Pinocchio’s Pupil: Using eyetracking and Pupil Dilation to Understand Truth Telling and Deception

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Introduction

“Why do almost all people tell the truth in ordinary everyday life?—Certainly not because a god has forbidden them to lie. The reason is, firstly because it is easier; for lying demands invention, dissimulation, and a good memory.”

-Friedrich Nietzsche, Human, All Too Human, II.54, 1878/1996

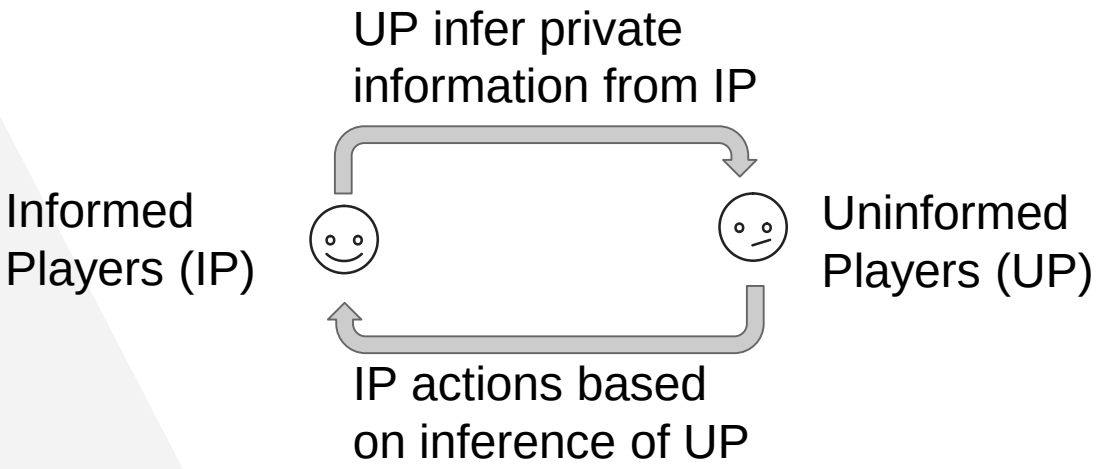
So why do people lie/exaggerate?

- In shares, managers lie to inflate earning prospects
- In universities, grade inflation and well polished recommendation letters help schools to promote their graduates
- Doctor patient relationship in healthcare choices

Aims & Objectives

Aim of the Experiment

- Explore experiments on sender-receiver games with divergent preferences in which one agent has an incentive to exaggerate the truth to another agent



Aim of the Experiment

- Overcommunication and systematic deception can be explained by level-k model
- To investigate the cause behind the behavior patterns in such games

Definitions

Overcommunication: **Messages sent out are more informative of the true state than they should be in equilibrium**

Divergent preferences: **when the players have different preferences thus having incentives to tweak the truth**

Hypothesis:

Senders tend to exaggerate when their preference differ from the receivers so as to maximise their incentives.

Experiment Design

Sender-Receiver Games: Experiment Design

- 2 Players: Sender and Receiver
- True state $S=\{1,2,3,4,5\}$
- Sender sends a costless message M to receiver
- Receiver then choose an action $A=\{1,2,3,4,5\}$

Sender-Receiver Games: Experiment Design

- Payoffs depend on *S* and *A*, so message *M* is “cheap talk”
- Receiver prefers to choose *A*=*S*
- Sender wants receiver to choose *A*=*S* + *b* where *b* is a known bias parameter
- Value of *b* is varied across rounds, *b*={0,1,2} with known probabilities

Sender-Receiver Games: Experiment Design

- Payoffs for receiver: $U_R = 110 - 20|S - A|^{1.4}$
- Payoffs for sender: $U_s = 110 - 20|S + b - A|^{1.4}$
- Receiver earns the highest payoff if action matches the true state
- Sender earns the highest payoff if action of receiver is equal to $S + b$

Sender-Receiver Games: Experiment Design

- When $b=0$, senders prefer receiver to choose S and announces $M=S$, receivers believe them and chooses $A=M$
- When $b>0$, senders prefer to exaggerate and announce $M>S$ if they thought receivers would believe them

Sender-Receiver Games: Experiment Design

- Sender’s eye movements and pupil dilation are measured with an eyetracker
- Video-eyetracking is used to measure what payoffs or game parameters sender subjects are looking at
- ‘Dilation’ is used to infer deceptive behaviour because senders find deception stressful or cognitively difficult

Sender-Receiver Games: Experiment Design

- If deceptive behaviour is observed, we want to find out if it translates to the actions sent out
- Also, if guilt plays a role in the overcommunication

Level-*k* model

- *L0* senders (with lowest level of sophistication) tells the truth, *L0* receivers best response to *L0* senders by following the message
- *L1* senders best respond to *L0* receivers by inflating the message (stating their preferred states)
- *L1* receivers best respond to *L1* senders by discounting the message

Measures

- Informativeness of senders' messages by the correlation between the true states *S* and the messages *M*
- How trusting the receivers are of the senders by the correlation between messages *M* and actions they take, *A*

The Experiment

- Subjects: 60 Caltech Students
- 6 sessions of 6 subjects randomly paired in the ‘hidden bias-stranger’ with different receivers in each round
- Other 12 pairs were run in the ‘display bias-partner’
- Same game is played 45 times among the pair with random choices of bias *b* in each round

Results

a.Comparative Statics and Behavior

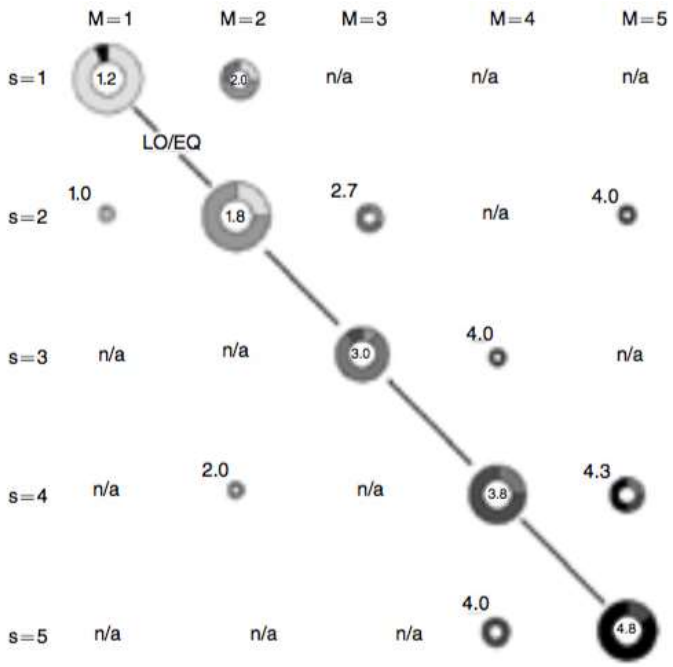


FIGURE 1. RAW DATA PIE CHARTS ($b = 0$)
(HIDDEN BIAS–STRANGER)

- Area of pie chart in each cell is scaled by the number of occurrences for the corresponding state and message
- Rows: senders' behavior w.r.t different states
- Columns: informativeness of each message
- Diagonal lines: predicted messages for various level-*k* types

a.Comparative Statics and Behavior

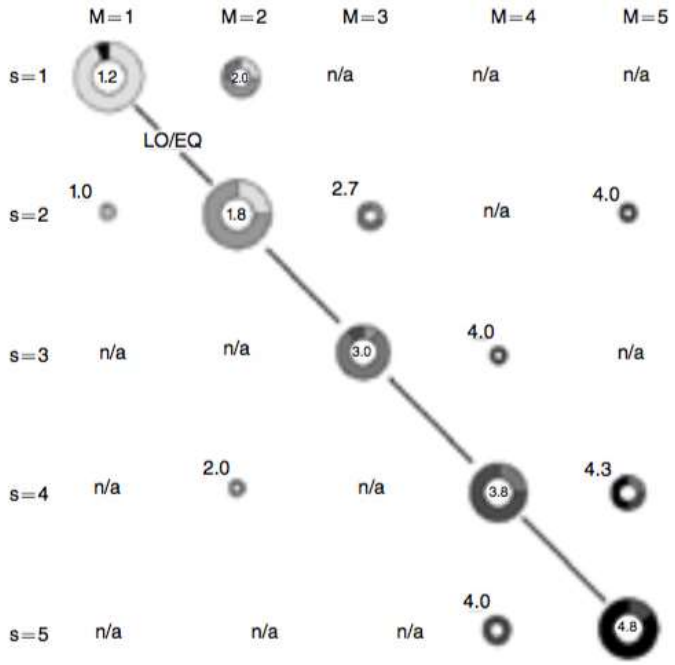


FIGURE 1. RAW DATA PIE CHARTS ($b = 0$)
(HIDDEN BIAS–STRANGER)

- Average receiver action is the number inside the pie
- When *b*=0, no conflict of interest, large pie charts are concentrated on diagonal line (*L0/EQ* sender behavior)
- Corresponds to truth-telling equilibrium predicted by equilibrium theory and *L0* type in level-*k* model

a.Comparative Statics and Behavior

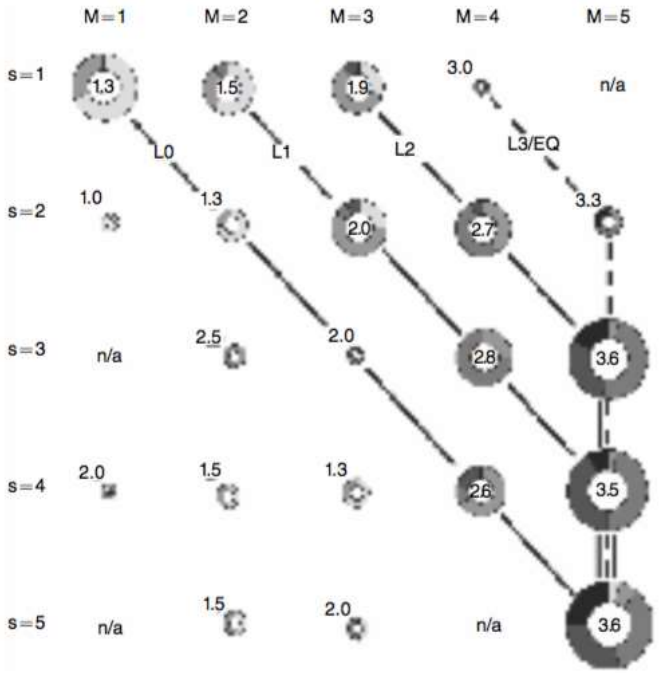


FIGURE 2. RAW DATA PIE CHART ($b = 1$)
(HIDDEN BIAS–STRANGER)

- Large tendency for deception
- Lopsided - most common messages are the state itself or higher messages
- Consistent with *L1* and *L2* sender behaviors
- Some information is transmitted

a.Comparative Statics and Behavior

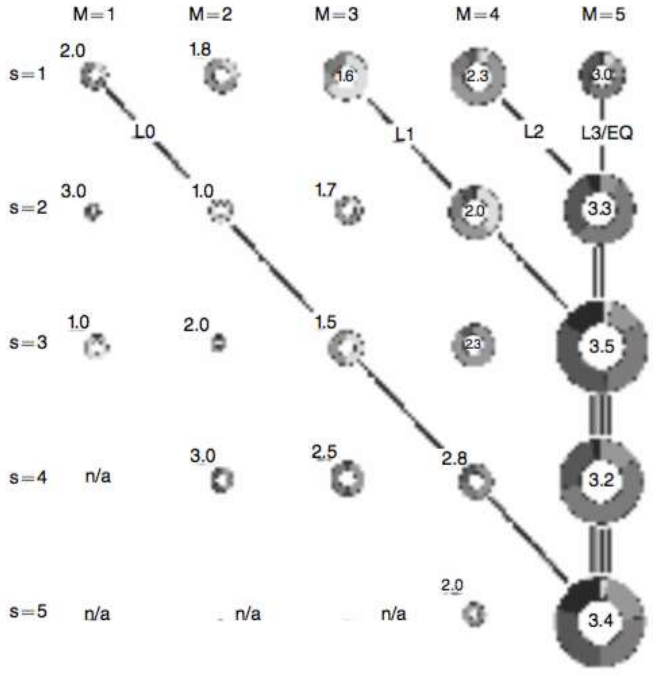


FIGURE 3. RAW DATA PIE CHART ($b = 2$)
(HIDDEN BIAS–STRANGER)

- Equilibrium theory predicts a babbling equilibrium
- However, substantial information is transmitted due to non-uniform distribution of state frequencies
- Consistent with level-*k* model where *L1, L2, EQ* senders send *M*=5 for *S*={3,4,5}

a.Comparative Statics and Behavior

TABLE 2—INFORMATION TRANSMISSION: CORRELATIONS BETWEEN STATES S, MESSAGES M, AND ACTIONS A

Bias	Eyetracked	$r(S,M)$		$r(M,A)$		$r(S,A)$		Predicted $r(S,A)$
0	Yes	0.92	0.93	0.90	0.92	0.86	0.86	1.00
	No	0.94		0.94		0.88		
1	Yes	0.68	0.64	0.73	0.71	0.53	0.49	0.65
	No	0.51		0.61		0.35		
2	Yes	0.41	0.34	0.52	0.58	0.34	0.32	0.00
	No	0.23		0.63		0.28		

- When bias *b* is large, information transmission is higher and payoffs are higher for senders than predicted by equilibrium theory
- Overcommunication exists

b. Lookup Patterns

i. Attention to structure:

Expect senders to pay attention to important parameters (state and bias) of the sender-receiver game

b. Lookup Patterns

TABLE 5—AVERAGE SENDER LOOKUP TIMES (IN SECONDS) ACROSS GAME PARAMETERS

Bias b	Response time		State	Sender payoffs	Receiver payoffs	Sender-to-receiver ratio
	Periods 1–15	Periods 31–45				
0	9.78	7.24	0.83	2.93	1.71	1.72
1	11.77	8.76	0.81	3.80	2.66	1.43
2	16.84	8.99	0.91	4.67	3.26	1.43
all	13.47	8.52	0.86	3.99	2.72	1.47

i. Attention to structure:

Results:

- Senders are thinking carefully about the game
- Senders look at their own payoffs longer
- High receiver-lookup group is more deceptive than the low group, inconsistent with guilt hypothesis

b. Lookup Patterns

ii. Truth Bias:

- Level-*k* model assumes subjects best respond to perceived beliefs about their opponents' behaviors
- Sender subjects focus too much on the true state payoff row
- Demonstrates curse of knowledge

b. Lookup Patterns

TABLE 6—AVERAGE LOOKUP TIME PER ROW DEPENDING ON THE STATE

Bias b	True state rows	Other state rows	True-to-other ratio
0	2.76	0.47	5.89
1	3.88	0.64	6.02
2	4.29	0.91	4.70
overall	3.83	0.72	5.33

ii. Truth Bias:

- Subjects look longer at payoffs in rows corresponding to the true state than payoffs in rows corresponding to other states
- Subjects don’t think in others’ shoes and cannot fully think like a receiver

b. Lookup Patterns

iii. Individual Level-K Type Lookup Patterns

Sender subjects focus on the payoffs corresponding to the action A = S (L0 reasoning), A = S + b (L1 reasoning),..., up to the corresponding level-k reasoning for each individual subject based on his or her level-k type.

b. Lookup Patterns

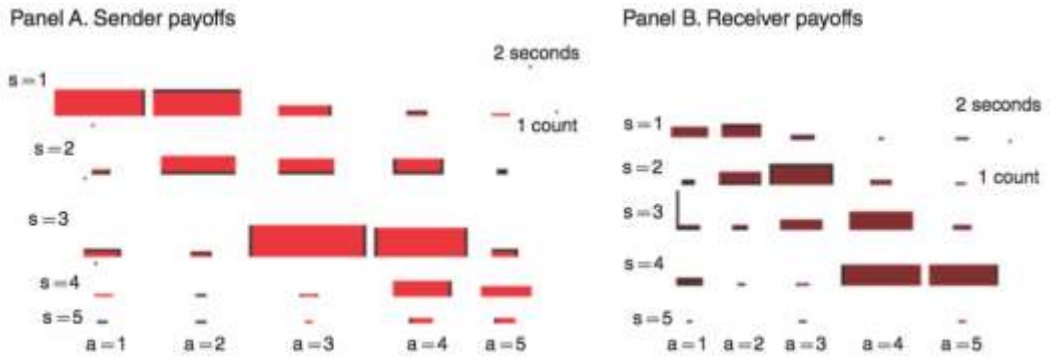


FIGURE 4: LOOKUP ICON GRAPH FOR $b = 1$, HIDDEN BIAS–STRANGER, TYPE = $L1$

iii. Individual Level-K Type Lookup Patterns

- Strong bias for senders to look more at payoffs from the true state
- Similar patterns arise for different bias and types when subjects looking at payoffs corresponding to what level-*k* model predicts

c. Pupil Dilation

- Results show that deception is reliably correlated with pupil dilation
- Shown by calculating average pupil size before and after the sender's message decision

$$PUPIL_i = \alpha + \sum_{b=0}^{\hat{} \beta_{1b} LIE\_SIZE \times BIAS_b + \sum_{b \neq 2} \beta_{2b} \times BIAS_b + \sum_{s \neq 3} \beta_{3s} STATE_s$$

$$+ \sum_{k=1}^{K} (\gamma_{k,1} ROUND \times SUBJ_k + \gamma_{k,2} ROUND^2 \times SUBJ_k) + \varepsilon$$

c. Pupil Dilation

TABLE 8—PUPIL SIZE REGRESSIONS FOR 400 MSEC INTERVALS

Y	$PUPIL_i$	−1.2~ −0.8 sec	−0.8~ −0.4 sec	−0.4~ 0.0 sec	0.0~ 0.4 sec	0.4~ 0.8 sec
constant	α	107.27	108.03	106.19	109.56	108.67
		(2.81)	(2.55)	(2.57)	(2.05)	(2.16)
$LIE\_SIZE \times BIAS_b$ interactions	β_{10}	2.83	2.36	3.07	5.35***	5.57**
		(1.85)	(2.23)	(2.46)	(1.76)	(2.19)
	β_{11}	−1.02	−0.46	−0.36	2.16*	2.64**
		(1.26)	(1.31)	(1.28)	(1.21)	(1.15)
	β_{12}	2.06**	1.52*	1.47**	1.83**	2.00***
		(0.86)	(0.79)	(0.75)	(0.75)	(0.74)
	N	414	415	414	415	414
	χ^2	323.86	235.43	194.40	258.49	352.49
	R^2	0.291	0.299	0.263	0.365	0.438

- After decision is made (0s -0.8s later), β_{1b} coefficients are significantly higher at about 2% for all biases
- Sending less accurate messages is correlated with pupil dilation

c. Pupil Dilation

- Note: Bias condition itself does not generate pupil dilation (i.e. nearly all coefficients β_{2s} are insignificant and are omitted)

d. Results of the Display Bias-Partner Design

- Display bias-partner condition brings about more overcommunication compared to the hidden bias-stranger condition
- The pupil dilation results are stronger than in the hidden bias–stranger design

e. Lie-Detection and Prediction

- Asked receivers to predict the true state using only messages and lookup patterns

$$\log[\Pr(STATE \geq j)] = \theta_j + \sum_{b=1,2} (\beta_{1b} MESSAGE + \beta_{2b} ROW_{self} + \beta_{3b} ROW_{other}) BIAS_b + \varepsilon$$

- β_{1b} : information about *S* contained in *M*
- β_{2b} : effects of the “most viewed row” of one’s own payoffs
- β_{3b} : effects of the “most viewed row” of opponent’s payoffs

e. Lie-Detection and Prediction

TABLE 9—PREDICTING TRUE STATES (*Resampling 100 times*) (*SE in parentheses*)

X		Hidden bias–stranger	
MESSAGE × BIAS = 1	β_{11}	0.46[c]	(0.12)
MESSAGE × BIAS = 2	β_{12}	0.42[†]	(0.09)
ROW_{self} × BIAS = 1	β_{21}	1.07[†]	(0.24)
ROW_{self} × BIAS = 2	β_{22}	1.72[†]	(0.20)
ROW_{other} × BIAS = 1	β_{31}	1.27[†]	(0.22)
ROW_{other} × BIAS = 2	β_{32}	0.44[†]	(0.15)
total observations N[a]		357	
N used in estimation		238.3	
N used to predict		118.7	
		Actual data	Holdout sample
Percent of wrong prediction ($b = 1$)		58.5	28.9
Percent of errors of size (1, 2, 3+) ($b = 1$)		(61, 28, 11)	(79, 19, 2)
Average predicted payoff ($b = 1$)[b]		87.5 (28.8)	101.7[†] (2.1)
Percent of wrong prediction ($b = 2$)		77.9	37.9
Percent of errors of size (1, 2, 3+) ($b = 2$)		(60, 30, 10)	(72, 24, 4)
Average predicted payoff ($b = 2$)[b]		80.9 (26.9)	98.0[c] (2.2)

- β_{1b} significance indicates that messages are informative about states, smaller message indicates a smaller true state
- Lookup data is significantly correlated with states, improving predictability even when controlling for the message

e. Lie-Detection and Prediction

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- Model accuracy is better than the actual performance of the receiver subjects in the experiment
- We can almost erase the cost to receivers for not knowing the true state just by looking at attention along with messages

Conclusion

Main takeaway: *experiment shows “overcommunication”, where messages are more informative of the state than they should be, in* ***equilibrium****.*

Reiteration of key findings

- Senders do not appear to be thinking strategically enough
- Senders’ pupils also dilate when they send deceptive messages ($M \neq S$) and dilate more when the deception $|M - S|$ is larger in magnitude.

Reiteration of key findings

- Combining sender messages and look up patterns can help to predict the true state, which will increase receiver’s payoff

Thank you

Q&A