On the Demand for Mental Models

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Motivation

- Information is available in various forms
  - Historical data about how actions, states and outcomes are correlated
  - (Subjective) models of the data generating process

$\Rightarrow$ How do data and models influence decision-making?

Motivation

(a) Sports Statistics

(b) Technical Analysis

Figure: Decision Support in the Media

Research Questions

- How does exposure to models affect decision-makers' assessments in a prediction task?
- What kinds of models are (perceived as) more convincing?
- How do decision-makers choose between learning more data and learning about a potential model?
- Does a potential model affect beliefs differently than data?
- Do decision-makers exhibit wishful thinking?

Literature on Subjective Mental Models

Theory

- Schwartzstein and Sunderam [2021]: Correlational (joint density of states and outcome), good fit as selection criterion
- Spiegler [2016], Eliaz and Spiegler [2020]: Causal (directed acyclic graph), anticipatory utility as selection criterion

Empirics

- Kendall and Oprea [2021]: People form mental models, prefer simple ones, want to communicate them
- Kendall and Charles [2022]: Exposure to contradictory MMs can move beliefs in different directions
- Barron and Fries [2023]: People prefer mental models that have a good fit with historical data
- Ambuehl and Thysen [2024]: Heterogeneity in preferences for models (types: caution, wishful thinking, historical fit), non-utilization of Occam's razor

Other Literature Strands

- Wishful Thinking: Barron [2021], Caballero and López Pérez [2020], Mayraz [2011], Lahav and Santo [2022], Caplin and Leahy [2019]
- Demand for Information: Ambuehl and Li [2018], Eliaz and Schotter [2010]
- Applications of Mental Models: Flynn and Sastry [2022] (Macro), Molavi et al. [2021] (Finance), Schumacher and Thysen [2022] (Contract Theory)

Design

In a nutshell...

- Two roles:
  - Senders
  - Receivers
- Data tables
  - Consist of 0s and 1s
  - Three explanatory variables, one outcome variable
- Prediction tasks
- Hints

Design

Receivers

y	X		
	$E1$	$E2$	$E3$
0	1	1	0
1	0	1	1
1	0	1	1
1	0	1	1
0	1	1	0
0	0	0	0
1	0	0	0
0	1	1	0
?	1	1	1

Phase 1:

- 6 rounds: All receivers see 8 historical rows + prediction row of the dataset
- Some receivers see a *hint*:
  - In the historical data, it looks like there could be an effect of E3 on the main observation (*Soft*).
  - If E3 equals 1, the main observation also always equals 1 (*Strong*).
- Task: Assess the probability that ? $= 1$.

Phase 2:

- 6 rounds: Receivers can decide whether to see more rows of the table **OR** another hint (or neither).

Receivers

With what probability do you think that there is a 1 behind the question mark? Please enter this probability into the text field below.

Y	E1	E2	E3
0	1	0	0
0	1	0	1
1	1	1	0
1	1	1	0
0	1	0	1
0	0	0	0
1	1	1	0
1	0	0	0
?	1	1	1

Receivers

More data

In the historical data, it looks like there could be an effect of E2 on the main observable.

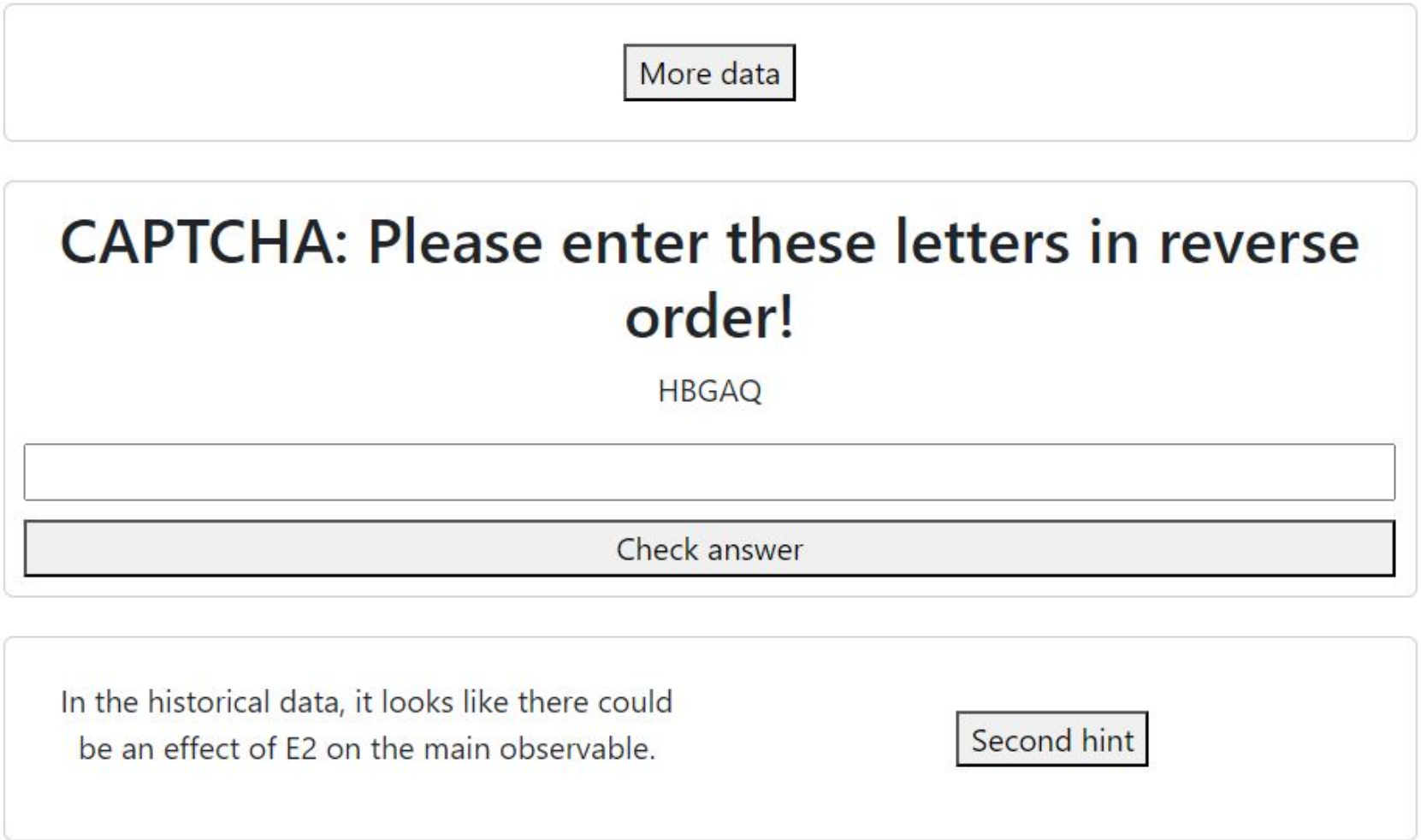
Second hint

What do you think is the probability that there is a 1 behind the question mark (?)?

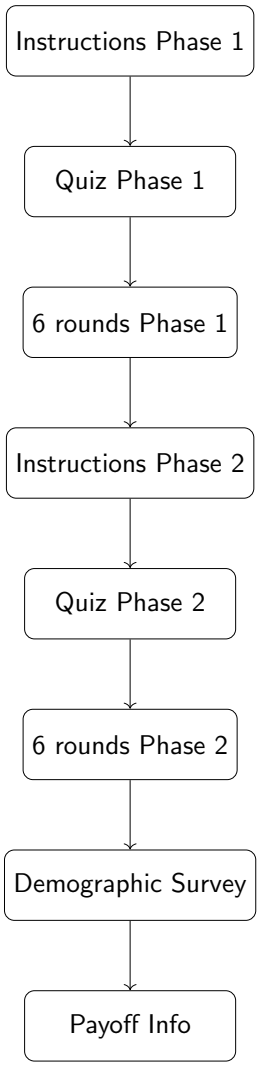
%.

Next

Receivers


More data
CAPTCHA: Please enter these letters in reverse order!
HBGAQ
Check answer
In the historical data, it looks like there could be an effect of E2 on the main observable.
Second hint

Timeline and Treatments for Receivers



- 2x3 between-subjects design varying:
  - Payment:
    - Payoff Group A(ccuracy): Incentivized to match realization of ? (binarized procedure)
    - Payoff Group B(onus): Incentivized to match realization of ? (binarized procedure) **OR** Bonus if ?=1
  - Hints:
    - NoHint
    - SoftHint: "It looks like there could be an effect of X on Y."
    - StrongHint: "If X equals 1, Y also always equals 1."
- Within-subjects: vary whether datasets are deterministic or stochastic ("almost always...")

Senders

Decision Task

Table 1:

Y	E1	E2	E3
1	0	0	0
0	0	0	0
1	1	0	1
0	1	0	0
0	1	1	0
1	1	0	1
0	1	1	0
1	1	0	1
?	1	1	1

Table 2:

Y	E1	E2	E3
1	1	1	0
0	1	0	0
1	1	0	1
0	1	1	0
0	1	0	1
1	1	0	1
0	1	1	0
1	1	0	1
?	1	1	1

Senders

Decision Task

The following hints imply that there is a 1 behind the question mark (?), each referring to the indicated table above:

Table 1:
Hint 1: The following always holds: If E3 equals 1, the main observation (Y) also equals 1.

Hint 2: In the historical data, it looks like there could be an effect of E3 on the main observation (Y).

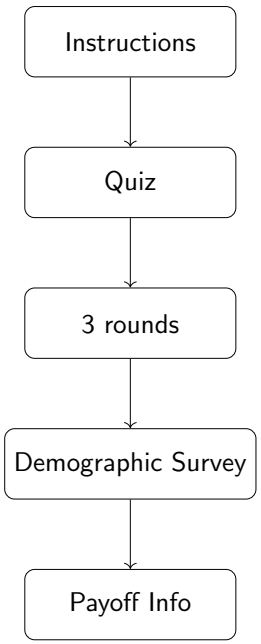
Table 2:
Hint 1: The following almost always holds: If E3 equals 1, the main observation (Y) also equals 1.

Hint 2: In the historical data, it looks like there could be an effect of E3 on the main observation (Y).

Which table do you want to send to the receiver?

- ○ Table 1
- ○ Table 2

Senders



- Want to convince receivers that a 1 is hidden behind the question mark
- Choose which table and which hint to send
  - Stochastic vs. deterministic table
  - Soft vs. strong hint
- Know whether their matched receiver is in Group A(ccuracy) or B(onus)

Senders

Instructions

Instructions

In this experiment you play three independent rounds of a persuasion task. Independent means that you cannot infer from one round to another. In each of the three rounds, you see two datasets in the form of tables and four "hints", two per table. The tables have a question mark (?) in the last row, and the hints are sentences which point out a relationship between the values in the visible part of the dataset in order to help receivers decide whether there is a 0 or a 1 behind that question mark (?). You will be asked to choose one of the tables and one of the hints. Another participant of the experiment (a receiver) will see the combination you chose without any additional information. You want to choose the combination in such a way that this receiver reports a high probability that there is a 1 hidden behind the question mark (?).

Tables

The datasets are presented in tables, see the example displayed below. The tables consist of 9 rows and 4 columns, see the example table below. Each cell contains either a 0 or a 1. In the first column you see 8 entries of the main observation (Y); in columns 2 to 4 you see 9 entries for each of the three side observations (E1, E2, and E3). In the 9th row the main observation (Y) is missing but you can see the side observations (E1, E2, and E3).

Each row represents observations that were made simultaneously. Please note that there is no temporal relationship between the different rows. It is therefore not true that the events that have led to the entries in the first row have necessarily happened before the events that have led to the entries in the 9th row.

There may or may not be a causal relationship between the main and the three side observations. Whether causal or not, the relationship between the observations is the same in each row.

Senders

Instructions

The hints

The hints point out potential relationships between the main observation and the side observations in the visible part of the dataset. You will be asked to send one of two hints to a receiver.

Your task

Your task is to convince a receiver that the entry hidden behind the question mark (?) in the last row of the main observation is equal to 1. On a scale of 0 to 100 the receiver states the probability that this entry is equal to 1. To convince the receiver that there is a 1 behind the question mark (?), you have two tools at your disposal. You will be shown two tables, which slightly differ in their content. For each of the tables you will be shown two hints that argue that there is a 1 behind the question mark (?). You must first choose one of the tables, and then one of the hints referring to the datasets. Your chosen combination of dataset and hint will be sent to the receiver.

The receiver only sees the dataset you chose and the corresponding hint that you chose. They are asked to report their assessment of the probability that there is a 1 hidden behind the question mark (?), and they are paid in such a way that it is optimal for them to state their true assessment.

Procedures

- Programmed in otree & run on Prolific with US-subjects
- IRB-approval & pre-registration
- Receivers earned $4.2, spent 22 minutes on the experiment
- Senders earned $2.8, spent 14 minutes on the experiment

Table: Participants

	Receivers			
	NoHint	SoftHint	HardHint	Senders
NoBonus	87	85	87	91
Bonus	87	87	85	89

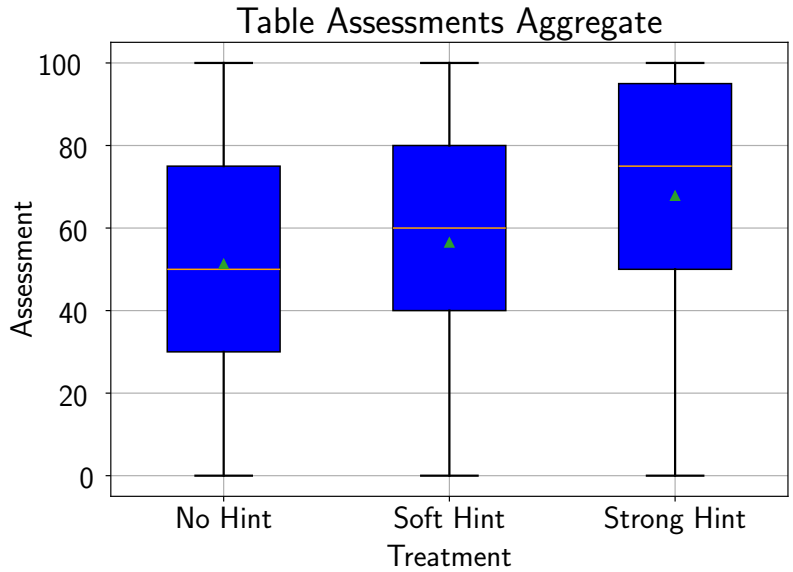
Research Questions

Receivers

1. Do hints about possible mental models influence receivers' assessment?
   - 1.1 Are receivers differently influenced by deterministic vs. stochastic hints?
   - 1.2 Are receivers differently influenced by soft vs. strong hints?
2. Do receivers engage in wishful thinking?
   - 2.1 Is the degree of wishful thinking influenced by whether the receiver sees deterministic vs. stochastic hints?
   - 2.2 Is the degree of wishful thinking influenced by whether the receiver sees soft vs. strong hints?
3. Do receivers prefer to see additional data or an additional hint if given the choice?
   - 3.1 Does their choice depend on previously presented data and hint?
   - 3.2 Does their choice depend on whether they are in the BONUS treatment?

Results

Impact of Hints



Seeing a message has a positive effect on the receivers' assessment ($p < 0.001$, Wilcoxon rank sum tests on subject-level averages).

- Soft hints: $p = 0.012$
- Strong hints: $p < 0.001$

Results

Impact of Hints

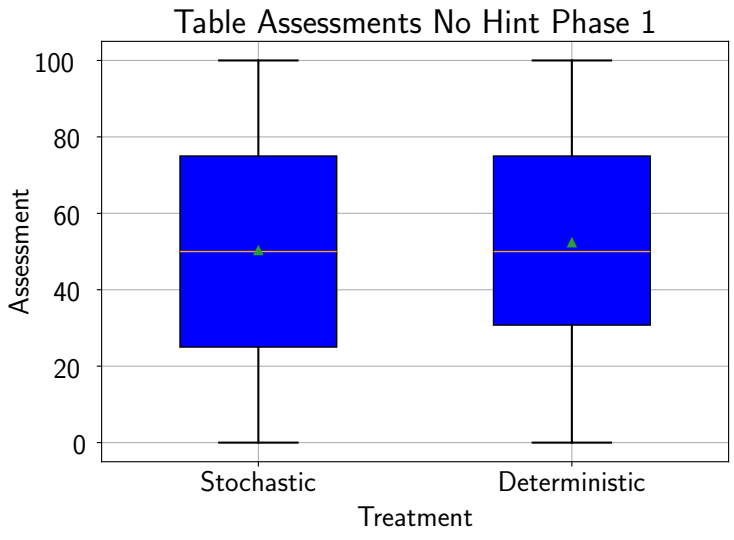


Figure: No Hint

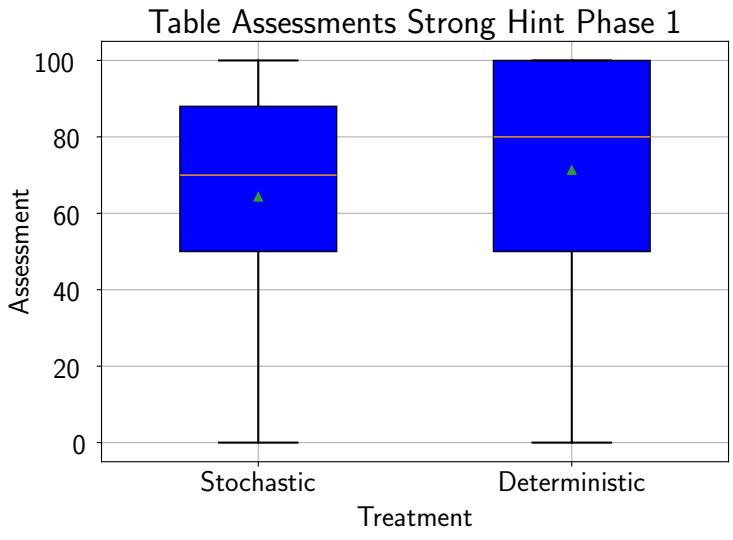


Figure: Strong Hint

$\Rightarrow$ Without hint: no difference between stochastic and deterministic tables.

$\Rightarrow$ Effect of strong hints smaller when stochastic.

Impact of Hints

Regressions

	(1)	(2)
Soft	4.424**	4.293**
	(1.961)	(2.101)
Strong	15.696***	18.072***
	(2.049)	(2.317)
Bonus	0.146	0.146
	(1.663)	(1.665)
Stochastic		-2.523
		(1.675)
Soft*Stochastic		0.262
		(1.962)
Strong*Stochastic		-4.754**
		(2.045)
Period	-0.319	-0.280
	(0.273)	(0.272)
Constant	53.144***	52.934***
	(1.893)	(2.386)
R^2	0.103	0.103
N	3270	3270

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

$\Rightarrow$ Both strong and soft hints increase receivers' assessment.

$\Rightarrow$ Effect smaller when strong hints are stochastic.

Results

Impact of Bonus (Wishful Thinking?)

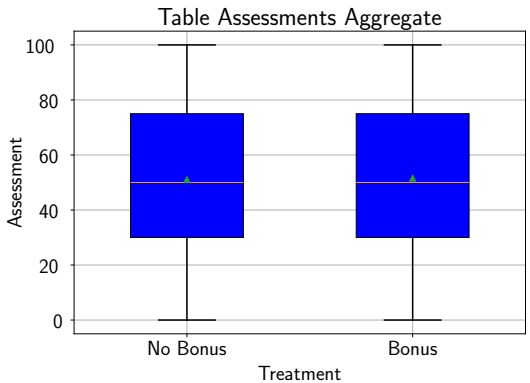


Figure: Without Hint

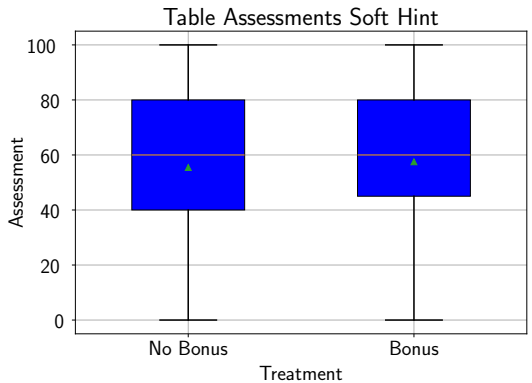


Figure: Soft Hint

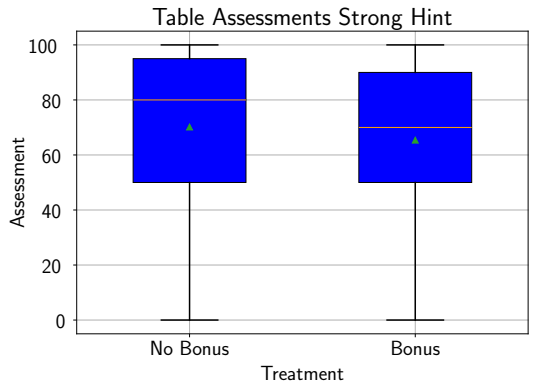


Figure: Strong Hint

Results

Impact of Bonus (Wishful Thinking?)

	(1) Hints	(2) Det	(3) Stoch
Bonus	1.804	-0.728	4.354
	(2.662)	(2.775)	(3.175)
Soft	3.798	2.174	5.432
	(2.776)	(2.867)	(3.344)
Strong	18.880***	19.577***	18.501***
	(2.809)	(3.188)	(3.185)
Bonus*Soft	1.235	4.161	-1.821
	(3.915)	(4.194)	(4.552)
Bonus*Strong	-6.480	-2.853	-10.288**
	(4.084)	(4.617)	(4.496)
Period	-0.319	0.287	-0.786**
	(0.273)	(0.391)	(0.392)
Constant	52.315***	52.385***	51.684***
	(2.171)	(2.301)	(2.811)
R^2	0.110	0.117	0.072
N	3270	1635	1635

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

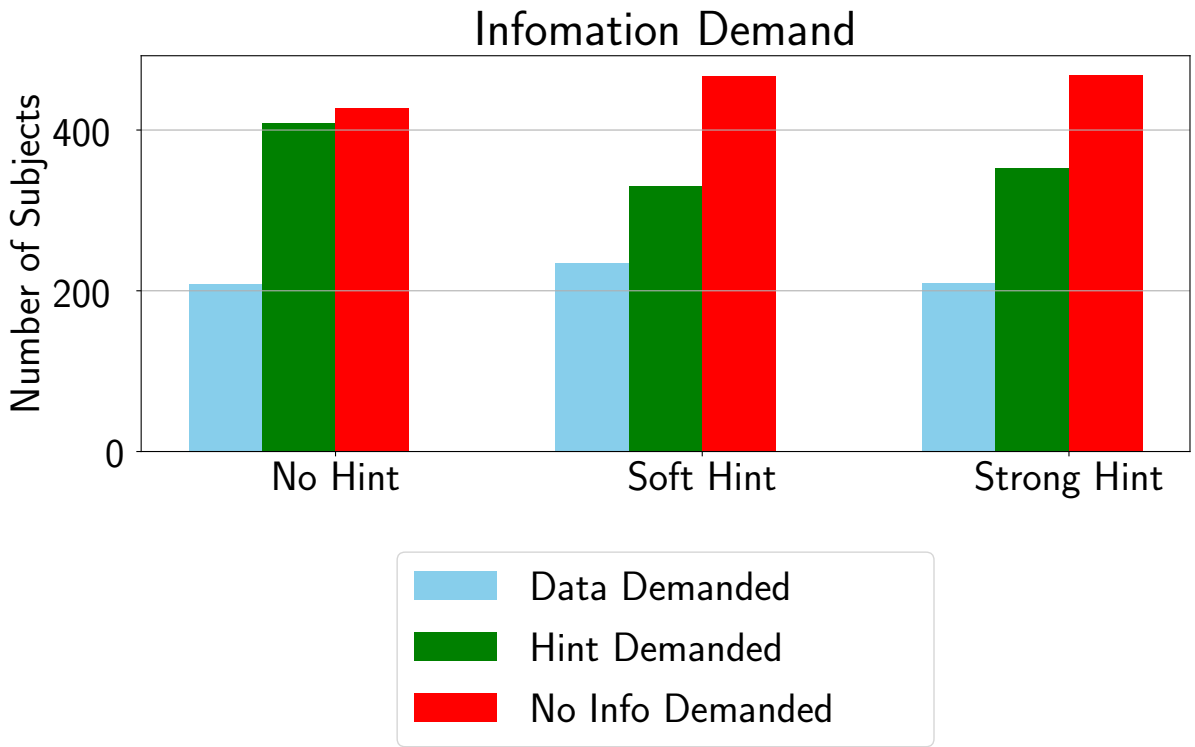
	(1) Det	(2) Stoch
Bonus		
NoHint	-0.728	4.354
	(2.775)	(3.175)
Soft	3.433	2.533
	(3.145)	(3.263)
Strong	-3.581	-5.933*
	(3.692)	(3.184)
Soft		
NoBonus	2.174	5.432
	(2.867)	(3.344)
Bonus	6.335**	3.611
	(3.062)	(3.090)
Strong		
NoBonus	19.577***	18.501***
	(3.188)	(3.185)
Bonus	16.724***	8.213***
	(3.339)	(3.174)

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

⇒No evidence of wishful thinking.

Results

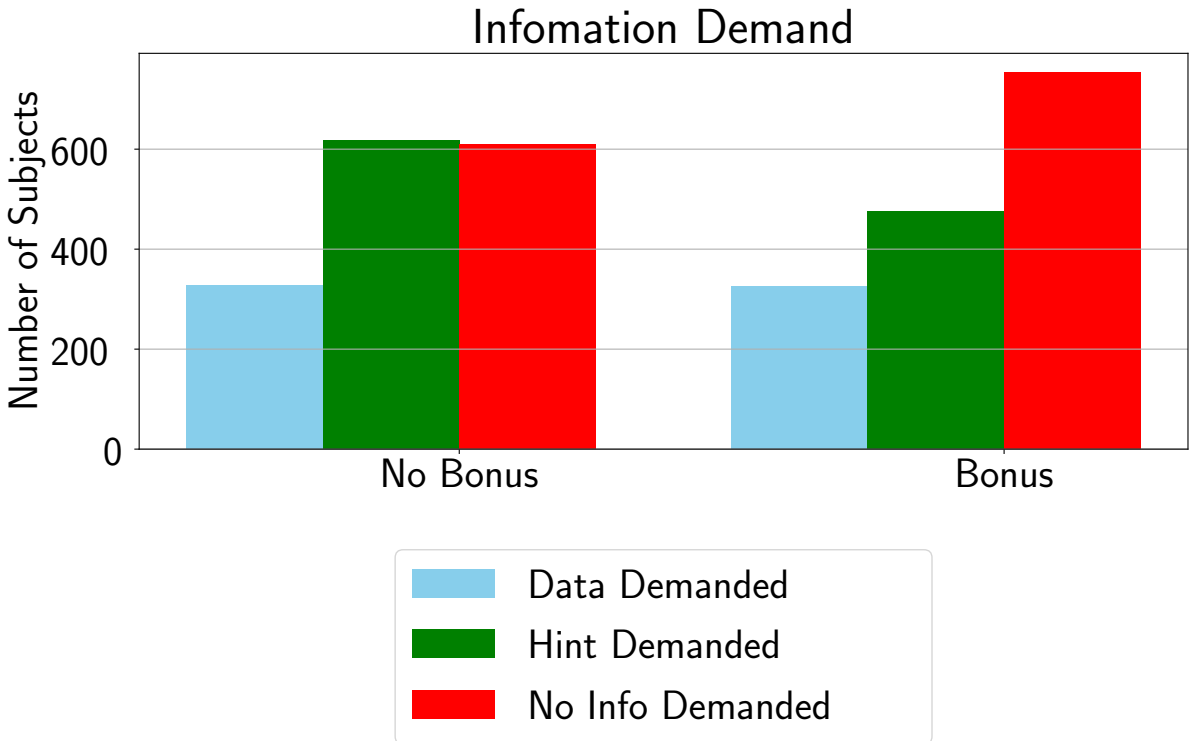
Information Demand



Hints are preferred over data.

Results

Information Demand



BONUS treatment induces subjects to:

$\Rightarrow$ demand fewer hints

$\Rightarrow$ refrain from demanding more information.

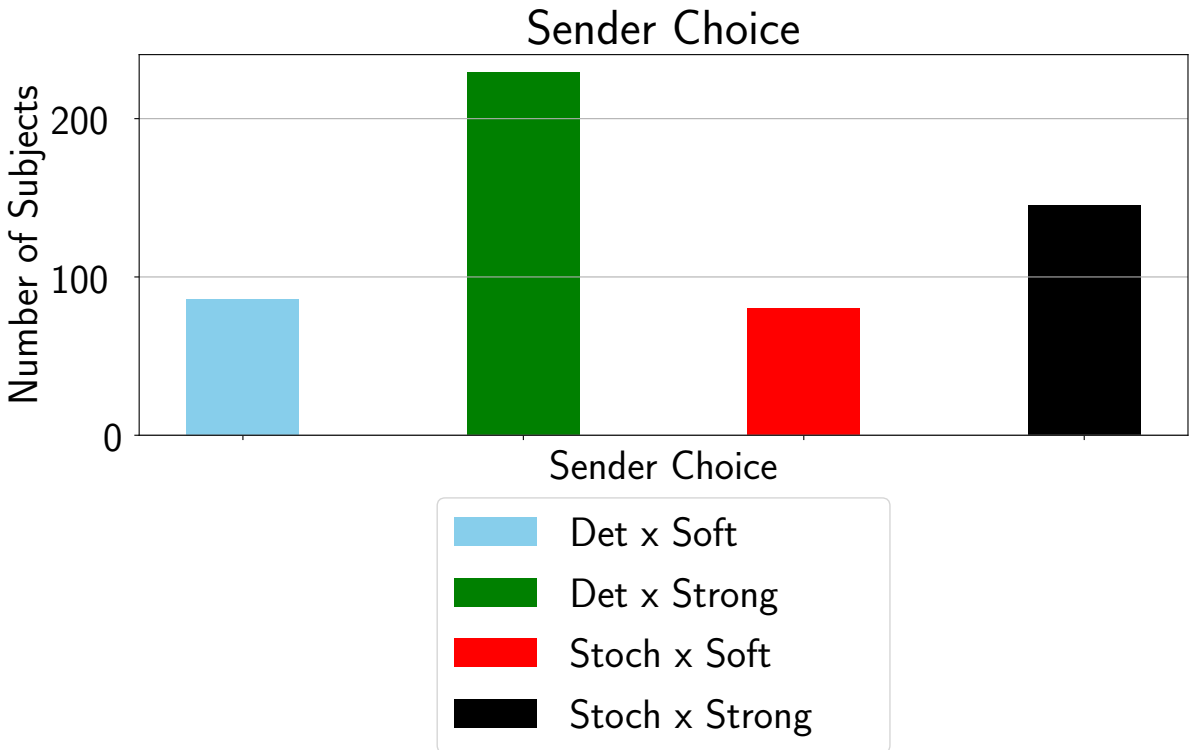
	(1) ΔAssessment	(2) ΔAssessment	(3) ΔCertainty	(4) ΔCertainty
DataD	-1.852	-0.646	0.124	0.160
	(1.669)	(2.870)	(0.130)	(0.241)
HintD	10.728***	5.944**	0.821***	0.502***
	(1.544)	(2.626)	(0.123)	(0.184)
Bonus	-1.930	-1.532	-0.022	0.013
	(1.378)	(1.355)	(0.121)	(0.118)
Period	0.041	-0.042	-0.007	-0.013
	(0.336)	(0.334)	(0.024)	(0.024)
Soft		0.044		0.101
		(2.588)		(0.182)
Strong		1.717		0.375*
		(2.610)		(0.197)
DataD*Soft		-2.251		-0.002
		(4.210)		(0.313)
DataD*Strong		-1.197		-0.059
		(3.936)		(0.305)
HintD*Soft		15.531***		1.329***
		(3.784)		(0.297)
HintD*Strong		0.523		-0.231
		(3.501)		(0.267)
Constant	3.386	3.396	0.106	-0.018
	(3.616)	(3.783)	(0.260)	(0.273)
R^2	0.082	0.125	0.080	0.116
N	3270	3270	3270	3270

Research Questions

Senders

1. Which kind of hint do senders expect to be more convincing – soft vs. strong?
2. Which kind of dataset do senders expect to be more convincing – deterministic vs. stochastic?
3. Is their choice influenced by whether or not their receiver is in the BONUS treatment?

Senders



- Strong and deterministic hints are preferred.
- Bonus treatment has no effect.

Conclusion

- Hints (=mental models) have a strong influence on assessments.
- Decision-makers prefer hints over data.
- No evidence of wishful thinking (with and without hint).

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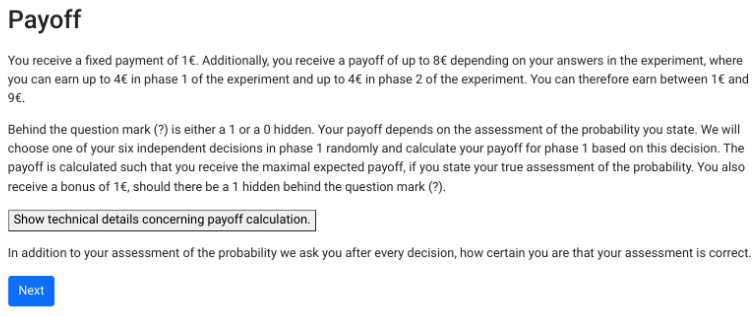
Jeffrey Yang. A criterion of model decisiveness. *Available at SSRN 4425088*, 2023.

Instructions



Payoff

You receive a fixed payment of 1€. Additionally, you receive a payoff of up to 8€ depending on your answers in the experiment, where you can earn up to 4€ in phase 1 of the experiment and up to 4€ in phase 2 of the experiment. You can therefore earn between 1€ and 9€.

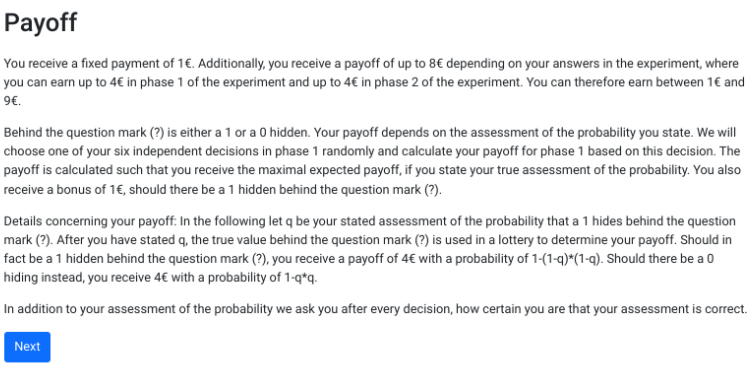
Behind the question mark (?) is either a 1 or a 0 hidden. Your payoff depends on the assessment of the probability you state. We will choose one of your six independent decisions in phase 1 randomly and calculate your payoff for phase 1 based on this decision. The payoff is calculated such that you receive the maximal expected payoff, if you state your true assessment of the probability. You also receive a bonus of 1€, should there be a 1 hidden behind the question mark (?).

Show technical details concerning payoff calculation.

In addition to your assessment of the probability we ask you after every decision, how certain you are that your assessment is correct.

Next

Instructions



Payoff

You receive a fixed payment of 1€. Additionally, you receive a payoff of up to 8€ depending on your answers in the experiment, where you can earn up to 4€ in phase 1 of the experiment and up to 4€ in phase 2 of the experiment. You can therefore earn between 1€ and 9€.

Behind the question mark (?) is either a 1 or a 0 hidden. Your payoff depends on the assessment of the probability you state. We will choose one of your six independent decisions in phase 1 randomly and calculate your payoff for phase 1 based on this decision. The payoff is calculated such that you receive the maximal expected payoff, if you state your true assessment of the probability. You also receive a bonus of 1€, should there be a 1 hidden behind the question mark (?).

Details concerning your payoff: In the following let q be your stated assessment of the probability that a 1 hides behind the question mark (?). After you have stated q, the true value behind the question mark (?) is used in a lottery to determine your payoff. Should in fact be a 1 hidden behind the question mark (?), you receive a payoff of 4€ with a probability of 1-(1-q)*(1-q). Should there be a 0 hiding instead, you receive 4€ with a probability of 1-q*q.

In addition to your assessment of the probability we ask you after every decision, how certain you are that your assessment is correct.

Next

Instructions

Phase 1 of the experiment

In this experiment you see datasets and make decisions based on these. The experiment has two phases, you will now receive the instructions for the first phase, the instructions for the second phase will be displayed after finishing phase 1. You make six independent decisions in total, concerning six different datasets. Independent means here that you cannot make inferences about one decision from another.

Datasets

The datasets are presented in tables, like in the example table below. Each cell can contain a 0 or a 1. In the first column you see 8 entries of the main observation (HB); in columns 2 to 4 you see 9 entries each, for 3 side observations (NB). The entries in the individual rows represent observations that were made simultaneously. Please note that there is no temporal relationship between the individual rows. It is therefore not true that the events that have led to the entries in the first row have necessarily happened before the entries in the 9. row. In the 9. row the main observation is missing but you can see the side observations. There can be a causal relationship between main and side observations, but this doesn't have to be the case. Whether causal or not, the relationship between the observations is the same in each row.

Example table:

HB	NB1	NB2	NB3
1	1	1	1
1	1	1	1
1	1	1	1
0	0	0	0
1	1	1	1
1	1	1	1
1	1	1	1
0	0	0	0
?	1	1	1

Your task

Your task is to assess whether behind the question mark (?) there is a 0 or a 1 hidden. During the task you see the data table. In addition to this, you see a short explanation from a sender, which points out a possible relation in the data. This explanation can help you assess whether behind the question mark (?) there is a 0 or a 1 hidden.

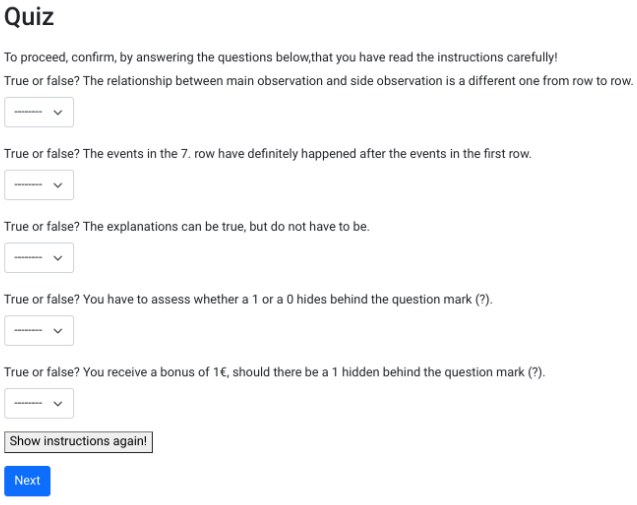
Explanations

This explanation can help you assess whether behind the question mark (?) there is a 0 or a 1 hidden. The explanations formulate a possible relation between main and side observations. This can be the true relationship; but it is not necessarily so. For instance, it could be due to chance that the main observation and the side observation are 1 at the same time. But it could also be that one of the observations is equal to 1 because another observation is equal to 1. For each dataset you see a single explanation.

For each dataset, you see a single explanation.

Next

Instructions



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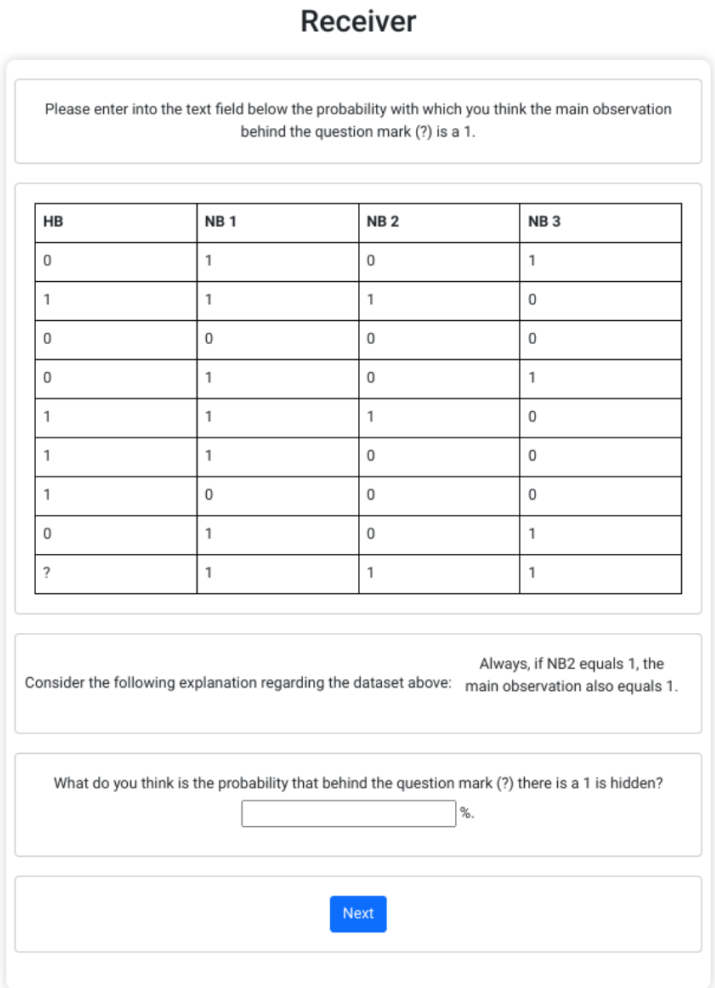


Receiver

Please enter into the text field below the probability with which you think the main observation behind the question mark (?) is a 1.

HB	NB 1	NB 2	NB 3
0	1	0	1
1	1	1	0
0	0	0	0
0	1	0	1
1	1	1	0
1	1	0	0
1	0	0	0
0	1	0	1
?	1	1	1

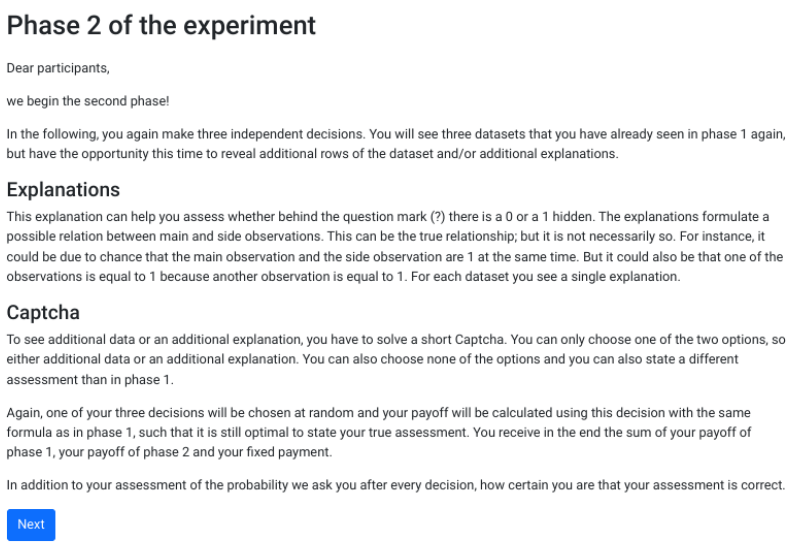
Consider the following explanation regarding the dataset above: Always, if NB2 equals 1, the main observation also equals 1.

What do you think is the probability that behind the question mark (?) there is a 1 is hidden?

%.

Next

Instructions



Phase 2 of the experiment

Dear participants,

we begin the second phase!

In the following, you again make three independent decisions. You will see three datasets that you have already seen in phase 1 again, but have the opportunity this time to reveal additional rows of the dataset and/or additional explanations.

Explanations

This explanation can help you assess whether behind the question mark (?) there is a 0 or a 1 hidden. The explanations formulate a possible relation between main and side observations. This can be the true relationship; but it is not necessarily so. For instance, it could be due to chance that the main observation and the side observation are 1 at the same time. But it could also be that one of the observations is equal to 1 because another observation is equal to 1. For each dataset you see a single explanation.

Captcha

To see additional data or an additional explanation, you have to solve a short Captcha. You can only choose one of the two options, so either additional data or an additional explanation. You can also choose none of the options and you can also state a different assessment than in phase 1.

Again, one of your three decisions will be chosen at random and your payoff will be calculated using this decision with the same formula as in phase 1, such that it is still optimal to state your true assessment. You receive in the end the sum of your payoff of phase 1, your payoff of phase 2 and your fixed payment.

In addition to your assessment of the probability we ask you after every decision, how certain you are that your assessment is correct.

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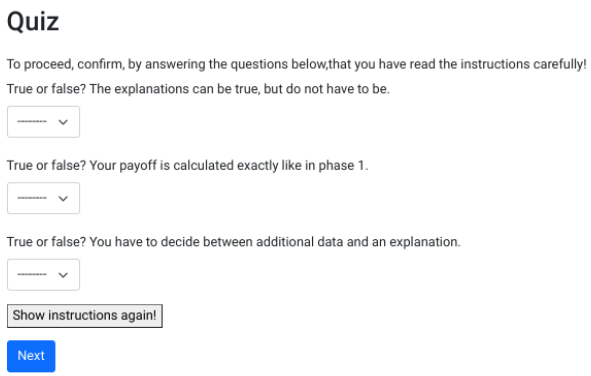
Instructions



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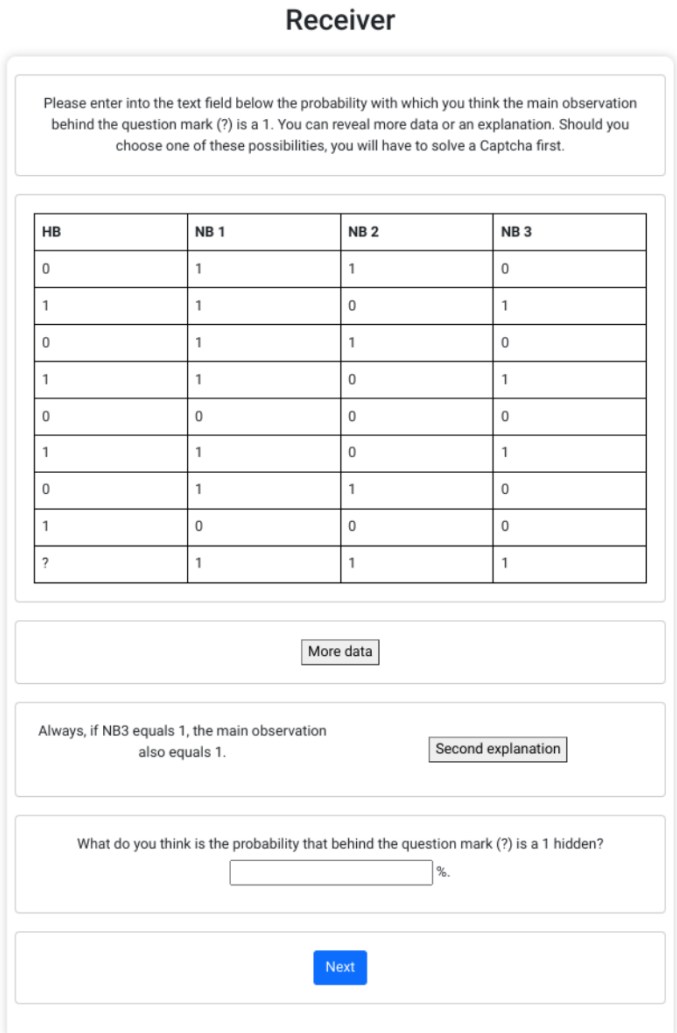


Receiver

Please enter into the text field below the probability with which you think the main observation behind the question mark (?) is a 1. You can reveal more data or an explanation. Should you choose one of these possibilities, you will have to solve a Captcha first.

HB	NB 1	NB 2	NB 3
0	1	1	0
1	1	0	1
0	1	1	0
1	1	0	1
0	0	0	0
1	1	0	1
0	1	1	0
1	0	0	0
?	1	1	1

More data

Always, if NB3 equals 1, the main observation also equals 1.

Second explanation

What do you think is the probability that behind the question mark (?) is a 1 hidden?

%.

Next

Instructions

Receiver

Please enter into the text field below the probability with which you think the main observation behind the question mark (?) is a 1. You can reveal more data or an explanation. Should you choose one of these possibilities, you will have to solve a Captcha first.

HB	NB 1	NB 2	NB 3
0	1	1	0
1	1	0	1
0	1	1	0
1	1	0	1
0	0	0	0
1	1	0	1
0	1	1	0
1	0	0	0
?	1	1	1

More data

CAPTCHA: Please enter these letters in reverse order!

OGFQQ

Check answer

Always, if NB3 equals 1, the main observation also equals 1.

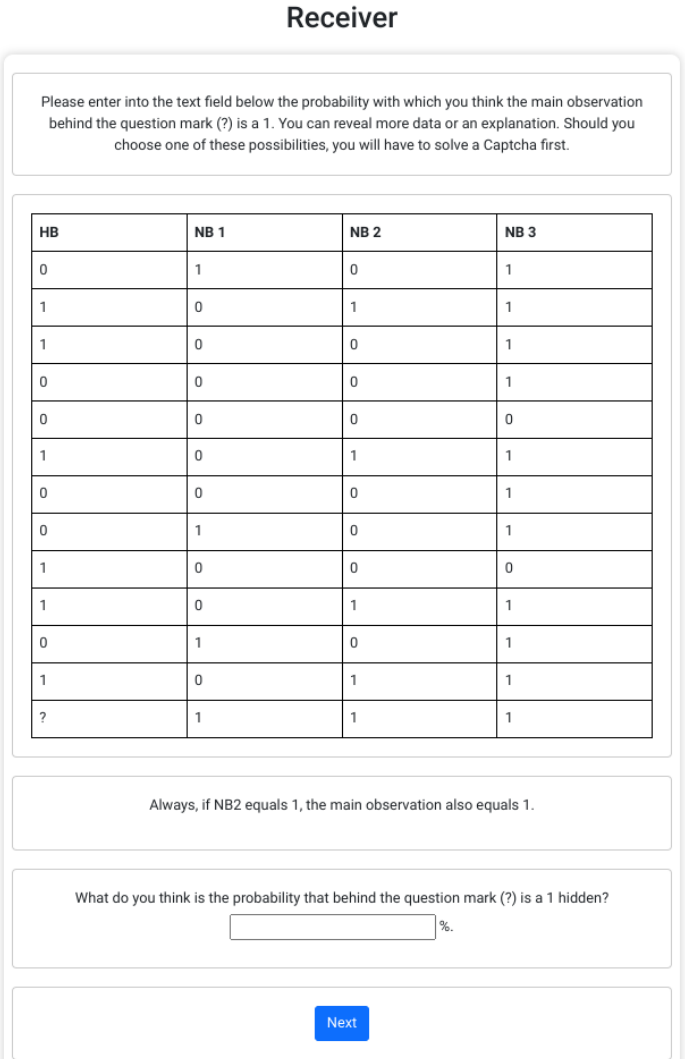
Second explanation

What do you think is the probability that behind the question mark (?) is a 1 hidden?

%.

Next

Instructions



Receiver

Please enter into the text field below the probability with which you think the main observation behind the question mark (?) is a 1. You can reveal more data or an explanation. Should you choose one of these possibilities, you will have to solve a Captcha first.

HB	NB 1	NB 2	NB 3
0	1	0	1
1	0	1	1
1	0	0	1
0	0	0	1
0	0	0	0
1	0	1	1
0	0	0	1
0	1	0	1
1	0	0	0
1	0	1	1
0	1	0	1
1	0	1	1
?	1	1	1

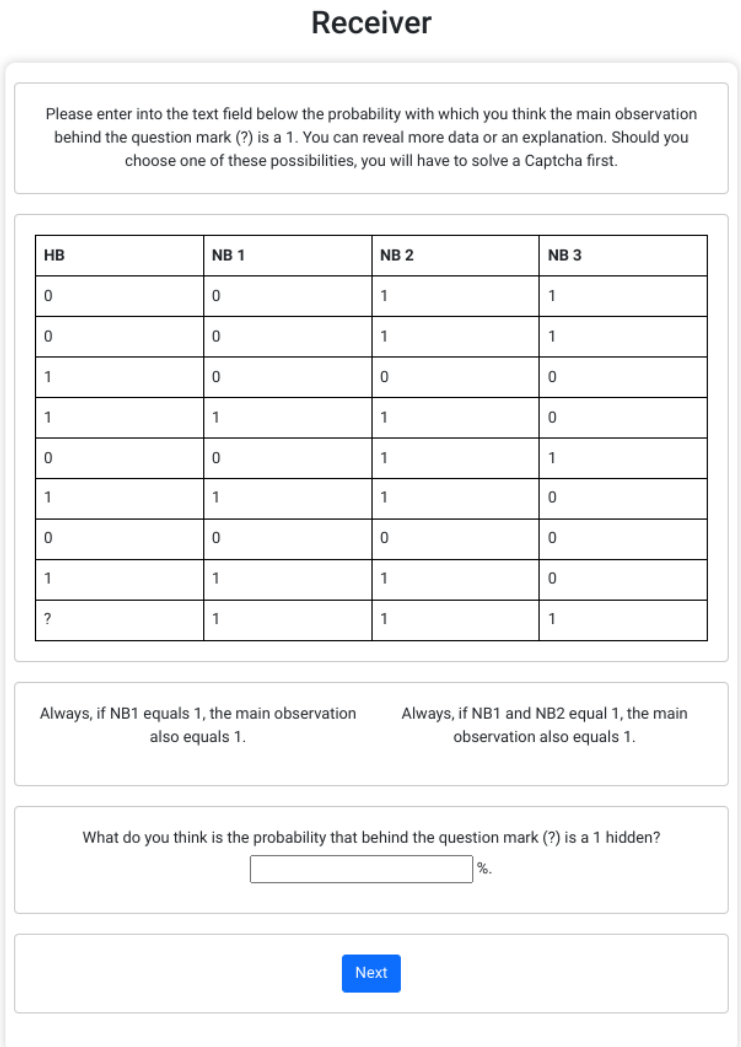
Always, if NB2 equals 1, the main observation also equals 1.

What do you think is the probability that behind the question mark (?) is a 1 hidden?

%.

Next

Instructions



Receiver

Please enter into the text field below the probability with which you think the main observation behind the question mark (?) is a 1. You can reveal more data or an explanation. Should you choose one of these possibilities, you will have to solve a Captcha first.

HB	NB 1	NB 2	NB 3
0	0	1	1
0	0	1	1
1	0	0	0
1	1	1	0
0	0	1	1
1	1	1	0
0	0	0	0
1	1	1	0
?	1	1	1

Always, if NB1 equals 1, the main observation also equals 1.

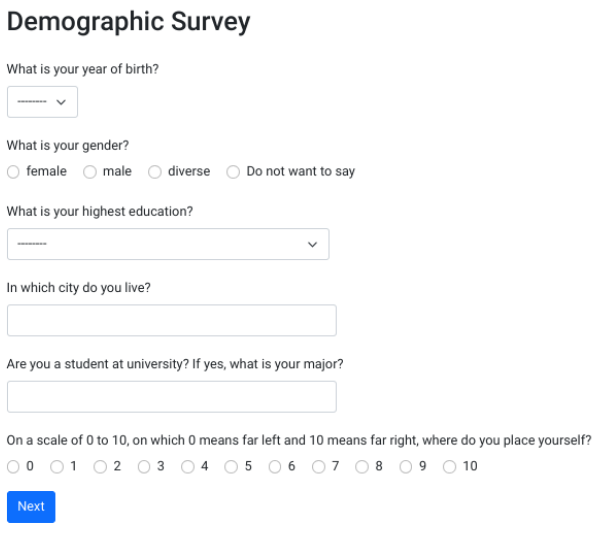
Always, if NB1 and NB2 equal 1, the main observation also equals 1.

What do you think is the probability that behind the question mark (?) is a 1 hidden?

%.

Next

Instructions



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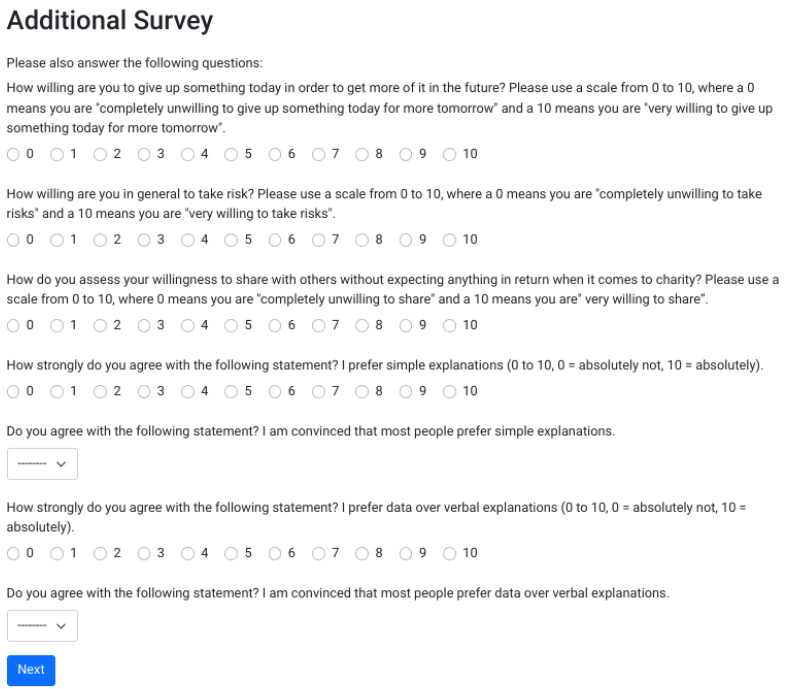

Additional Survey

Please also answer the following questions:

How willing are you to give up something today in order to get more of it in the future? Please use a scale from 0 to 10, where a 0 means you are "completely unwilling to give up something today for more tomorrow" and a 10 means you are "very willing to give up something today for more tomorrow".

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

How willing are you in general to take risk? Please use a scale from 0 to 10, where a 0 means you are "completely unwilling to take risks" and a 10 means you are "very willing to take risks".

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

How do you assess your willingness to share with others without expecting anything in return when it comes to charity? Please use a scale from 0 to 10, where 0 means you are "completely unwilling to share" and a 10 means you are" very willing to share".

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

How strongly do you agree with the following statement? I prefer simple explanations (0 to 10, 0 = absolutely not, 10 = absolutely).

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Do you agree with the following statement? I am convinced that most people prefer simple explanations.

How strongly do you agree with the following statement? I prefer data over verbal explanations (0 to 10, 0 = absolutely not, 10 = absolutely).

○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10

Do you agree with the following statement? I am convinced that most people prefer data over verbal explanations.

Next

Payoffs

- Fixed payoff:
  - €1.50 if RecNoBonus
  - €1 if RecBonus
- One round of the six rounds from the main task is payoff-relevant
  - Coin toss decides whether a 0 or a 1 is behind question mark.
  - Subject's assessment of the probability that there is a 1 hidden. q
    - Coin toss is a 1: Payoff = €3 with a probability of $1-(1-q)^2$, 0 with the complementary probability
    - Coin toss is a 0: €3 with a probability of $1-q^2$, 0 with the complementary probability

Payoffs

- Updating: One round is payoff-relevant
  - Coin toss decides whether a 0 or a 1 is behind question mark.
  - Subject's assessment of the probability that there is a 1 hidden. q
    - Coin toss is a 1: Payoff $=$ €3 with a probability of $1-(1-q)^2$, 0 with the complementary probability
    - Coin toss is a 0: €3 with a probability of $1-q^2$, 0 with the complementary probability
- Bonus: Payoff of 1 for a coin toss resulting in a 1.

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Results

Deterministic vs. Stochastic