Cognitive Uncertainty, GPT, and Contribution in Public Goods Game

Te Bao and Jiaoying Pei

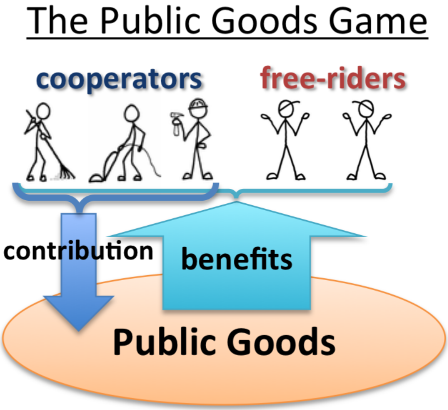
Nanyang Technological University

The Big Question for Behavioral Games

"Selfish or Not Selfish?" That is the question!

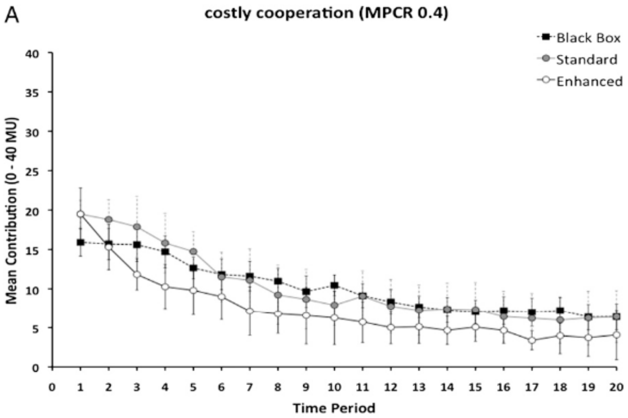
The Public Good Game

In economics, public good game is usually used to study human cooperation. Participants are usually faced with an opportunity to invest in a public good that generates a greater than 1 social return rate, and a less than 1 private return.



Burton-Chellew and West (2013), PNAS

Non-zero Contribution in PGG.
Prosocial Preference or Confusion?



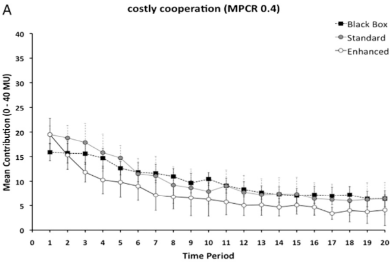
Burton-Chellew and West (2013), PNAS

Table 1. Comparison of the different information contents in the postdecision feedback of the three treatments

Treatment	Own decision	Knowledge of playing with others	Decisions of others (within-group)	Earnings of others (within-group)	Own earnings
Black box	Yes	No	No	No	Yes
Standard information*	Yes	Yes	Yes	No	Yes
Enhanced information	Yes	Yes	Yes	Yes	Yes

- Standard without-punishment public goods game, M=1.6, N=4
- Black box: do not know they are playing with others; their payoff is determined by a mathematical function on their input. No inequality aversion.
- Enhanced information: detailed breakdown of all group members' payoff; better able to see that cooperation is costly to themselves but beneficial to others.

Burton-Chellew and West (2013), PNAS



- Prosocial Preference cannot explain the non-zero contribution.
  - The level cooperation does not differ between a standard public-goods game vs. black-box treatment (i.e., where players did not even know their choices affected others).
  - Providing players with enhanced information about the earnings of their group members lead to lower levels of cooperation.
  - When MPCR $= 1.6$ (so that it is profitable to cooperate), contribution from Enhanced information $<$ Standard public goods game.

Burton-Chellew and West (2013), PNAS: New Hypothesis

- Initial 50%-endowment
  - Individuals are trying to maximise their financial gain (i.e., selfish)
  - Behaviour is imperfect b/c "uncertainty or false beliefs, or subject to some sort of noise, which could result from a variety of factors, including errors, boredom, learning, exploration, fluctuating preferences, or evolutionary constraints".
  - **But they did not have a measure of uncertainty/confusion to show the positive relationship between uncertainty/confusion and contribution!**

Andreoni (1995), AER

- Cooperative preference play a very important role in contribution behaivor
  - Using an experiment, they **separated** the subjects whose contribution in the public goods game is due to kindness from those who contribute out of errors or confusions.
  - They find that half of the cooperation comes from subjects who understand free-riding but still choose to cooperate.
  - Evidence show that the declining contribution over time is due to frustrated attempts at kindness instead of learning.

Enke and Greaber (2023), QJE: Cognitive Uncertainty

- Cognitive uncertainty
  - Definition: people's subjective uncertainty over which decisions maximizes their expected utility.
  - Represents an easily-measurable proxy for the unobserved noisiness or heuristics nature of people's decision modes, and can thus be used to predict and explain behavior.

Task 1 of 12

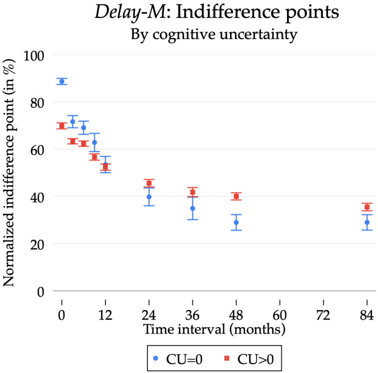
Your choices on the previous screen indicate that you value $50 **in 2 months** somewhere between $26 and $28 **today**.

How certain are you that you actually value $50 **in 2 months** somewhere between $26 and $28 **today**?

○ 0% ○ 5% ○ 10% ○ 15% ○ 20% ○ 25% ○ 30% ○ 35% ○ 40% ○ 45% ○ 50% ○ 55% ○ 60% ○ 65% ○ 70% ○ 75% ○ 80% ○ 85% ○ 90% ○ 95% ○ 100%

very uncertain **completely certain**

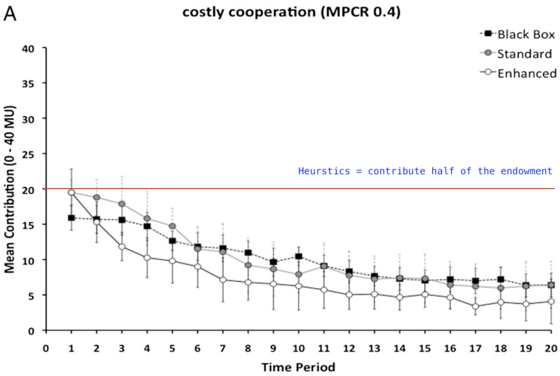
Cognitive Uncertainty (CU) in Intertemporal Choice



- Subjects are using simpler-than-optimal procedures
  - Heuristics, noisy introspection about one's discount factor, cognitive noise models in which decision makers combine imprecise mental representations with a prior.
- Decision makers act as if they treat different time intervals alike to some degree.
  - Explain anomalies e.g., short-term discounting, structural estimates of present bias, hyperbolicity

Hypothesis

- In a public goods game, cognitive uncertainty could reflect
  - Uncertainty over one's true social preference, or
  - Difficulty over translating true social preference into contribution actions that maximise their utility, conditional on knowing their true preference



$$Contribution = \lambda(noise^{-1}) \times truesocialpreference + (1 - \lambda(noise^{-1})) \times heuristics$$

Testable Hypothesis: Cognitive Uncertainty and Contribution

- *H1: Cognitive uncertainty decreases over time. As the game repeats, participants become more certain about their contribution decisions.*
- *H2: Higher measured cognitive uncertainty is associated with decisions closer to a 50% contribution of the endowment. This implies that as the game repeats, the absolute difference between the actual contribution and the 50% contribution of the endowment becomes larger.*
- *H3: Cognitive noise is positively correlated with contribution. In other words, cognitive uncertainty leads individuals to behave as if they are more cooperative.*

How are we doing differently in finding the explanation of contribution behavior in PGG?

- Instead of categorizing contribution behavior into pure kindness or pure confusion, this study accepts the premise that subjects can be confused and possess a cooperative preference at the same time.
- We capture / quantify the confusion using the concept of cognitive uncertainty:
  - Each contribution decision is a weighted function of CU and cooperative preference

Testable Hypothesis: Impact from GPT's Cooperative advice on CU and Contribution

Recent research shows that GPT outperforms humans in rationality in decision-making tasks concerning risk, time, social, and food (Chen et al., 2023).

GPT-3.5 makes cooperative advice (65% contribution decision out of 20 endowment):

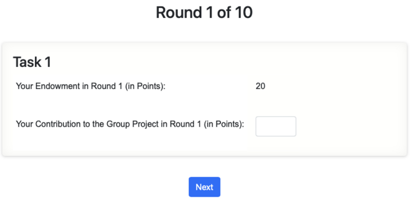
Table D.1 Summary Statistics on GPT's Contribution Decision

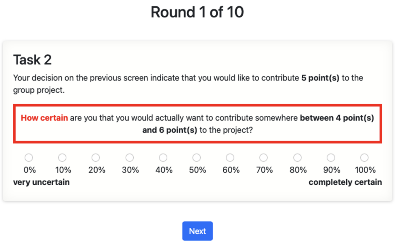
	N	Mean	SD	Min	Max
All sample	150	12.64	4.32	0	20
Temperature = 0	50	11.26	4.55	0	20
Temperature = 0.5	50	13.72	4.38	8	20
Temperature = 1	50	12.94	3.69	8	20

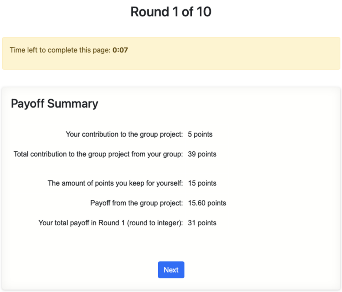
- *H4: Participants' cognitive uncertainty changes when they receive a cooperative recommendation, and their decision also leans towards the cooperative recommendation. Furthermore, participants may trust and adopt recommendations to different extents depending on whether or not they are informed that it comes from GPT.*

Experimental Design and Procedure: Treatment Baseline

- All groups; First game (Round 1-10)
- Without-punishment PGG: M = 1.6; N = 4; no reciprocity (reshuffle group composition) and minimise inequality aversion (10 sec. to view own payoff)
- Elicitation CU after each decision







Experimental Design and Procedure: Group and Treatment

Table B.2: List of Treatment Condition

Group, abbrev.	Description	Treatment: All Rounds	Treatment: First Game Round 1-10	Treatment: Restart Round 11-20	Sample
Baseline (SPCU_B)	Subjects are placed into groups of four and play for 20 rounds, with a restart prior to Rounds 11.	Baseline	Baseline	Baseline	44
GPT (SPCU_G)	Same as Baseline, except that participants are prompted with a recommendation from GPT-3.5 of contributing 65% of the endowment after the end of the restart game.	Mixed	Baseline	GPT	48
Adviser (SPCU_A)	Same as GPT, except that participants are not told the recommendation is made by GPT-3.5, and only know that the recommendation is from an anonymous adviser.	Mixed	Baseline	Adviser	48

Experimental Design and Procedure: Group Adviser and Group GPT

Restart game: Group Adviser

The second part of the experiment consists of 10 rounds of games. The instructions for this part are exactly the same as the ones for the 10 rounds in the previous part. You can revise it in the "Recap of Instruction in Part I" Section.

Recommendation by the Adviser

The only difference is that, prior to the beginning of this part, we provide you with the contribution decisions made by the adviser.

The adviser was given the same instructions as you in the last part of the experiment and was instructed to make the decisions.

The contribution level chosen by the adviser is usually around 13 out of 20 points of the endowment.

Recap of Instruction in Part I

Restart game: Group GPT

The second part of the experiment consists of 10 rounds of games. The instructions for this part are exactly the same as the ones for the 10 rounds in the previous part. You can revise it in the "Recap of Instruction in Part I" Section.

Recommendation by GPT-3.5

The only difference is that, prior to the beginning of this part, we provide you with the contribution decisions made by Generative Pre-trained Transformer 3.5 (GPT-3.5).

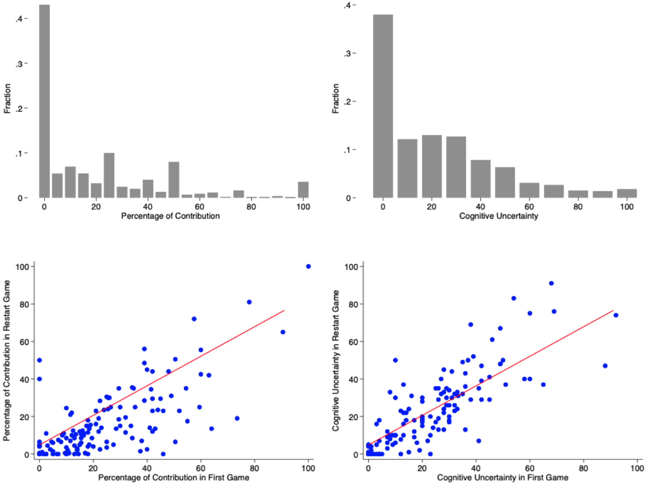
GPT-3.5 is a subclass of GPT-3 Models created by OpenAI that implements AI and focuses on natural language understanding and generation. You can read about it on Wikipedia here.

GPT-3.5 was given the same instructions as you in the last part of the experiment and was instructed to make the decisions.

The contribution level chosen by GPT-3.5 is usually around 13 out of 20 points of the endowment.

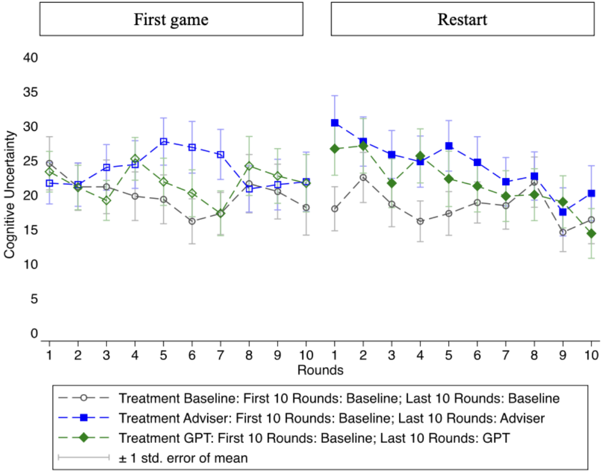
Recap of Instruction in Part I

Summary Statistics



- Average contribution: 19.43% of the endowment; 43% of zero contribution; 37.95% perfectly certain decisions.
- Subject FE effect: High within-domain stability in contribution ($\rho = 0.7247$) and CU ($\rho = 0.8312$).

Result 1: Decreasing Cognitive Uncertainty Only After Prompted With Cooperative Advice?



- Limited learning **over time**.
- Will discuss later: Jumps in CU is not statistically significant at 5% (P25).

Result 1: Decreasing Cognitive Uncertainty Only After Prompted With Cooperative Advice?

Table 1: Variation of Cognitive Uncertainty with respect to Rounds

	Dependent Variable: Cognitive Uncertainty							
Treatment	Pooled			Baseline			Adviser	GPT
Game	All	First	Restart	All	First	Restart	Restart	Restart
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Round	-0.15	-0.20	-0.86***	-0.16	-0.20	-0.27	-1.10***	-1.21***
	(0.10)	(0.25)	(0.21)	(0.16)	(0.25)	(0.40)	(0.36)	(0.36)
Average Lagged group members' % contribution	0.00	-0.04	0.03	-0.02	-0.04	0.03	0.06	-0.02
	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.07)	(0.08)	(0.07)
Observations	2,656	1,259	1,397	1,698	1,259	439	478	480
R-squared	0.60	0.63	0.67	0.59	0.63	0.59	0.66	0.73

Notes. Subject level fixed effect OLS estimates, with robust standard errors (in parentheses) are clustered at the subject level. Column (1)-(3) pooled all data in all groups and treatment but separate them by the game. Column (4)-(6) include all the data in Treatment Baseline. Specifically, Column (5) include data from all treatment in the First game, while Column (6) only include data from Group Baseline in the Restart Game. Column (7)-(8) restrict attention to the decisions in the Restart Game of Group Adviser and Group GPT, respectively. *** p<0.01, ** p<0.05, * p<0.1.

Result 1: Decreasing Cognitive Uncertainty Only After Prompted With Cooperative Advice, and an Absence of GPT Premium

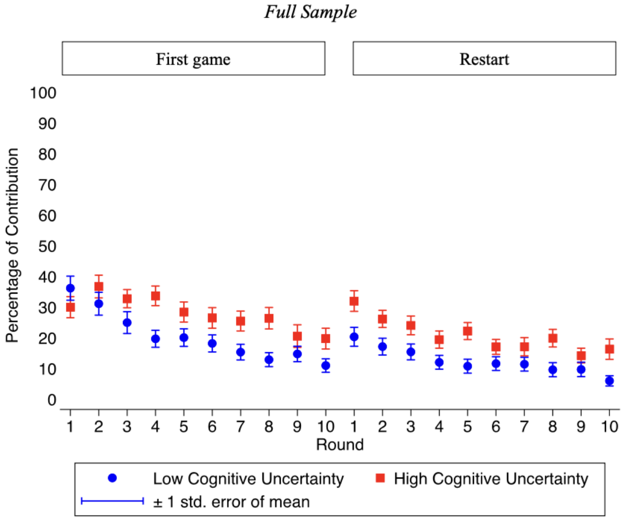
Table B.3: Variation of Cognitive Uncertainty with respect to Rounds

	Dependent Variable: Cognitive Uncertainty											
Rounds:	All Rounds (i.e., Round 1-20)				First Game (Round 1- 10)				Restart (Round 11-20)			
Group:	Pooled	Baseline	Adviser	GPT	Pooled	Baseline	Adviser	GPT	Pooled	Baseline	Adviser	GPT
Treatment	Mixed	Baseline	Mixed	Mixed	Baseline	Baseline	Baseline	Baseline	Mixed	Baseline	Adviser	GPT
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Aggregate Analysis												
Round	-0.15	-0.13	-0.15	-0.16	-0.20	-0.20	-0.35	-0.06	-0.86***	-0.27	-1.10***	-1.21***
	(0.10)	(0.19)	(0.17)	(0.17)	(0.25)	(0.42)	(0.47)	(0.44)	(0.21)	(0.40)	(0.36)	(0.36)
Average Lagged group members' % contribution	0.00	0.02	0.00	-0.02	-0.04	-0.01	-0.06	-0.06	0.03	0.03	0.06	-0.02
	(0.03)	(0.06)	(0.06)	(0.04)	(0.04)	(0.07)	(0.07)	(0.05)	(0.04)	(0.07)	(0.08)	(0.07)
Observations	2,656	834	910	912	1,259	395	432	432	1,397	439	478	480
R-squared	0.60	0.54	0.55	0.67	0.63	0.63	0.55	0.71	0.67	0.59	0.66	0.73
Panel B: Individual Analysis												
Decreasing trend of cognitive uncertainty as game repeats												
No. subjects	19	5	7	7	16	4	6	6	16	1	8	7
Increasing trend of cognitive uncertainty as game repeats												
No. subjects	16	7	5	4	9	2	3	4	8	4	2	2
Total Subjects	140	44	48	48	140	44	48	48	140	44	48	48

Notes. Panel A: Subject level fixed effect OLS estimates, with robust standard errors (in parentheses) are clustered at the subject level, controlling for lagged average contribution from group members. Column (1)-(4) include data from all rounds of the games. Column (5)-(8) restrict attention to decisions in the first 10 rounds of the game, where no treatment has been imposed in any of the group. By contrast, column (9)-(12) look at the decisions after the restart of the game, where treatment was imposed at the beginning of the new 10 rounds. *** p<0.01, ** p<0.05, * p<0.1; Panel B: OLS estimates on each subject, controlling for the lagged average group members contribution showed in Panel A. Subjects are categorized as showing decreasing (increasing) trend of cognitive uncertainty as game repeats when the coefficient of round is smaller than (greater than) zero, and the p-value of the coefficient is less than 0.05.

- Wald test confirm a change of slope on CU=f(round) in Group Adviser (p=0.002) and Group GPT (p=0.025) when comparing the slope before and after the restart. but not in Group Baseline (p=0.759).
- Absence of GPT premium: we fail to find any significant difference in the slope between Treatment GPT and Treatment Adivser (p=0.945).

Result 2: Cognitively Uncertain Decisions are Closer to the Cognitive Default



Result 2: Cognitively Uncertain Decisions are Closer the Cognitive Default

Table 2: Absolute Deviation from Cognitive Default with regards to Cognitive uncertainty

	Dependent Variable: Absolute Contribution Deviation from 50% of the Endowment							
Treatment	Pooled			Baseline			Adviser	GPT
Game	All (1)	First (2)	Restart (3)	All (4)	First (5)	Restart (6)	Restart (7)	Restart (8)
Cognitive Uncertainty	-0.16*** (0.03)	-0.14*** (0.05)	-0.18*** (0.04)	-0.15*** (0.04)	-0.14*** (0.05)	-0.20*** (0.06)	-0.13* (0.07)	-0.22*** (0.06)
Average Lagged group members' % contribution	-0.20*** (0.02)	-0.19*** (0.03)	-0.18*** (0.03)	-0.20*** (0.03)	-0.19*** (0.03)	-0.17*** (0.04)	-0.19*** (0.04)	-0.17*** (0.05)
Observations	2,656	1,259	1,397	1,698	1,259	439	478	480
R-squared	0.12	0.10	0.12	0.10	0.10	0.14	0.09	0.16
Number of Subject	140	140	140	140	140	44	48	48

Notes. Fixed effects model with cluster-robust standard errors for panels nested within subject level. Column (1)-(3) pooled all data in all groups and treatment but separate them by the game. Column (4)-(6) include all the data in Treatment Baseline. Specifically, Column (5) include data from all treatment in the First game, while Column (6) only include data from Group Baseline in the Restart Game. Column (7)-(8) restrict attention to the decisions in the Restart Game of Group Adviser and Group GPT, respectively. *** p<0.01, ** p<0.05, * p<0.1

Result 3: On aggregate, cognitively Uncertain Decisions leads people to behave as if they are more cooperative; But Heterogeneity exists.

Table 3: Percentage of Contribution with respect to Cognitive Uncertainty

	Dependent Variable: Percentage of Contribution							
Treatment	Pooled			Baseline			Adviser	GPT
Game	All	First	Restart	All	First	Restart	Restart	Restart
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Aggregate Analysis								
Cognitive Uncertainty	0.23***	0.25***	0.21***	0.25***	0.25***	0.24***	0.18**	0.23***
	(0.05)	(0.07)	(0.04)	(0.06)	(0.07)	(0.08)	(0.08)	(0.07)
Average Lagged group members' % contribution	0.30***	0.31***	0.20***	0.31***	0.31***	0.18***	0.21***	0.23***
	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.05)	(0.07)
Observations	2,656	1,259	1,397	1,698	1,259	439	478	480
R-squared	0.12	0.12	0.09	0.12	0.12	0.10	0.10	0.08
Number of Subject	140	140	140	140	140	44	48	48
Panel B: Individual Analysis								
Cognitive uncertainty makes them contribute more								
No. subjects	40	25	27	15	9	9	8	10
Cognitive uncertainty makes them contribute less								
No. subjects	5	11	5	2	3	0	2	3
Total Subjects	140	140	140	44	44	44	48	48

Result 3: Cognitive noise complements, rather than replaces, taste-based social preference to explain the contribution decision.

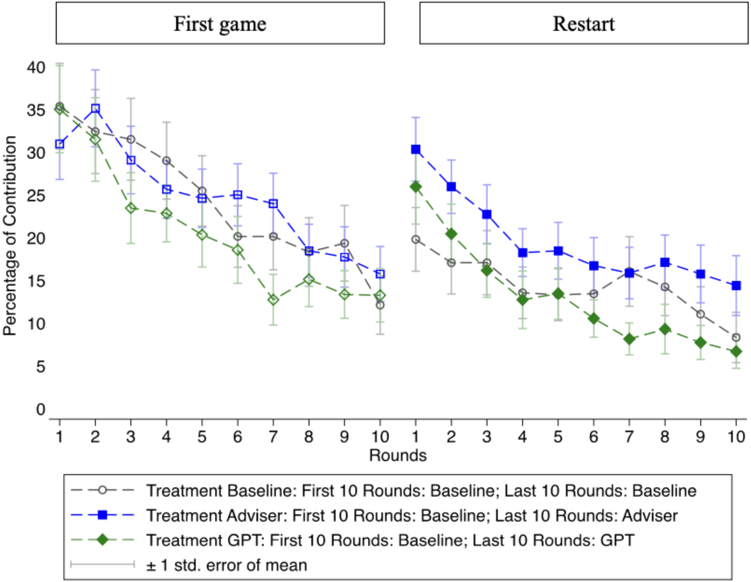
Table B.7: Percentage of Contribution with respect to Cognitive Uncertainty

	Dependent Variable: Percentage of Contribution							
Treatment	Pooled			Baseline			Adviser	GPT
Game	All	First	Restart	All	First	Restart	Restart	Restart
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cognitive Uncertainty	0.23***	0.21**	0.22***	0.22***	0.21**	0.24***	0.20**	0.24***
	(0.05)	(0.08)	(0.05)	(0.07)	(0.08)	(0.08)	(0.09)	(0.07)
Observations	2,798	1,399	1,399	1,839	1,399	440	479	480
R-squared	0.04	0.03	0.06	0.03	0.03	0.06	0.06	0.05
Number of Subject	140	140	140	140	140	44	48	48

Notes. Fixed effects model with cluster-robust standard errors for panels nested within subject level. Column (1)-(3) pooled all data in all groups and treatment but separate them by the game. Column (4)-(6) include all the data in Treatment Baseline. Specifically, Column (5) include data from all treatment in the First game, while Column (6) only include data from Group Baseline in the Restart Game. Column (7)-(8) restrict attention to the decisions in the Restart Game of Group Adviser and Group GPT, respectively. *** p<0.01, ** p<0.05, * p<0.1.

- Both frustrated attempts at kindness (negative coefficient of rounds indicating declining contribution; P18 and P25) and CU (P21) have explanation power on contribution.
- Low R^2 from Cognitive Uncertainty only.
- A 100% increase in the cognitive uncertainty could only increase contribution by 20% - 30% of the contribution.

Result 4: Subjects' responses is biased towards GPT's decisions in SR in the absence of supervision during online experiments, ...



Result 4: ..., and the jump in contribution cannot be captured by change in CU.

Table 4: Covariate-adjusted Sharp RD Estimates using Local Polynomial Regression

Dependent Variable	Percentage of Contribution				Cognitive Uncertainty			
Group	Pooled (1)	Baseline (2)	Adviser (3)	GPT (4)	Pooled (5)	Baseline (6)	Adviser (7)	GPT (8)
Panel A: Pooled								
Sharp RD Estimate	14.49*** (3.22)	8.78* (5.27)	17.32*** (4.92)	14.68** (5.78)	5.12 (3.36)	0.24 (5.54)	10.25* (5.90)	4.55 (5.98)
Observations	2,656	789	861	864	2,656	789	861	864
Panel B: Inexperienced GPT user								
Sharp RD Estimate	12.41*** (4.01)	6.71 (6.54)	17.49*** (6.12)	13.96* (8.10)	7.36 (4.83)	1.75 (6.68)	5.72 (7.83)	12.99 (10.18)
Observations	1,083	360	306	360	1,083	360	306	360
Panel C: Experienced GPT user								
Sharp RD Estimate	15.97*** (4.58)	10.72 (8.13)	17.19** (6.83)	14.37* (7.93)	3.81 (4.68)	-0.08 (8.85)	12.58 (8.19)	-1.63 (7.09)
Observations	1,573	429	555	504	1,573	429	555	504

Notes. Local polynomial sharp regression discontinuity estimates, RD cutoff point at round = 10.5 and additionally control for the lagged average contribution by the group members, with robust standard error clustered (in parentheses) clustered at subject level. *** p<0.01, ** p<0.05, * p<0.1

- No GPT premium: Participants do not adopt the cooperative advice more if they learn that the advice is from GPT.
- DID: the jump in contribution is not sustained.

Causal Study

Round 1 of 10

Task 1

In this round, all points contribute to the group project are multiplied by M = 1.4 and split evenly among the 4 group members. Recall that your payoff in points is as follows:

Your Payoff in Points
= (20–your contribution to group project) + (M ÷ 4) × (total contributions to the group project)

Your Endowment in Round 1 (in Points): 20

Your Contribution to the Group Project in Round 1 (in Points):

Next

- Complexity Number: Changing the value of MPCR in each period; N=48

Causal Study

Round 1 of 10

Time left to complete this page: **0:15**

Task 1

In this round, all points contribute to the group project are multiplied by

M = (4*6/20)+((8*9-52)/100)

and split evenly among the 4 group members. Recall that your payoff in points is as follows:

Your Payoff in Points
= (20−your contribution to group project) + (M ÷ 4) × (total contributions to the group project)

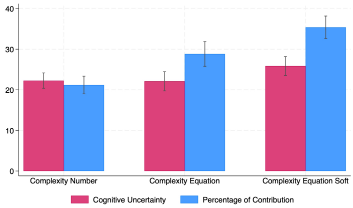
Your Endowment in Round 1 (in Points):	20
Your Contribution to the Group Project in Round 1 (in Points):	

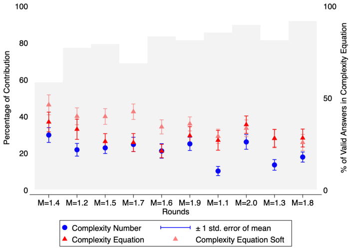
Next

- Complexity Equation: Participants have to calculate the value of MPCR; N=48

Causal Study: Results

- Complexity Soft: the same as Complexity except that the time limit is not binding; N=44.





Consistent with correlational result: A manipulation on complexity increases both cognitive uncertainty and contribution.

Strategic Uncertainty

Some people may argue CU does not add much on the explanatory power of strategic uncertainty. We add a treatment where one participant has FULL INFORMATION and therefore zero strategic uncertainty

Round 1 of 10

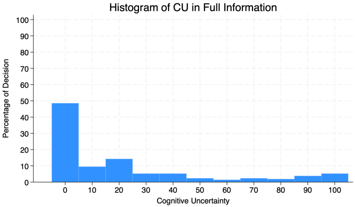
Task 1

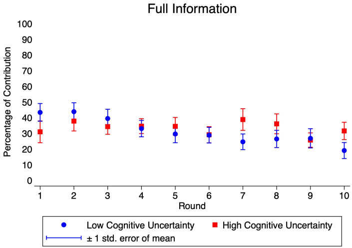
Contribution to the Group Project (out of 20 Points) from each of your group member:	17; 17; 3;
Your Endowment in Round 1 of 10 (in Points):	20
Your Contribution to the Group Project in Round 1 of 10 (in Points):	

Next

Strategic Uncertainty: Result

- CU is not zero even for the participant with full information.
- CU is again positively related to contribution (FE Panel with s.e. cluster at subject level, controlling for payment history); N = 21; coefficient = 0.20, p=0.13





Conclusion

- This paper establishes a connection between cognitive noise (Enke and Graeber, 2023) and the level of contribution in the public goods game.
- Cognitive noise complements, rather than replaces, taste-based social preference to explain the contribution decision.
    - Cognitive uncertainty is positively correlated with contribution in the public goods game at the aggregate level, or cognitive uncertainty lead people to behave as if they are more cooperative.
        - Causal results are consistent with correlational results; And the results are robust to when removing strategic uncertainty.
    - There is heterogeneity, where cognitive noise is negatively correlated with the contribution level of some participants at an economically significant extent.
    - The finding suggests the significance of only considering contribution decisions that exceed a certain cognitive certainty threshold in a public goods game if they are to be taken at face value.

Thank you !

Te Bao: baote@ntu.edu.sg
Jiaoying Pei: peij0003@e.ntu.edu.sg