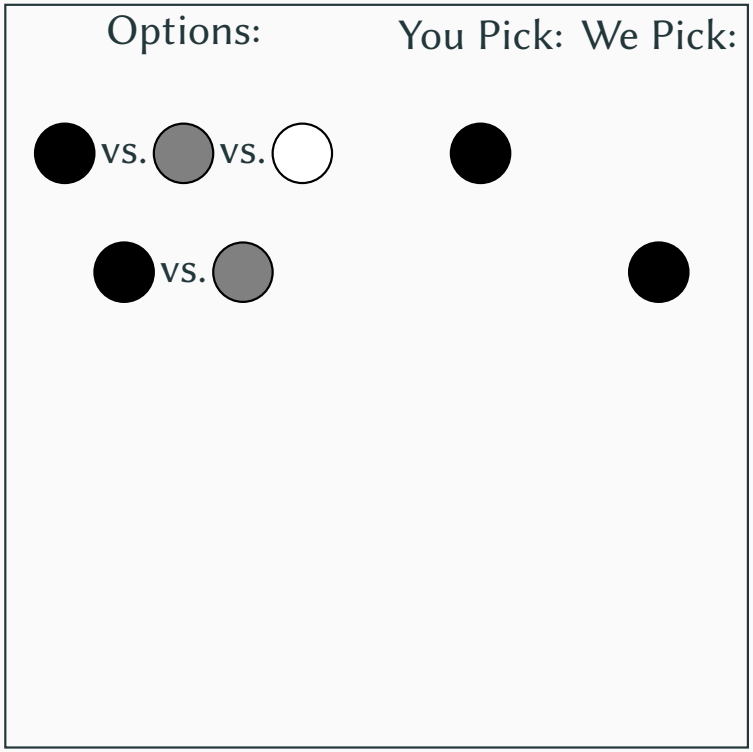
White:
80% chance of $0
20% chance of $7

Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

In the first row, you chose **Black**. In the second row, you chose **Grey**. **Black** and **Grey** are the same in these two decisions, so the rule would make the same choice between Options **Black** and **Grey** in the two choices.

UN-ENDORSING AXIOM

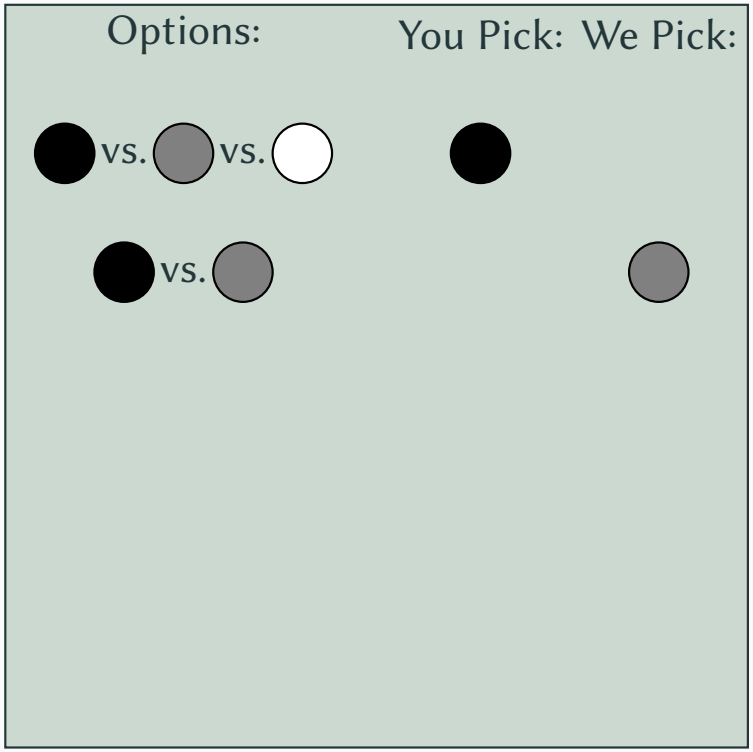


Black:	**Grey**:	**White**:
80% chance of $0	60% chance of $0	80% chance of $0
20% chance of $10	40% chance of $6	20% chance of $7

Black:	**Grey**:
80% chance of $0	60% chance of $0
20% chance of $10	40% chance of $6

In the first row, you chose **Black**. In the second row, you chose **Grey**. **Black** and **Grey** are the same in these two decisions, so the rule would make the same choice between Options **Black** and **Grey** in the two choices.

C–AXIOM RECONCILIATION



Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

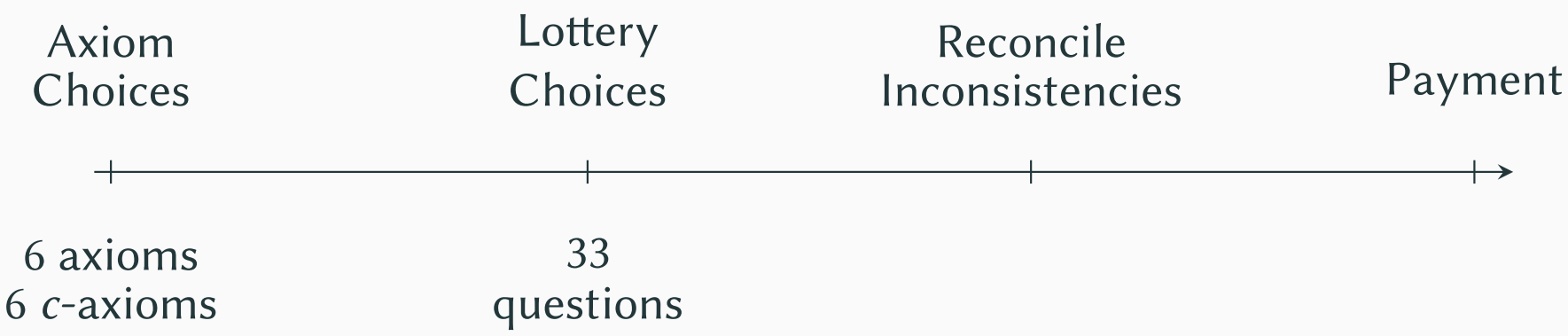
White:
80% chance of $0
20% chance of $7

Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

In the first row, you chose **Black**. In the second row, you chose **Grey**. **Black** and **Grey** are the same in these two decisions, so the rule would make the same choice between Options **Black** and **Grey** in the two choices.

EXPERIMENT TIMELINE



EXPERIMENT TIMELINE

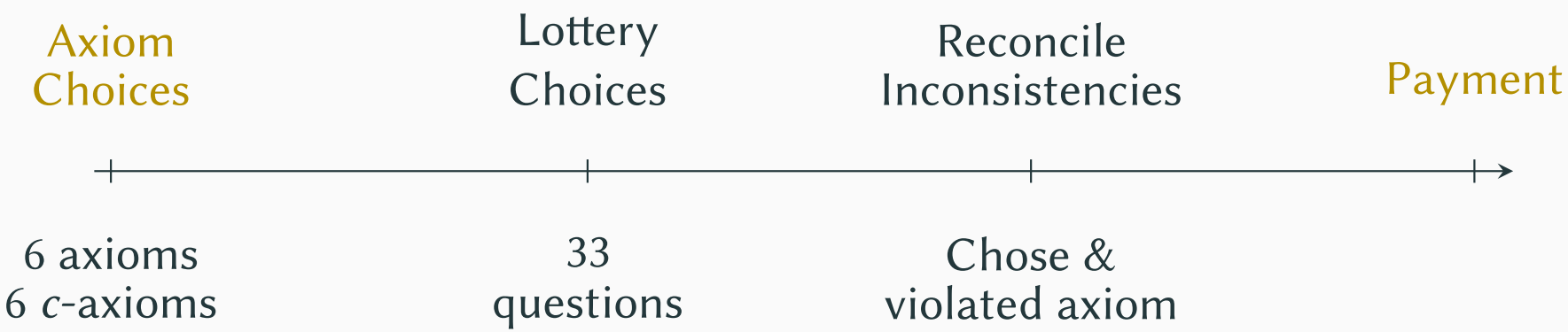
Axiom Choices	Lottery Choices	Reconcile Inconsistencies	Payment
6 axioms 6 c-axioms	33 questions	Chose & violated axiom	

EXPERIMENT TIMELINE

Axiom Choices	Lottery Choices	Reconcile Inconsistencies	Payment
6 axioms 6 c-axioms	33 questions	Chose & violated axiom	

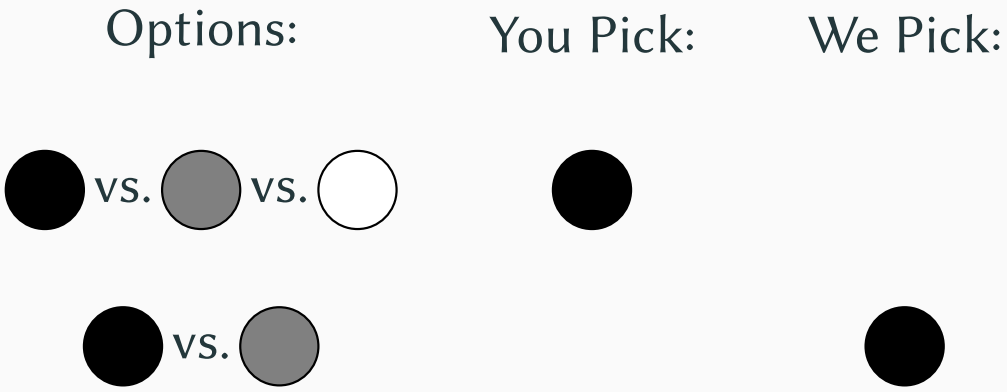
Paid for one randomly-selected decision

EXPERIMENT TIMELINE



If paid from Part 1 (axiom choices)

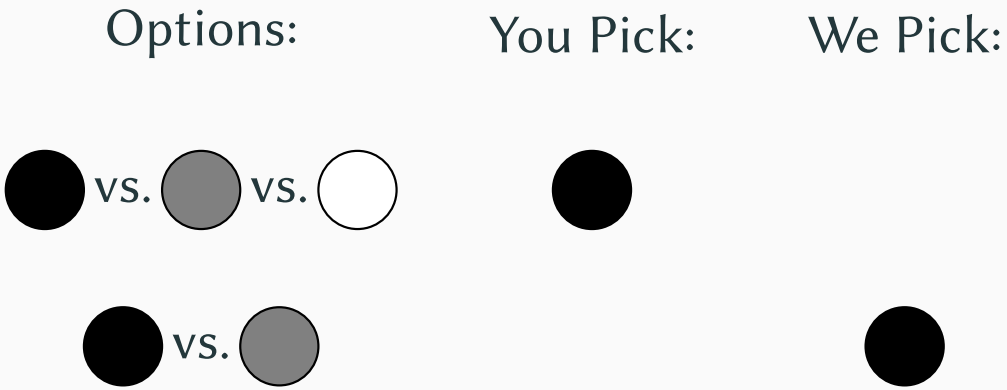
INCENTIVIZATION: IIA



If we pay for IIA:

- Present the subject with three *new* lotteries: $\{p, q, r\}$
- Subject chooses their most preferred $\mapsto$ "p"

INCENTIVIZATION: IIA



If we pay for IIA:

- Present the subject with three *new* lotteries: $\{p, q, r\}$
- Subject chooses their most preferred $\mapsto$ "p"
- **Did choose IIA**: paid p as choice of p over q
- **Did not choose IIA**: presented with p vs. q and paid lottery chosen from this second question

EXPERIMENT TIMELINE

If paid from Part 2 (lottery choices)

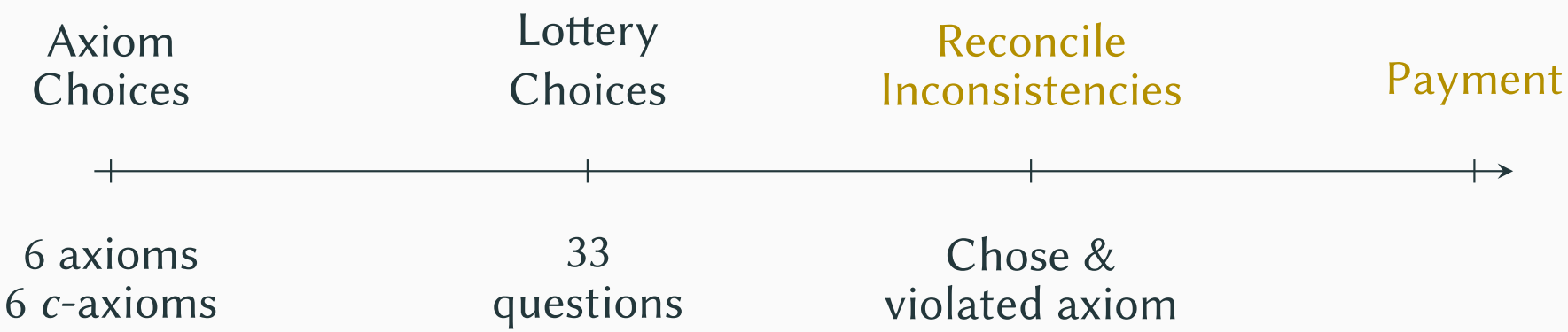
LOTTERY PAYMENTS

- Randomly select one of the 33 decisions a subject made

LOTTERY PAYMENTS

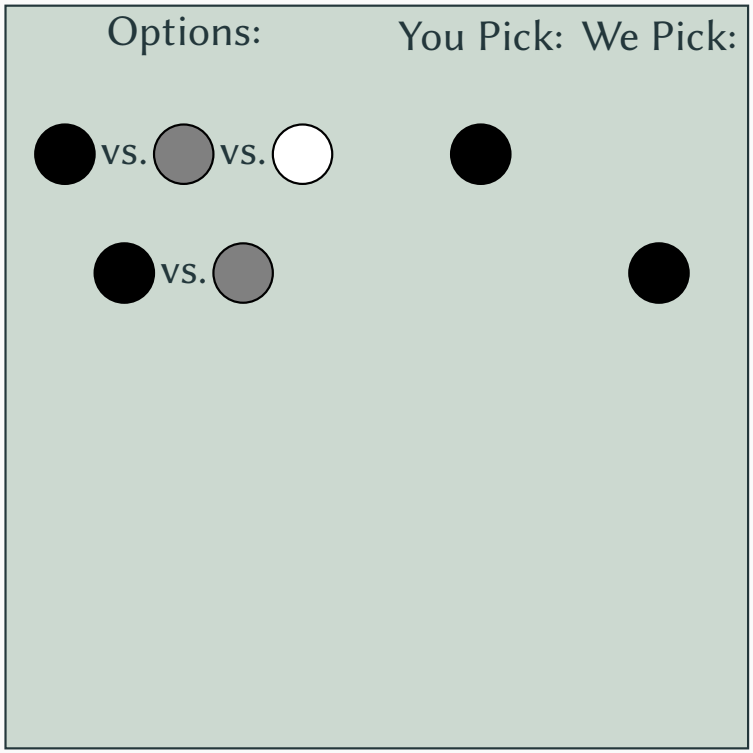
- Randomly select one of the 33 decisions a subject made
- Pay lottery the subject chose in this decision

EXPERIMENT TIMELINE



If paid from Part 3 (reconciled choices)

RECONCILIATION



Black:
80% chance of $0
20% chance of $10

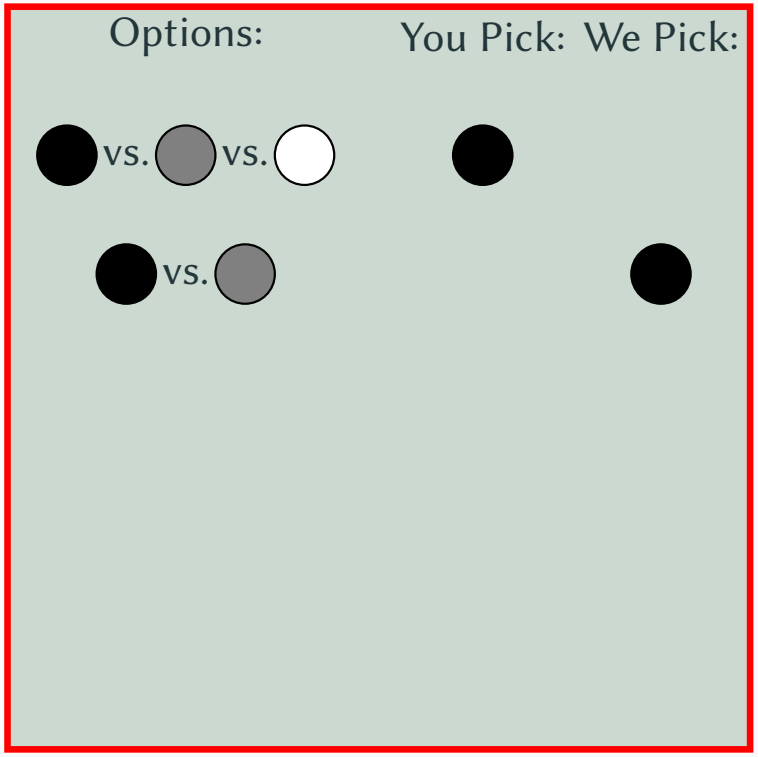
Grey:
60% chance of $0
40% chance of $6

White:
80% chance of $0
20% chance of $7

Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

RECONCILIATION



Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

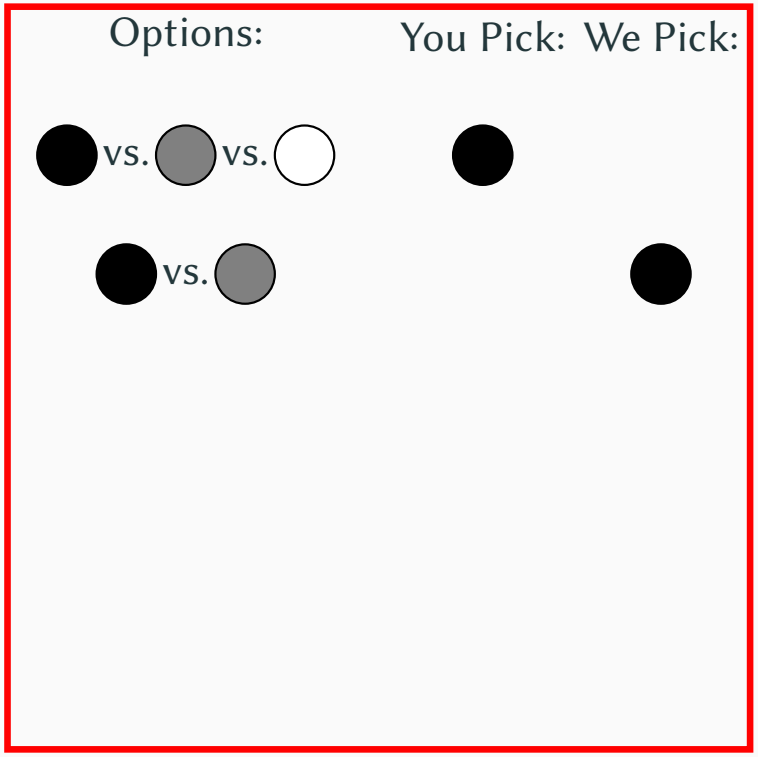
White:
80% chance of $0
20% chance of $7

Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

Subject chooses p from $\{p, q, r\}$, automatically paid p from $\{p, q\}$

RECONCILIATION



Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

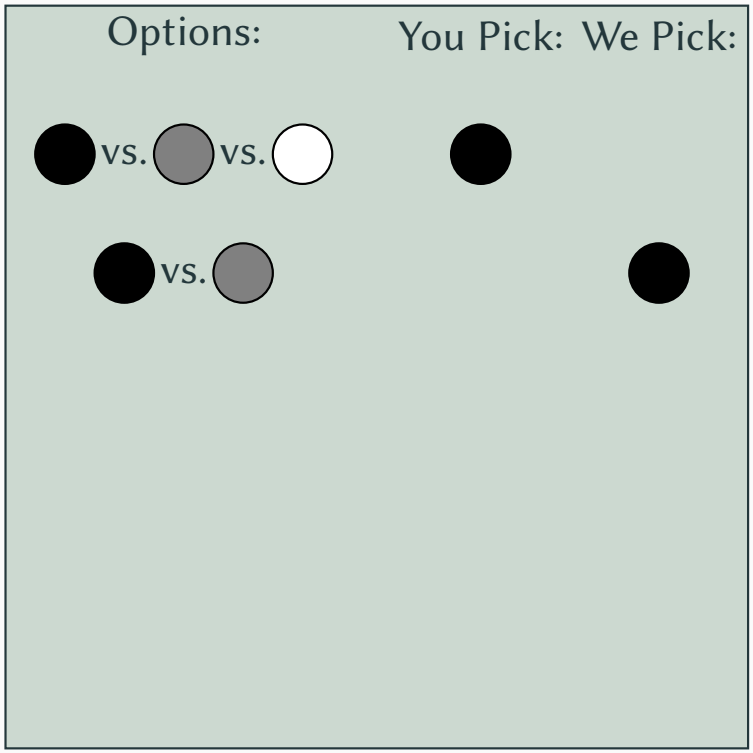
White:
80% chance of $0
20% chance of $7

Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

Subject chooses p from $\{p, q, r\}$, paid own choice from $\{p, q\}$

RECONCILIATION



Black:
80% chance of $0
20% chance of $10

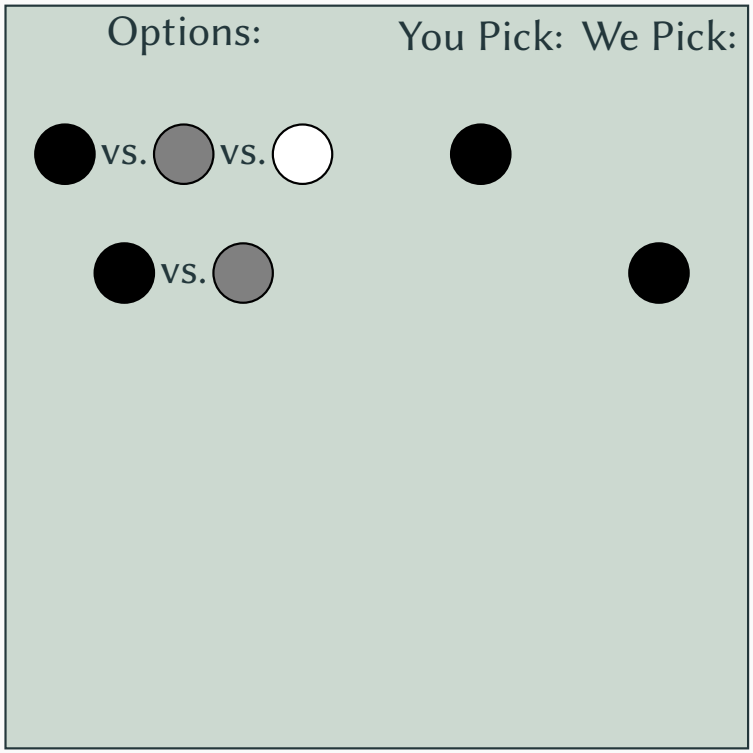
Grey:
60% chance of $0
40% chance of $6

White:
80% chance of $0
20% chance of $7

Black:
80% chance of $0
20% chance of $10

Grey:
60% chance of $0
40% chance of $6

RECONCILIATION

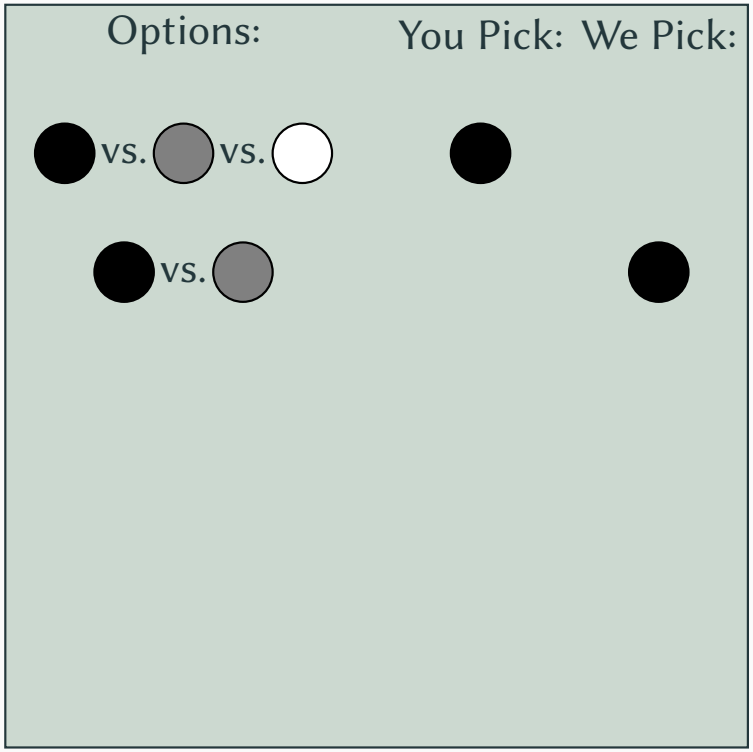


Black:	**Grey**:	**White**:
80% chance of $0	60% chance of $0	80% chance of $0
20% chance of $10	40% chance of $6	20% chance of $7

Black:	**Grey**:
80% chance of $0	60% chance of $0
20% chance of $10	40% chance of $6

Paid lottery selected

RECONCILIATION



Black:	**Grey**:	**White**:
80% chance of $0	60% chance of $0	80% chance of $0
20% chance of $10	40% chance of $6	20% chance of $7

Black:	**Grey**:
80% chance of $0	60% chance of $0
20% chance of $10	40% chance of $6

Paid lottery selected

PROCEDURES

- Initial data collection in-person
- 110 Ohio State undergraduate students
  - Robustness treatment with 114 additional subjects
  - Replicated online with 500 Prolific participants
- Sessions lasted about an hour, ~ $15
- Paid after everyone finished

RESULTS

RESULTS OUTLINE

Main Questions:

1. How often do individuals choose the axioms? c-axioms?

RESULTS OUTLINE

Main Questions:

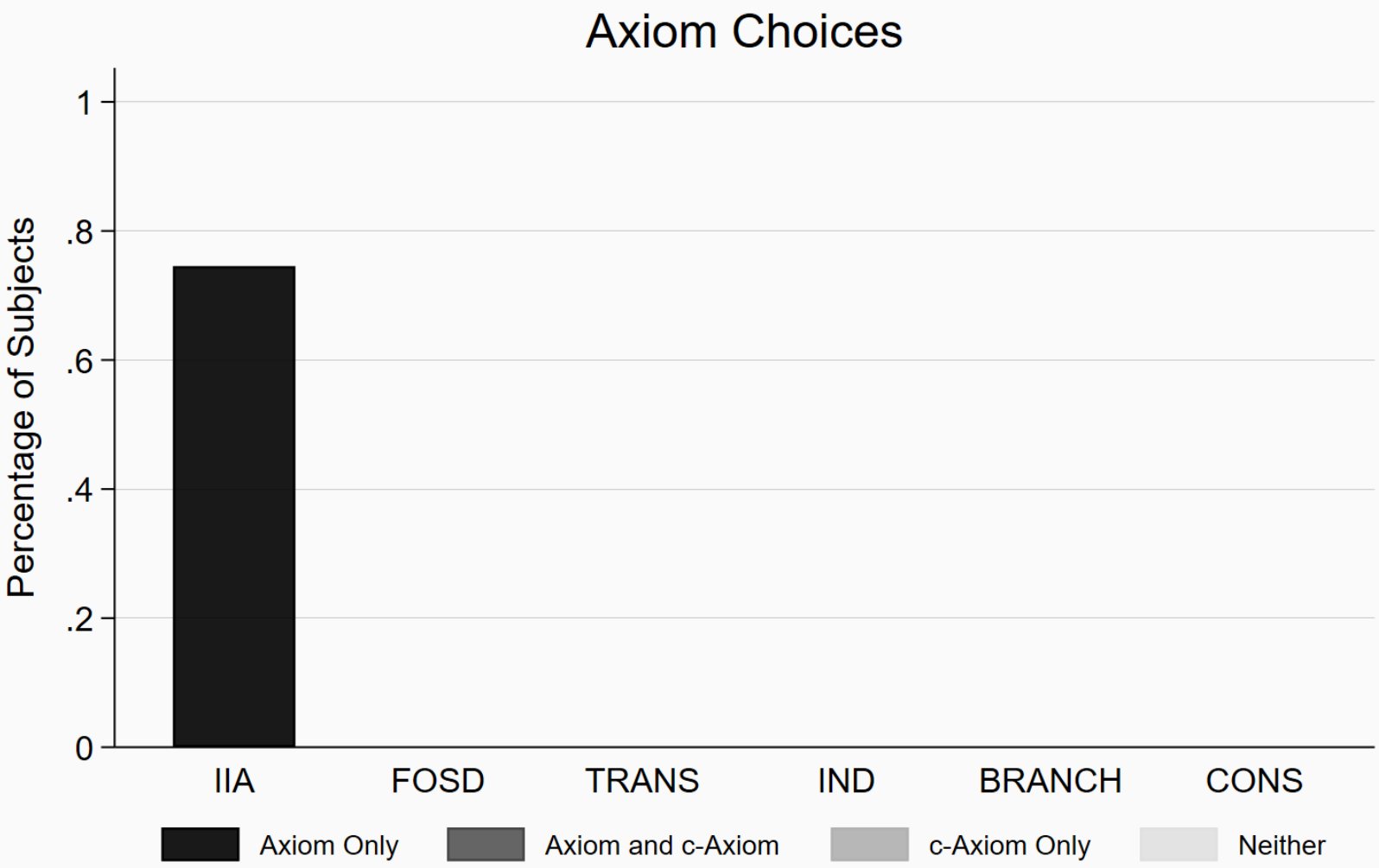
1. How often do individuals choose the axioms? c-axioms?
2. Does choosing an axiom lead to fewer violations of the axiom?

RESULTS OUTLINE

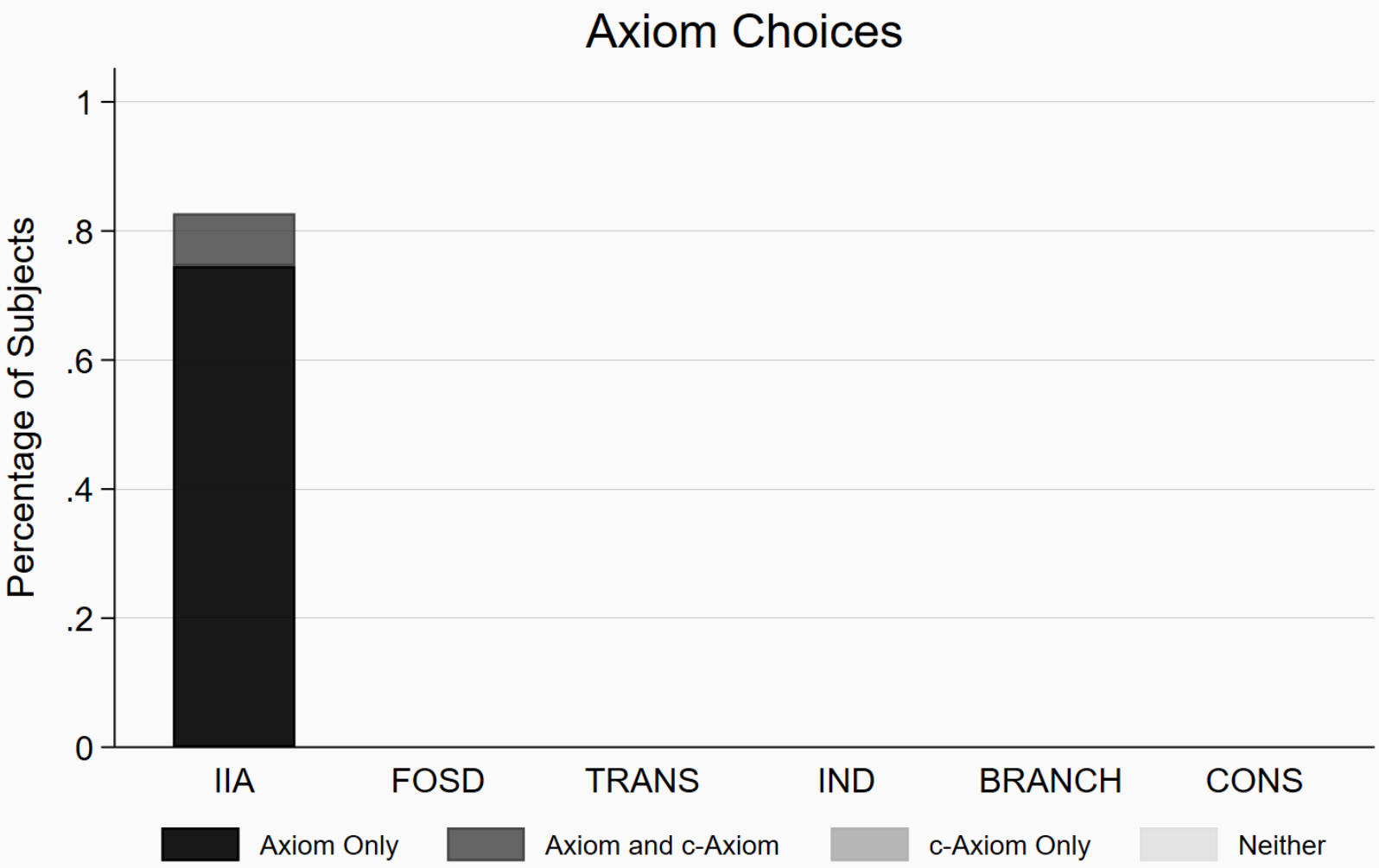
Main Questions:

1. How often do individuals choose the axioms? c-axioms?
2. Does choosing an axiom lead to fewer violations of the axiom?
3. How do individuals reconcile violations of axioms they had chosen?
    - Change choices to agree with axiom? (à la Savage)
    - Keep choices an un-endorse axiom?

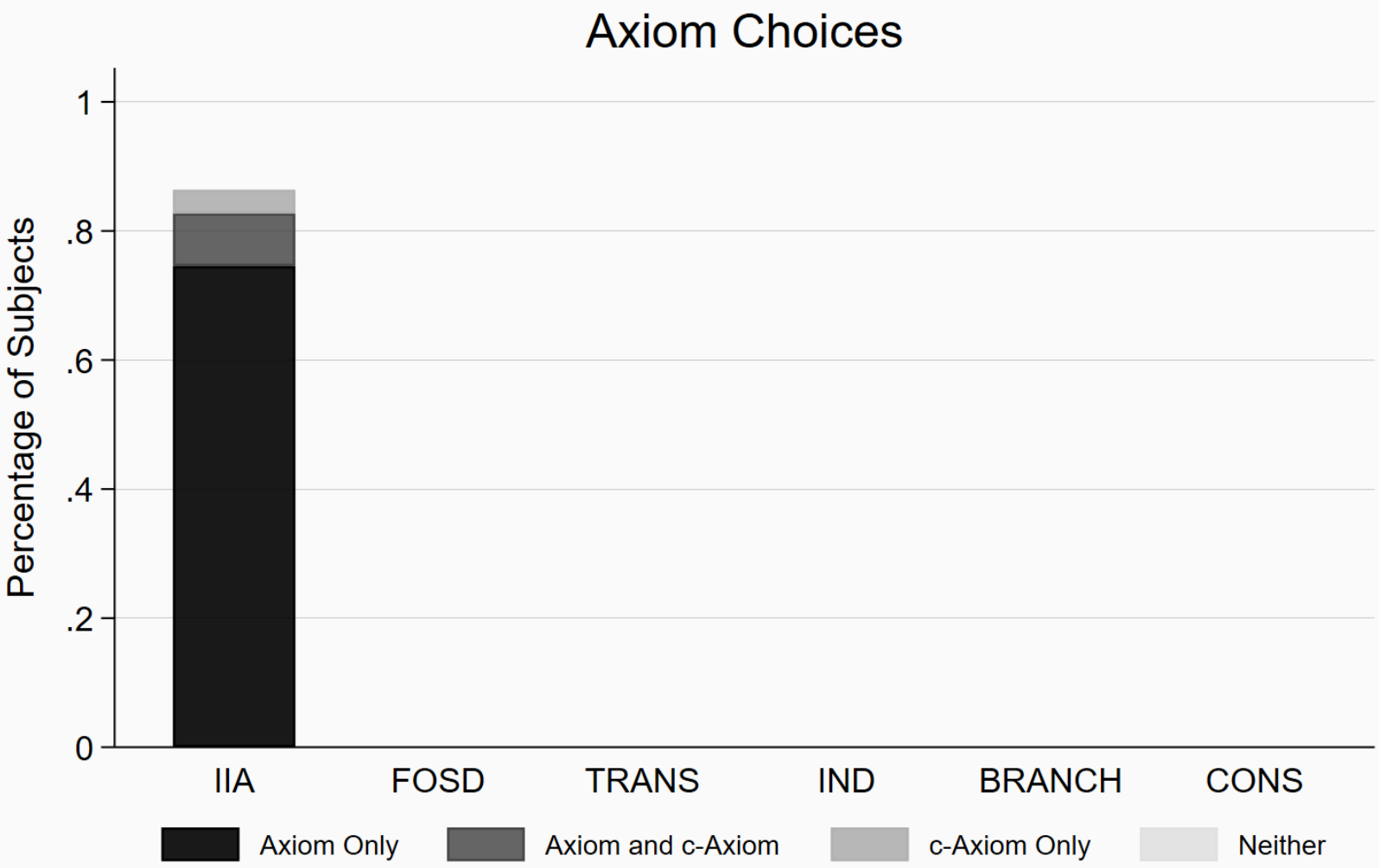
AXIOM SELECTION



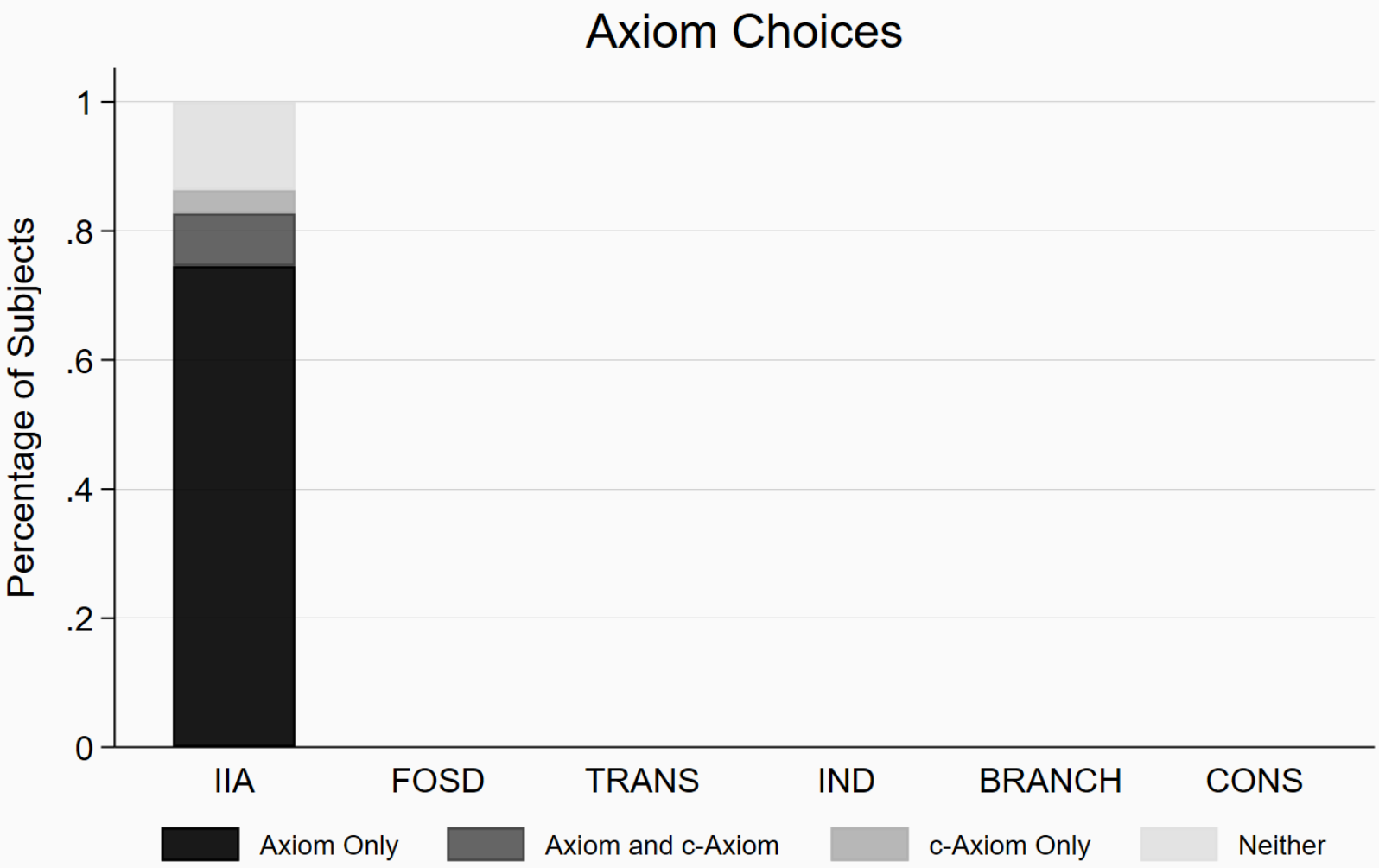
AXIOM SELECTION



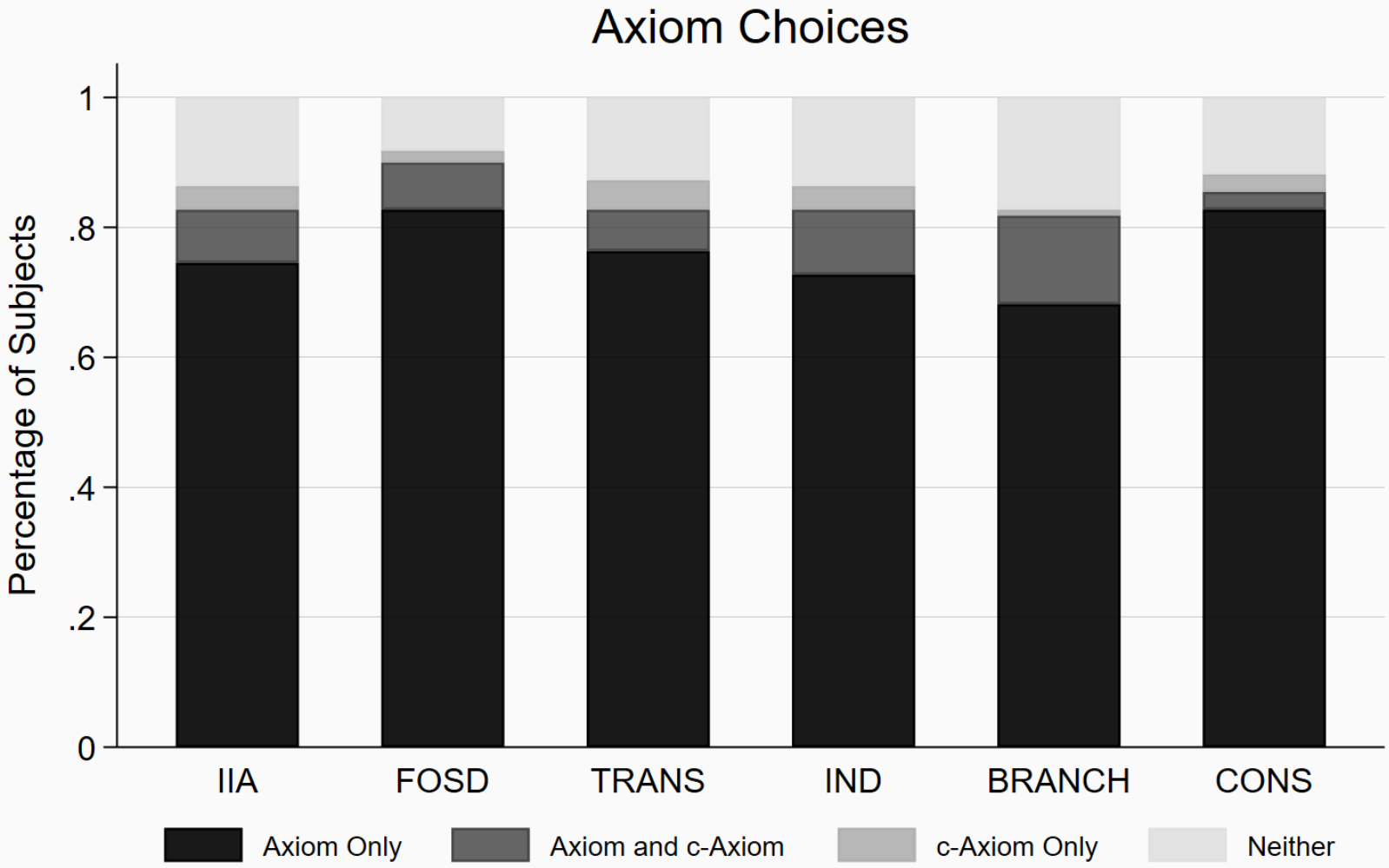
AXIOM SELECTION



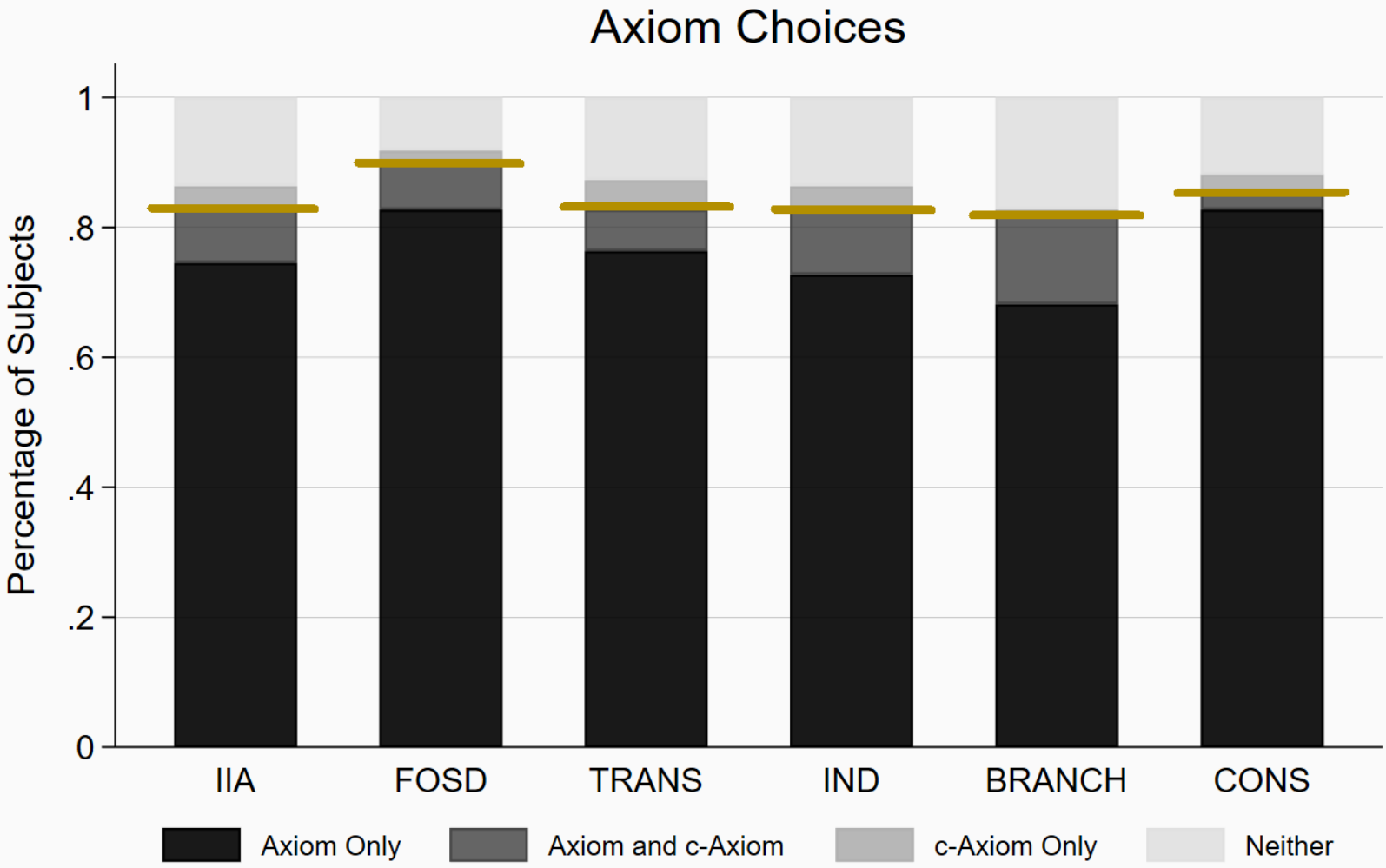
AXIOM SELECTION



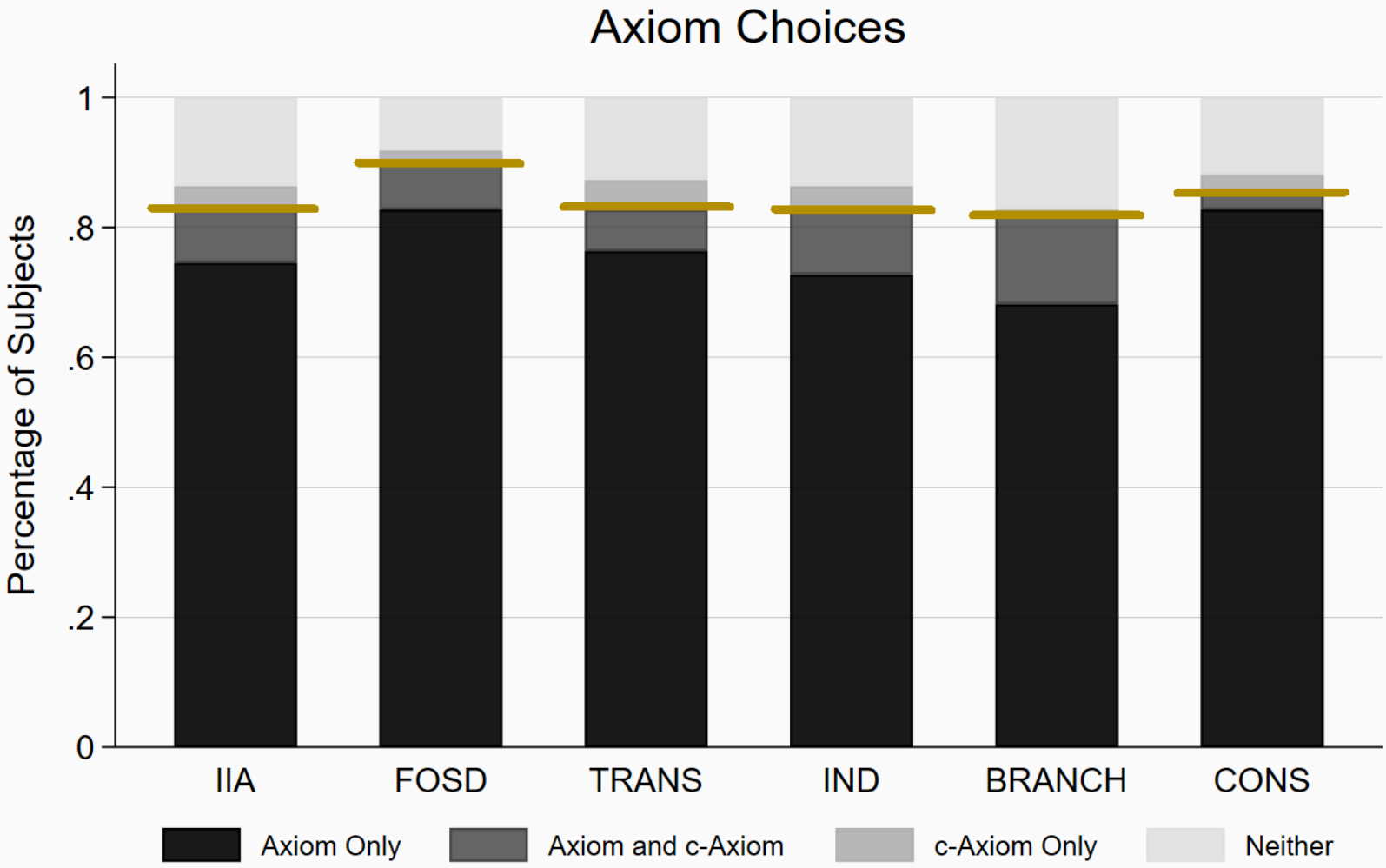
AXIOM SELECTION



AXIOM SELECTION

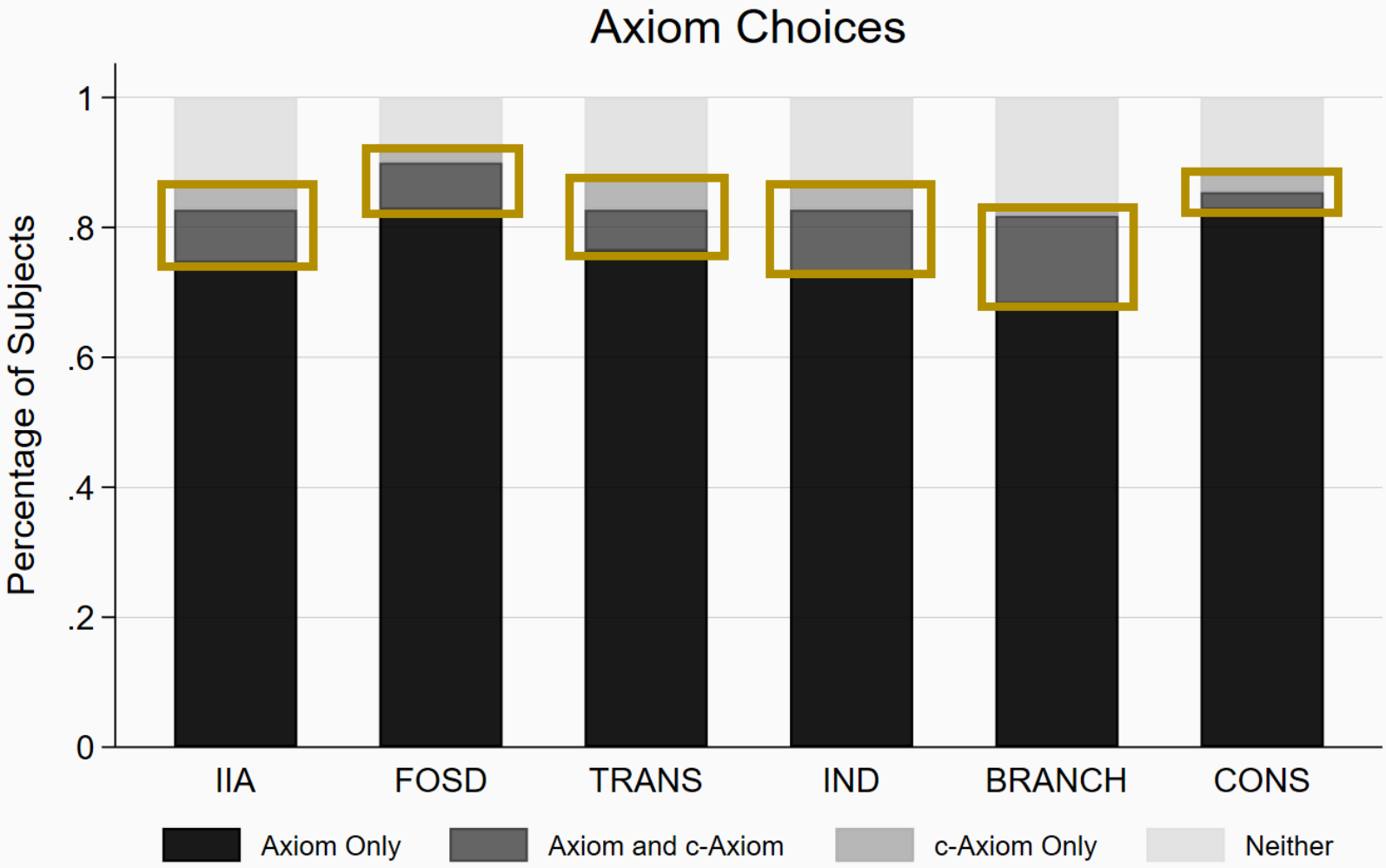


AXIOM SELECTION



~ 85% select axioms (76% select *only* axiom)

AXIOM SELECTION



~ 15% select *c*-axioms (3% select *only* *c*-axiom)

AXIOM SELECTION

#Axioms Selected	Number of c–Axioms Selected 0	1	2	3	4	5	6	Total
0								
1								
2								
3								
4								
5								
6								
Total								100

Axiom and c-selection axiom at a subject-level, in percent

AXIOM SELECTION

#Axioms Selected	Number of c–Axioms Selected 0	1	2	3	4	5	6	Total
0								3.6
1								1.8
2								2.7
3								6.4
4								8.2
5								17.3
6								60
Total								100

Axiom and c-selection axiom at a subject-level, in percent

AXIOM SELECTION

#Axioms Selected	Number of c–Axioms Selected 0	1	2	3	4	5	6	Total
0								3.6
1								1.8
2								2.7
3								6.4
4								8.2
5								17.3
6								60
Total								100

Axiom and c-selection axiom at a subject-level, in percent

AXIOM SELECTION

#Axioms Selected	Number of c–Axioms Selected 0	1	2	3	4	5	6	Total
0								3.6
1								1.8
2								2.7
3								6.4
4								8.2
5								17.3
6								60
Total	64.5	22.7	5.5	1.8	2.7	0.9	1.8	100

Axiom and c-selection axiom at a subject-level, in percent

AXIOM SELECTION

#Axioms Selected	Number of c–Axioms Selected 0	1	2	3	4	5	6	Total
0								3.6
1								1.8
2								2.7
3								6.4
4								8.2
5								17.3
6								60
Total	64.5	22.7	5.5	1.8	2.7	0.9	1.8	100

Axiom and c-selection axiom at a subject-level, in percent

AXIOM SELECTION

#Axioms Selected	Number of c–Axioms Selected 0	1	2	3	4	5	6	Total
0	2.7	–	–	–	–	–	0.9	3.6
1	0.9	–	0.9	–	–	–	–	1.8
2	2.7	–	–	–	–	–	–	2.7
3	3.6	–	–	–	1.8	0.9	–	6.4
4	3.6	2.7	1.8	–	–	–	–	8.2
5	11.8	2.7	1.8	–	0.9	–	–	17.3
6	39.1	17.3	0.9	1.8	–	–	0.9	60
Total	64.5	22.7	5.5	1.8	2.7	0.9	1.8	100

Axiom and c-selection axiom at a subject-level, in percent

AXIOM SELECTION

#Axioms Selected	Number of c–Axioms Selected 0	1	2	3	4	5	6	Total
0	2.7	–	–	–	–	–	0.9	3.6
1	0.9	–	0.9	–	–	–	–	1.8
2	2.7	–	–	–	–	–	–	2.7
3	3.6	–	–	–	1.8	0.9	–	6.4
4	3.6	2.7	1.8	–	–	–	–	8.2
5	11.8	2.7	1.8	–	0.9	–	–	17.3
6	39.1	17.3	0.9	1.8	–	–	0.9	60
Total	64.5	22.7	5.5	1.8	2.7	0.9	1.8	100

Axiom and c-selection axiom at a subject-level, in percent

AXIOM SELECTION

#Axioms Selected	Number of c–Axioms Selected 0	1	2	3	4	5	6	Total
0	2.7	–	–	–	–	–	0.9	3.6
1	0.9	–	0.9	–	–	–	–	1.8
2	2.7	–	–	–	–	–	–	2.7
3	3.6	–	–	–	1.8	0.9	–	6.4
4	3.6	2.7	1.8	–	–	–	–	8.2
5	11.8	2.7	1.8	–	0.9	–	–	17.3
6	39.1	17.3	0.9	1.8	–	–	0.9	60
Total	64.5	22.7	5.5	1.8	2.7	0.9	1.8	100

Axiom and c-selection axiom at a subject-level, in percent

Main Results:

1. Individuals select axioms at very high rates

VIOLATIONS

- Aggregating across all questions and all axioms...
  - 27% of choices violate an axiom

VIOLATIONS

- Aggregating across all questions and all axioms...
  - 27% of choices violate an axiom
- Are these violations from individuals who chose the axiom or those who did not?

VIOLATIONS

- Aggregating across all questions and all axioms...
  - 27% of choices violate an axiom
- Are these violations from individuals who chose the axiom or those who did not?
- 87% of violations are from individuals who indicated initial agreement with the axiom
  - Conditional on choosing: violate in 24% of instances
  - Conditional on not choosing: violate in 30% of instances ($p = 0.131$)

Main Results:

1. Individuals select axioms at very high rates

2. Individuals selecting an axiom are no less likely to violate it

IDENTIFYING MISTAKES

- In total, 468 instances of subjects violating an axiom they had chosen

IDENTIFYING MISTAKES

- In total, 468 instances of subjects violating an axiom they had chosen
- How do individuals respond when confronted with this inconsistency?

IDENTIFYING MISTAKES

- In total, 468 instances of subjects violating an axiom they had chosen
- How do individuals respond when confronted with this inconsistency?
  - Un-select axiom
    - Violation reflects intentional deviation; axiom is not universal

IDENTIFYING MISTAKES

- In total, 468 instances of subjects violating an axiom they had chosen
- How do individuals respond when confronted with this inconsistency?
  - Un-select axiom
    - Violation reflects intentional deviation; axiom is not universal
  - Change lottery choices (à la Savage)
    - Lottery choices constituted a mistake

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total				
IIA				
TRANS				
CONS				

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%		
IIA				
TRANS				
CONS				

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%		
IIA				
TRANS				
CONS				

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%		
IIA				
TRANS				
CONS				

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%	6%	16%
IIA				
TRANS				
CONS				

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%	6%	16%
IIA	2%	78%	2%	19%
TRANS	5%	68%	10%	17%
CONS	0%	79%	8%	13%

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%	6%	16%
IIA	2%	78%	2%	19%
TRANS	5%	68%	10%	17%
CONS	0%	79%	8%	13%
Mixture Axiom Total				

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%	6%	16%
IIA	2%	78%	2%	19%
TRANS	5%	68%	10%	17%
CONS	0%	79%	8%	13%
Mixture Axiom Total	18%	32%		

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%	6%	16%
IIA	2%	78%	2%	19%
TRANS	5%	68%	10%	17%
CONS	0%	79%	8%	13%
Mixture Axiom Total	18%	32%		

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%	6%	16%
IIA	2%	78%	2%	19%
TRANS	5%	68%	10%	17%
CONS	0%	79%	8%	13%
Mixture Axiom Total	18%	32%	2%	48%

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%	6%	16%
IIA	2%	78%	2%	19%
TRANS	5%	68%	10%	17%
CONS	0%	79%	8%	13%
Mixture Axiom Total	18%	32%	2%	48%
FOSD	21%	29%	1%	49%
IND	16%	34%	3%	47%
BRANCH	0%	55%	5%	41%

Sample: All instances of selecting and violating axiom

AXIOM RECONCILIATIONS

Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple Axiom Total	2%	76%	6%	16%
IIA	2%	78%	2%	19%
TRANS	5%	68%	10%	17%
CONS	0%	79%	8%	13%
Mixture Axiom Total	18%	32%	2%	48%
FOSD	21%	29%	1%	49%
IND	16%	34%	3%	47%
BRANCH	0%	55%	5%	41%

Sample: All instances of selecting and violating axiom

Conditional on reconciling, 80% change lotteries ($p < 0.001$)

SUMMARY OF MAIN RESULT

- Over 2/3 axiom violations reconciled

SUMMARY OF MAIN RESULT

- Over 2/3 axiom violations reconciled
- When reconciled, more likely to change lottery choices to be *consistent with the axiom*
  - Just as Savage did
  - Interpretation: many violations were “mistakes”

SUMMARY OF MAIN RESULT

- Over 2/3 axiom violations reconciled
- When reconciled, more likely to change lottery choices to be *consistent with the axiom*
  - Just as Savage did
  - Interpretation: many violations were "mistakes"
- Do people always revise in favor of rules?
  - Compare to c-axiom revisions
  - **But** there are issues of selection

C-AXIOM RECONCILIATIONS

$c-$Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple c-Axiom Total	44%	22%	3%	31%

Sample: All instances of selecting and violating axiom

C-AXIOM RECONCILIATIONS

c–Axiom	% Unselect Axiom	% Change Lotteries	% Change Both	% Keep Inconsistent
Simple c-Axiom Total	44%	22%	3%	31%
c-IIA	44%	15%	2%	39%
c-TRANS	50%	27%	0%	23%
c-CONS	17%	50%	33%	0%
Mixture c-Axiom Total	29%	29%	1%	41%
c-FOSD	19%	44%	0%	38%
c-IND	30%	26%	4%	41%
c-BRANCH	50%	0%	0%	50%

Sample: All instances of selecting and violating axiom

Conditional on reconciling, 40% change lotteries

SELECTION

- Can't fully control for selection here
- Condition just on people who select axiom and c-axiom
  - Axiom: Change lotteries 40%, un-select axiom 23%
  - c-Axiom: Change lotteries 19%, un-select c-axiom 43%

SELECTION

- Can't fully control for selection here
- Condition just on people who select axiom and c-axiom
  - Axiom: Change lotteries 40%, un-select axiom 23%
  - c-Axiom: Change lotteries 19%, un-select c-axiom 43%
- We also allow them to reconcile conflicting rules
  - Conditional on un-selecting one, 89% un-select the c-axiom
  - Note: some sample sizes of c-axiom selection are very small

Main Results:

1. Individuals select axioms at very high rates
2. Individuals selecting an axiom are no less likely to violate it
3. Two-thirds of axiom and $c-$axiom violations are revised
4. Revisions are more likely to favor axioms than $c-$axioms

REPLICATION AND ROBUSTNESS

REPLICATION AND ROBUSTNESS

- One reason to use (good and bad) rules is that it's hard to make decisions on your own

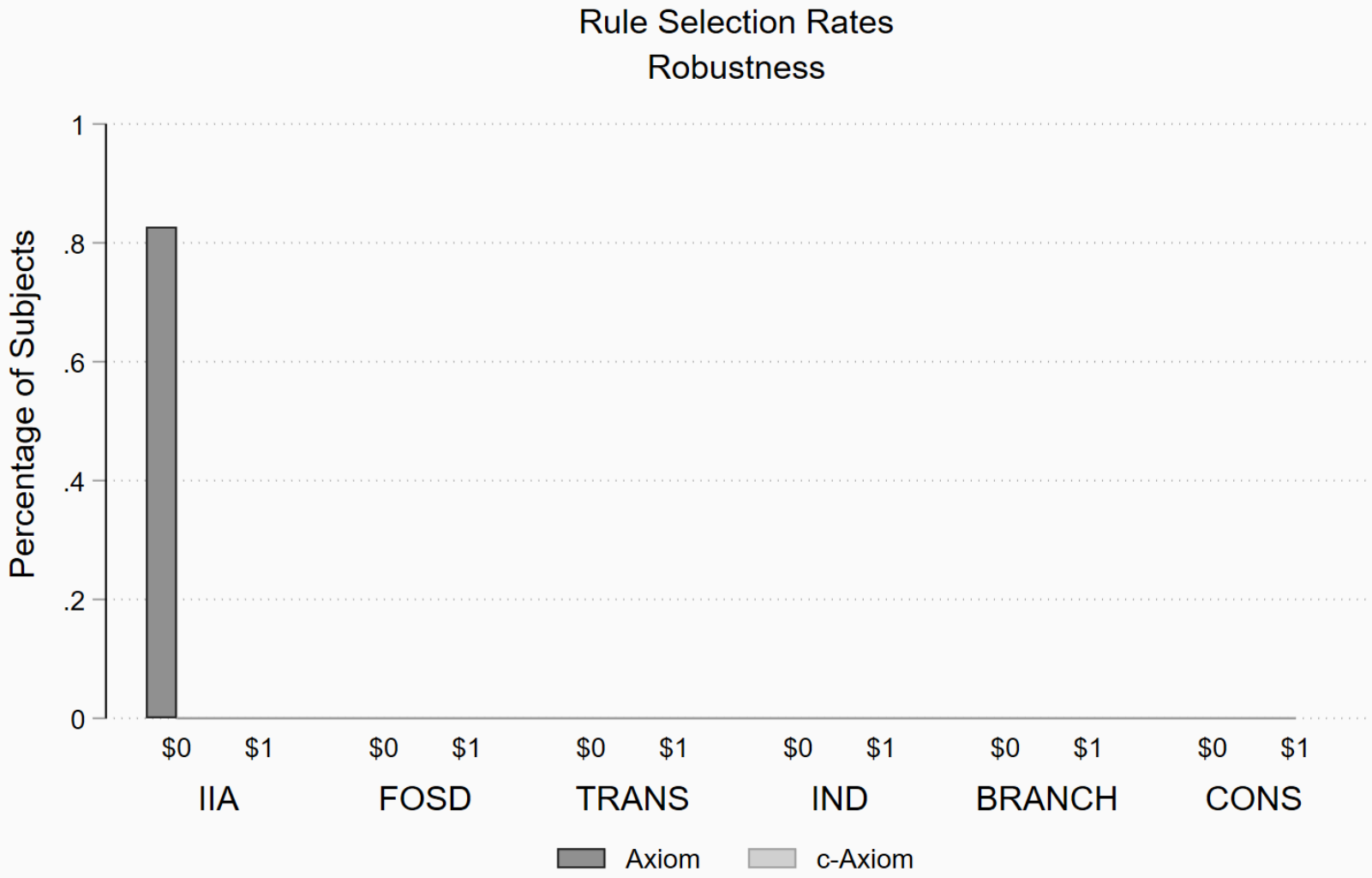
REPLICATION AND ROBUSTNESS

- One reason to use (good and bad) rules is that it's hard to make decisions on your own
- We can't observe decision costs, but we can exogenously make decisions *more* costly
  - Cost: pay $1 to make choices on your own

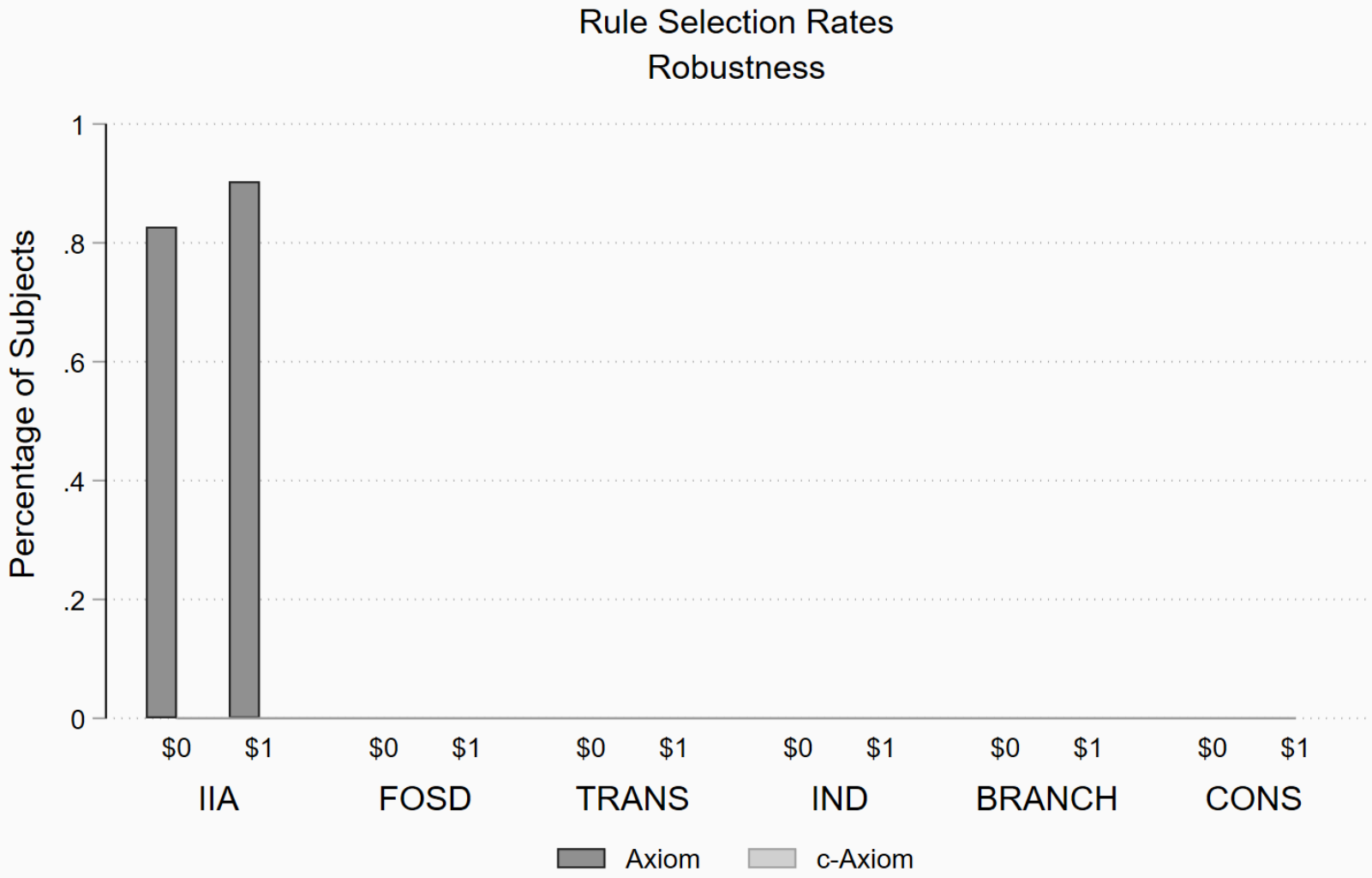
REPLICATION AND ROBUSTNESS

- One reason to use (good and bad) rules is that it's hard to make decisions on your own
- We can't observe decision costs, but we can exogenously make decisions *more* costly
  - Cost: pay $1 to make choices on your own
- Do people follow rules more?
  - Result: not much
  - Interpretation: axiom selection is not primarily due to decision avoidance

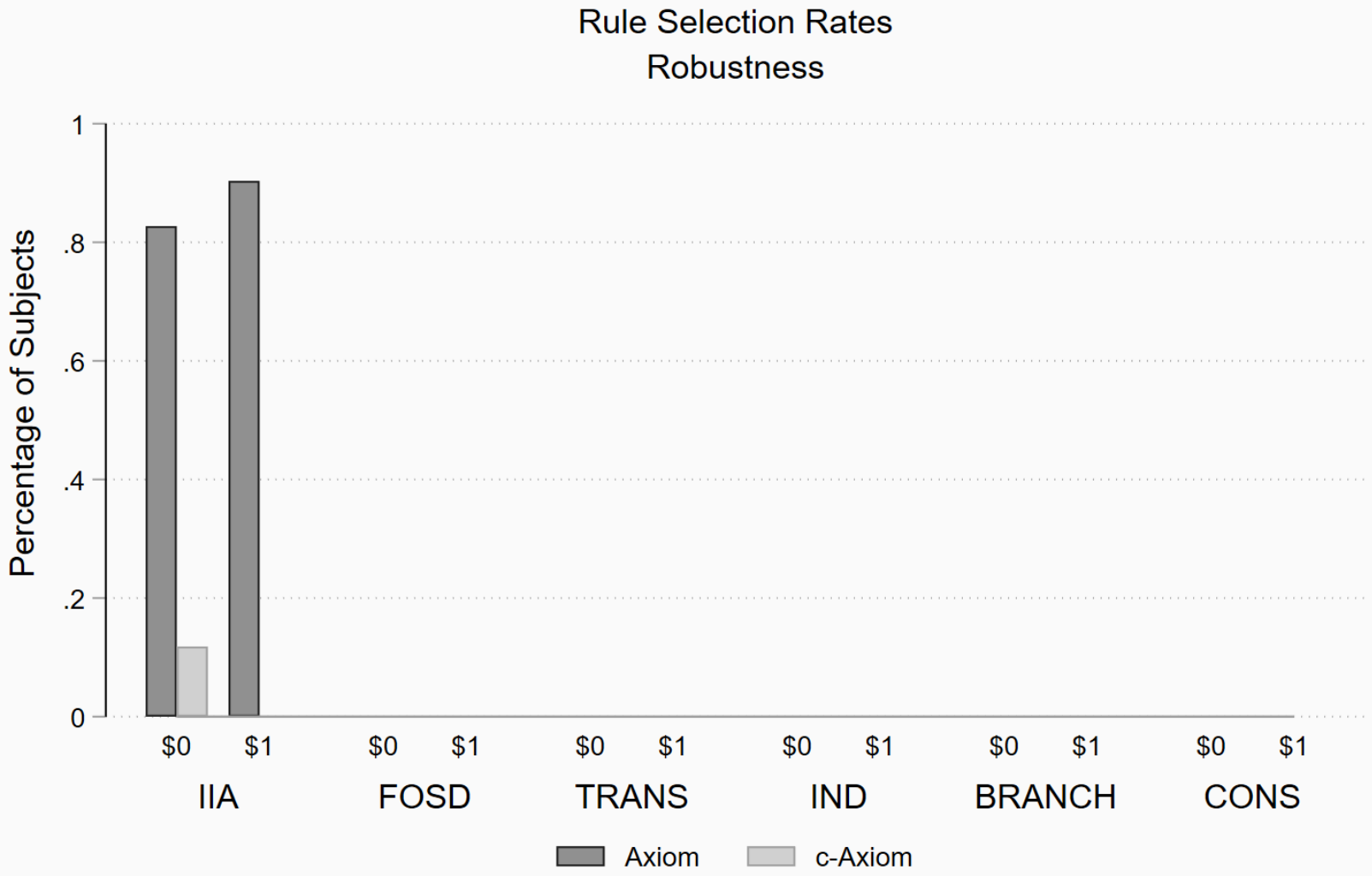
REPLICATION



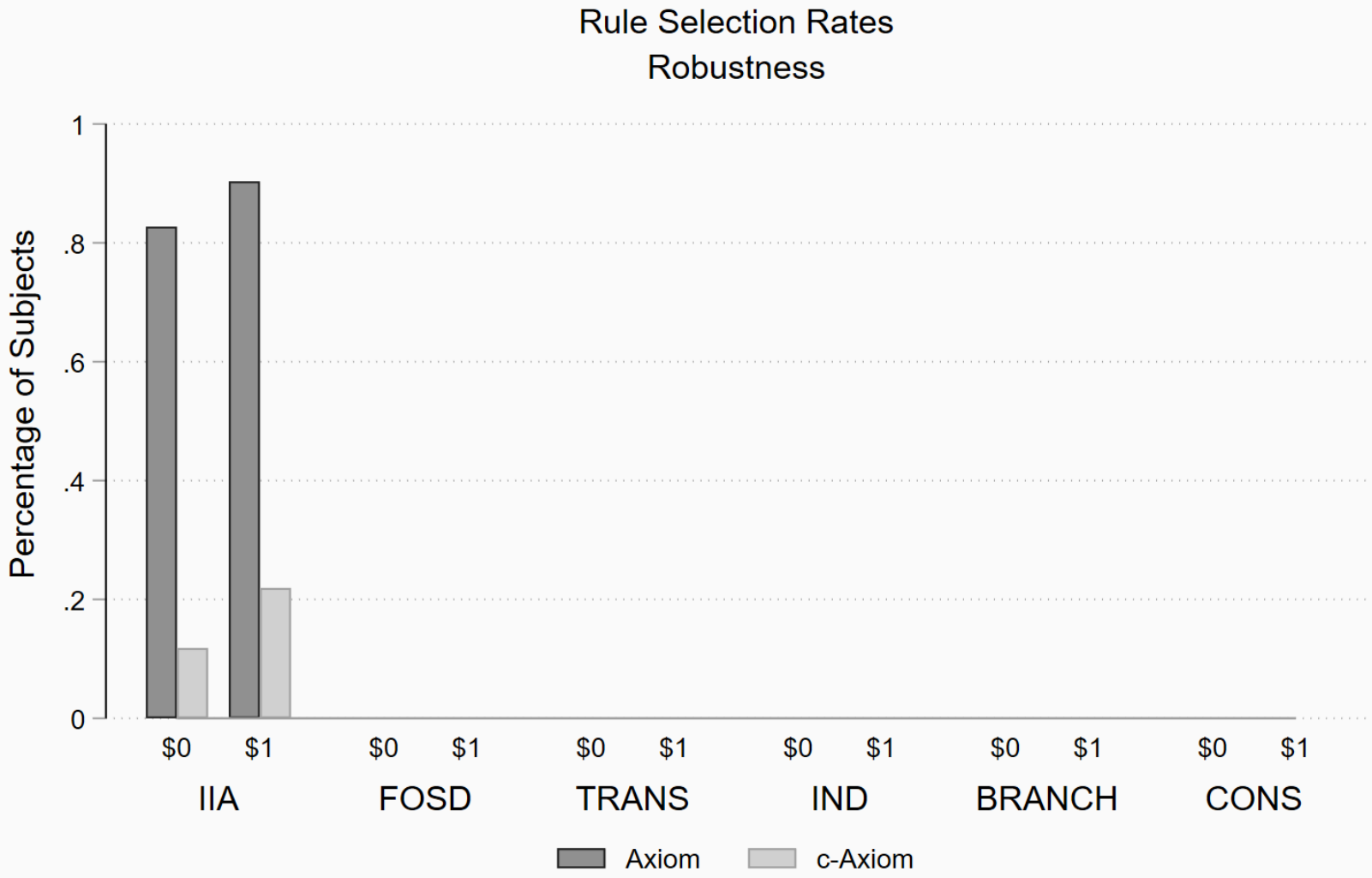
REPLICATION



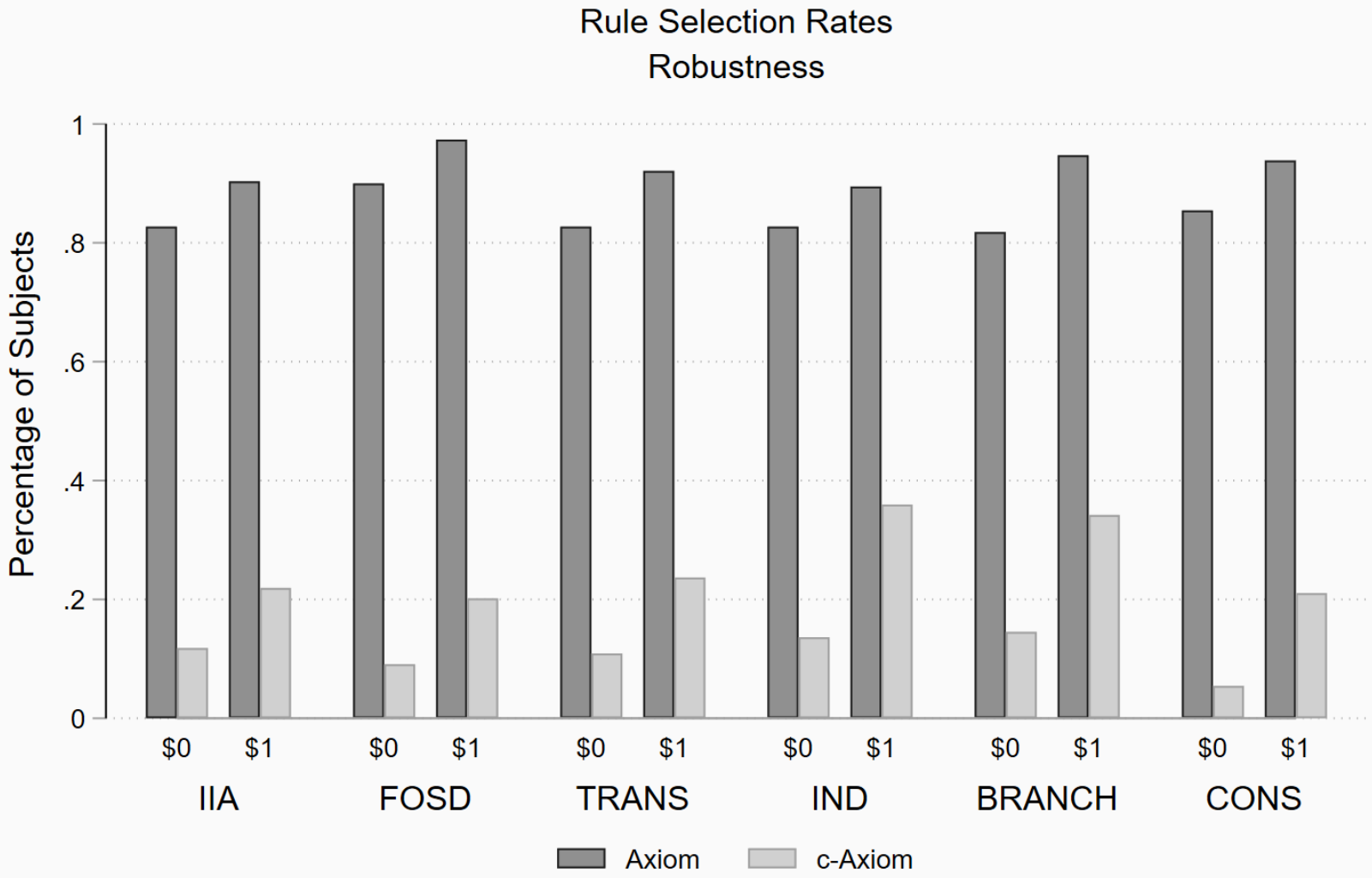
REPLICATION



REPLICATION



REPLICATION



$1 COST

% of revisions in favor of axiom:

	$0 Treatment	$1 Treatment
Axioms	79%	91%
$c-$Axioms	40%	50%
p-value	< 0.001	< 0.001

$1 COST

% of revisions in favor of axiom:

	$0 Treatment	$1 Treatment
Axioms	79%	91%
$c-$Axioms	40%	50%
p-value	< 0.001	< 0.001

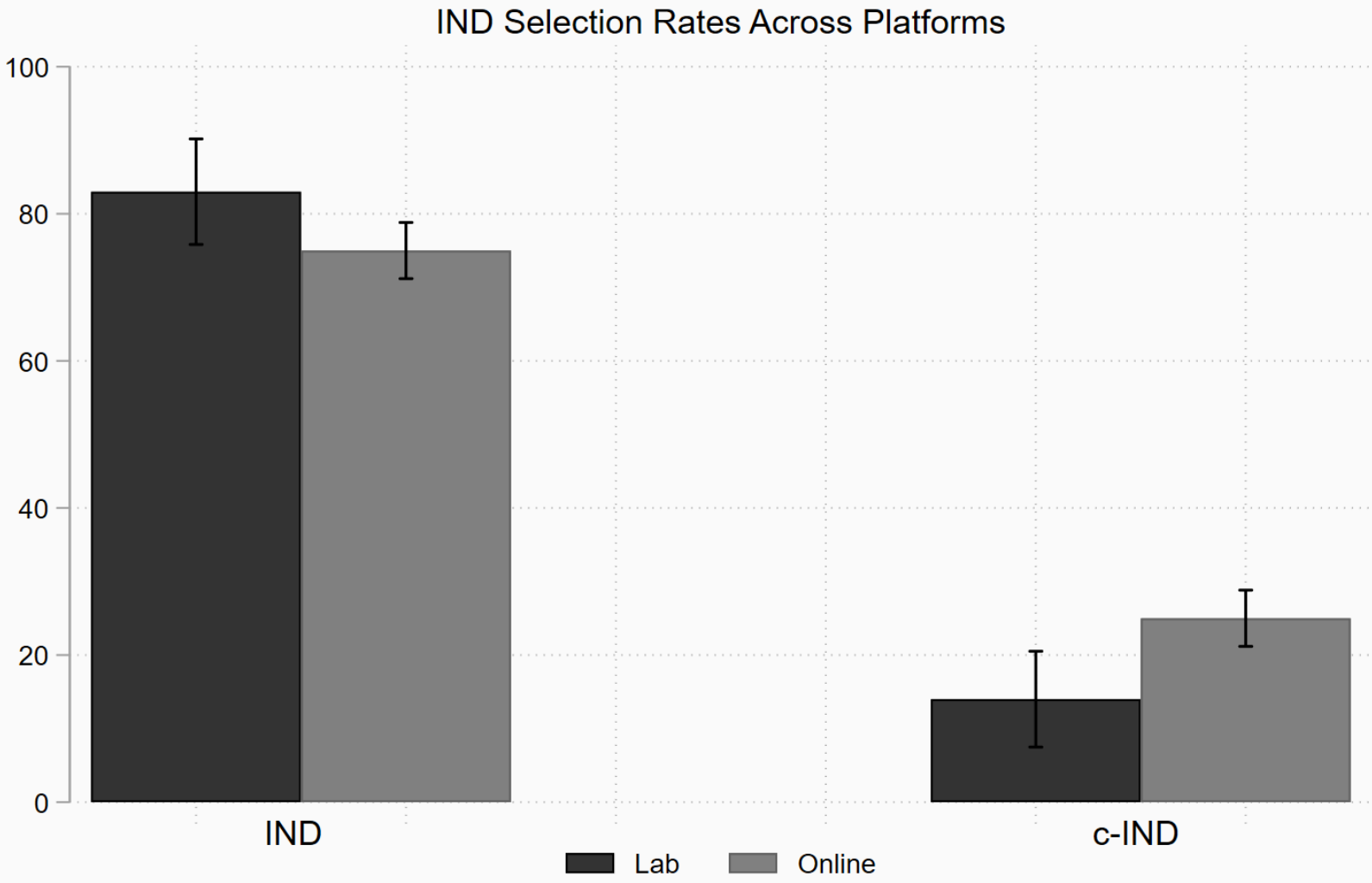
Follow rules *slightly more* (< 10pp) when decisions are costly

Still revise more often to follow axioms

REPLICATION

- Replicated our results online
- Prolific online research platform
  - General population
  - Primarily US and UK
  - Generally young, high school or college educated
- Focus just on IND as a “stress test”

REPLICATION



REPLICATION

Violate IND more online (41% vs. 34%, $p = 0.022$)

REPLICATION

Violate IND more online (41% vs. 34%, $p = 0.022$)

Axiom	Keep Inconsistent	Unselect Axiom	Change Lotteries	Change and Still Inconsistent
Lab IND	47%	16%	34%	3%
Online IND	40%	24%	31%	5%

CONCLUSION

- We revisit some of the canonical axiom violations in behavioral economics
- Evidence that not all violations are intentional deviations
  - Some are better thought of as *mistakes*
  - Source of mistakes?
    - Thinking costs
    - Cognitive constraints
    - Etc.
- Implies that we shouldn't necessarily use descriptive models to make welfare statements
- We use axioms as a proof of concept, but opens bigger questions for behavioral economists

THE END