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Sharing information and threshold ambiguity in public bads prevention

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Abstract

Public bads prevention problems, such as climate change, require people to cooperate above a certain threshold which is ambiguous and varies in many situations. In that case, people conjecture and share some information about the threshold. However, little is known about how sharing such information affects people to cooperate. We experimentally examine how people's cooperative choices are influenced by ambiguity and sharing information about the conjectures in public bads prevention, hypothesizing that sharing the information does not necessarily contribute to cooperation. We conduct the laboratory experiment with 400 subjects under five treatments each of which differs in ambiguity as well as in presence or absence of sharing the information. We find that (i) the percentages of cooperative choices are nonmonotonic, decreasing and then increasing over ambiguity levels and (ii) sharing the information tends to uniformly discourage cooperation, and the negative impact becomes prominent as the ambiguity levels rise. The result demonstrates an adverse effect between sharing information and threshold ambiguity on cooperation, being in sharp contrast with the literature. Overall, this study suggests that how or what information is shared among people should be carefully reconsidered for resolving any public bads problem involving threshold ambiguity, as everybody is able to easily publicize her conjectures during an era of digital democracy.

Key Words: Threshold ambiguity; sharing information; public bads; cooperation

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Contents

Nomenclature

Amb	Ambiguity treatment
Amb_info	Ambiguity with sharing info treatment
Base	Baseline treatment
JPY	Japanese yen
PBG	Public bads game
SVO	Social value orientation
WAmb	Wide ambiguity treatment
WAmb_info	Wide ambiguity with sharing info treatment

1 Introduction

Public bads prevention is an essential collective action for sustainability of our planet and wellbeing of both current and future generations in addressing global challenges, such as climate change (Mora et al., 2018, Lavonen, 2022). Public bads prevention problems are frequently characterized by the existence of thresholds which are ambiguous and vary in many situations, and the associated irreversible damage is claimed to get accrued when the states or degrees of cooperation become below certain thresholds (Lenton et al., 2008, Dannenberg et al., 2011, Barrett and Dannenberg, 2012). Many researchers have attempted to address the problems by considering how some mechanisms or institutions, such as communications and collective decision rules, enhance people's cooperation in public bads prevention. However, the problem remains complex, mainly due to the existence of ambiguous thresholds (Tavoni et al., 2011, Palfrey et al., 2017, Kenkel, 2019, Marini et al., 2020). In an era of information democracy through the spread of digital platforms all over the world, it is known that people can openly conjecture about the threshold and publicize the conjectures without taking any responsibility, when ambiguity gets involved (Sunstein, 2008, Stalder, 2018, Ahmad et al., 2020). Given this state of affairs, this research experimentally studies people's cooperative behaviors in public bads prevention as they share some information of individual conjectures towards ambiguous thresholds.

Literature investigates how threshold ambiguity and uncertainty impact individual cooperation and collective consequences (McBride, 2006, 2010, Kotani et al., 2014, Dannenberg et al., 2015, Kishishita and Ozaki, 2020). McBride (2006) develops a theoretical model and examines the effect of threshold uncertainty on people's contributions to a public good. The prediction implies that the relationship between the degree of threshold uncertainty and equilibrium contributions is non-monotonic. At the same time, the model also demonstrates that equilibrium contributions will be high under increased uncertainty for a large class of threshold probability distributions, if the public good's value is sufficiently high. These predictions are empirically examined by laboratory experiments in McBride (2010) and Kotani et al. (2014). In particular, Kotani et al. (2014) demonstrate that an intermediate level of the threshold uncertainty induces people to cooperate most in both public goods provision and bads prevention. These results imply that threshold uncertainty increases people's cooperative behaviors in some cases. On the contrary, there are some studies that have analyzed how threshold ambiguity can affect people in public goods provision and bad prevention. Kishishita and Ozaki (2020) develop a theoretical model to derive how people behave under threshold ambiguity in public goods provision, establishing that people reduce cooperation by ambiguity. Dannenberg et al. (2015) conduct laboratory experiments of public-goods games with threshold ambiguity, finding that the threshold ambiguity tends to decrease cooperation. Although the previous studies present that a presence of threshold ambiguity can decrease individual cooperation, they do not fully explore how people's cooperative behaviors change with the different levels of threshold ambiguity in public goods and public bads settings.

Communications and information are claimed to be key factors for motivating people to provide (prevent) public goods (bads) under some thresholds (Agastya et al., 2007, Tavoni et al., 2011, Costa and Moreira, 2012, Palfrey et al., 2017, Marini et al., 2020, Barron and Nurminen, 2020). Agastya et al. (2007) examine how non-binding communications affect joint-project investments in a voluntary contribution game, demonstrating that announcements about the total contribution increase a probability of the project completion. Palfrey et al. (2017) investigate the effects of communications in a threshold public goods game with Bayesian mechanism design, showing that unrestricted text chats raise subjects' contributions through better coordination and agreement among them. Costa and Moreira (2012) explore the impacts of cheap talk on public good provision in a laboratory experiment, showing that its overall impacts on contribution are limited, especially when subjects are obliged to truthfully report their choices. Kenkel (2019) seeks to reveal the effectiveness of cheap talk in a two-player collective action problem, documenting that it depends on specific situations of public goods provision (bads prevention). Chen et al. (2019) investigate the effects of disclosing donation lists as binding information, presenting that partial disclosure of the list fosters the donations. Marini et al. (2020) examine the roles of nonbinding communications on public goods provision under ambiguity, finding that unrestricted text chat enhances people's contributions to public goods by mitigating the negative effect of ambiguity. Barron and Nurminen

(2020) evaluate "norm-nudges" by labeling some contributions above one level as "good," and show that bringing such a norm enhances the contribution. These previous studies highlight how various forms of communication and information, such as cheap talk and disclosure, positively influence people's cooperation. However, its effectiveness is reported to vary depending on the scenarios and contexts.

The existing literature focuses on studying the impacts of various forms of information, such as commitments, contributions, intentions and gains in public goods provision and bads prevention. The information is generally established to enhance people's cooperation, even when it comes in the form of cheap talks or beyond (Agastya et al., 2007, Tavoni et al., 2011, Dannenberg et al., 2011, Costa and Moreira, 2012, Palfrey et al., 2017, Marini et al., 2020). However, in reality, there are many incidents or reports in public bads prevention where people's cooperation may be hampered by sharing information, especially when some threshold ambiguity is involved. Nowadays, it is so common that people conjecture and share information about ambiguous thresholds for public bads problems, such as climate change, knowing that the catastrophes are irreversible once their cooperation is not enough (Kennedy, 2019, Cann et al., 2021). Such conjectures are known to get easily publicized and shared among people via digital platforms, being expected to impact individual cooperation even though they are in the form of costless and nonbinding cheap talks (Costa and Moreira, 2012, Palfrey et al., 2017, Kenkel, 2019). Despite the importance, little is known about how sharing such information affects people to cooperate. We experimentally examine how people's cooperative choices are influenced by ambiguity and sharing information about the conjectures in public bads prevention, hypothesizing that sharing the information does not necessarily contribute to cooperation. We conduct the laboratory experiment with 400 subjects under five treatments each of which differs in ambiguity as well as in presence or absence of sharing the information.

2 Experimental design and procedures

The experiments were carried out at the computerized laboratory of Kochi University of Technology in Japan, encompassing 20 sessions. Each session includes a participant pool of 15 to 30 subjects, totaling 400 volunteer undergraduate students from diverse fields, such as engineering, economics and so on. Each subject participates in only one session and receives an average cumulative payoff of 3000 JPY (≈20 USD). Every session takes approximately 1.5 hours and consists of three parts. The 1st part is a "social value orientation" (SVO) game based on the triple dominance measure proposed by Van Lange et al. (1997, 2012). The 2nd part is an "ambiguity responses" game suggested by Halevy (2007), and the 3rd part is a "public bads prevention" game. In the public bads prevention game, five treatments are prepared and implemented, being designed to understand people's behaviors for preventing public bads with sharing information about ambiguous thresholds. Four sessions are conducted for each treatment and the basic procedures in each session follow some previous literature, such as McBride (2010), Kotani et al. (2014) and Marini et al. (2020).

Social value orientation (SVO) game assesses people's noncognitive social-value characteristics, such as individualistic, cooperative, or competitive orientations, to understand their social behaviors (Borghans et al., 2008, Fitzenberger et al., 2022). This game uses the 9-item triple dominance measure developed by Van Lange et al. (1997, 2012) to investigate how such characteristics influence making cooperative choices. In the game, subjects are randomly paired, ensuring anonymity and provided nine choice situations. Each situation offers three options A, B and C with different point distributions for the subject and her partner. An example of the three options is as follows: option A is "You get 500 and your partner gets 100," option B is "You get 500 and your partner gets 500," option C is "You get 550 and your partner gets 300." The game asks each subject to choose one among the three options based on her preference. Every option per situation corresponds to one of the social value orientations. In the above example, option A corresponds to the competitive orientation that maximizes the gap between the point of the subject and her partner ($500 - 100 = 400$), option B corresponds to the cooperative orientation that maximizes the joint outcome ($500 + 500 = 1000$) and option C corresponds to the individualistic orientation that maximizes the subject's outcome (550) and shows no interest in the partner's outcome. Each subject is classified as cooperative, individualistic or competitive if she consistently chooses six options that correspond to one orientation from nine situations. Otherwise, the subject is labeled as "unidentified." In the SVO game, each subject's payoff is the summation of the points associated with the options the subject and her partner chose for herself in nine situations. On average, a subject earns 5000 points, being equivalent to approximately 500 JPY by applying an exchange rate of 0.10 JPY per point.

The ambiguity responses game, adopted from Halevy (2007), is employed to explore how individual differences in managing ambiguity influence cooperative choices. It classifies subjects as ambiguity neutral or averse, potentially impacting decision making under ambiguity (Levati et al., 2016, Vinogradov and Makhlouf, 2021). This game draws on Halevy's experimental design to test the relationship between individual ambiguous attitudes and their behaviors toward compound objective lotteries. It highlights a tight link between ambiguity neutrality and the ability to reduce compound lotteries. In this game, each subject is asked to predict whether a ball drawn from a box is red or black and to submit an offer to sell for the prediction right that ranges from 0 JPY to 200 JPY. Four boxes are prepared with ten balls. The composition of balls in Box 1 consists of 5 red and 5 black balls. The composition of balls in Box 2 consists of 10 balls with an unknown mix of red and black balls. The composition of balls in Box 3 (Box 4) is determined by the card that is randomly chosen from eleven cards (two cards) by a computer numbering from 0 to 10 (0 or 10). The card number (the remaining out of 10) becomes the number of red (black) balls in the boxes. For each of the Boxes, every subject predicts the color and submits an offer to sell for the prediction right. After predicting the color and submitting an offer to sell for each box, a price between 0 JPY and 200 JPY is randomly generated by a computer. The right shall be sold if the price is higher or equal to the offer to sell, and the subject receives the offer as part of her payoff. Otherwise, it shall be unsold, and the subject gets 200 JPY (0 JPY) when her color prediction is correct (wrong). In fact, each of four boxes is designed to have an equal 50 % chance for a subject to correctly predict the color. However, it is not revealed to subjects. Given this state of affairs, if a subject submits the same offer to sell for the prediction right of the boxes 1, 3 and 4, it suggests her ambiguity neutral disposition. Conversely, any variation in her offers across these boxes indicates ambiguity aversion (Halevy, 2007). In this game, subjects earn 500 JPY on average.

The public bads prevention game comprises 10 rounds, and a subject decides whether to cooperate (choose "Blue") or not (choose "Yellow") for making public bads prevention in each round. Five treatments are prepared (table 1), and in Base, a subject is assigned to a group of five members and makes the decision, while the group members are reshuffled in each round to maintain their anonymity as well as to minimize their strategic behaviors (Sonnemans et al., 1998, Park, 2000, Kotani et al., 2014). The choice between "Blue" and "Yellow" made by each subject per round determines her payoff, which is a summation of the individual and group payoffs. The individual payoff associated with the "Blue" and "Yellow" choices are 0 points and 60 points, respectively. The group payoff depends on both the number of "Yellow" choices per group in each round and the threshold of public bads prevention. In Base, the threshold is set to be 2, following the experimental setup in literature (see, e.g., McBride, 2010, Kotani et al., 2014). If the number of "Yellow" choices per group is equal to or below 2, the public bads prevention is successful, and accordingly, each member in that group receives 185 points as her group payoff. Otherwise, it is not successful and each member receives 0 points. After each round, every subject observes the number of Yellow choices in her group, a consequence of the public bads prevention, her points as her individual and group payoffs in each round and cumulative points on her computer screen. The exact process repeats for 10 rounds where all subjects do not know how many rounds the game continues. The final payoff for each subject in this game is 2000 JPY on average, ranging between 1000 JPY and 3500 JPY after converting her cumulative points over 10 rounds to cash at a rate of 1.30 JPY per point.

Four treatments are concerned with ambiguous thresholds, introducing two different levels of "ambiguity (Amb)" and "wide ambiguity (WAmb)." They are different from one another only by the threshold ranges of $\{1, 2, 3\}$ and $\{0, 1, 2, 3, 4\}$ (table 1). In Amb and WAmb treatments,

Table 1: Five treatments (the abbreviations) in the public bads prevention game

Treatments	Threshold range	Sharing info
Baseline (Base)	$\{2\}$	-
Ambiguity (Amb)	$\{1, 2, 3\}$	No
Ambiguity with sharing info (Amb_info)	$\{1, 2, 3\}$	Yes
Wide ambiguity (WAmb)	$\{0, 1, 2, 3, 4\}$	No
Wide ambiguity with sharing info (WAmb_info)	$\{0, 1, 2, 3, 4\}$	Yes

subjects are asked to choose between "Blue" and "Yellow" in each round without knowing the threshold in advance. However, they understand that one threshold shall be selected from the corresponding threshold range just after their choices, while they remain uninformed about selection algorithms and probability distributions over the range.[1] Instead, we inform subjects of the selected threshold, say, X, as follows: X will affect subjects' group payoffs in each round per session. For instance, if X is selected to be 3 in one round and three subjects or less in one group choose "Yellow," each member receives 185 points as the group payoffs. Otherwise, they receive 0 points. The rest of the procedures are the same as the ones in Base. Two additional treatments are prepared, adding an element of "sharing information" for each level of ambiguous thresholds, i.e., "ambiguity with sharing info (Amb_info)" and "wide ambiguity with sharing info (WAmb_info)" treatments. Specifically, each subject is asked to conjecture about the threshold level out of the range that she thinks most likely to be realized in each round as well as to share her conjectures with everybody in the same round before her choice. All subjects' conjectures in each round are announced and displayed on a common screen at the laboratory, while everybody knows that individual anonymity is ensured. After sharing information about individual conjectures, the same procedures as in Amb and WAmb follow, that is, each subject chooses between "Blue" and "Yellow," one threshold level X is selected, the group payoff shall be decided according to the number of "Yellow" choices in a group and X in one round.

A subject registers for and participates in only one session. Subjects in a session are assigned

[1] Specifically, in Base, the threshold is fixed at 2 and known by subjects. In Amb and WAmb, a threshold in each round is selected according to the threshold-generating algorithms from the corresponding range along with the expected value of 2, and information regarding the selection algorithms is not revealed to the subjects.

to one treatment, and therefore, our experiments are considered to employ a between-subject design. Arriving at the laboratory, they are guided to sit at computers that are linked within a network for exchanging information about their choices and payoffs with the admin PC via Z-tree software (Fischbacher, 2007). They receive written instructions and consent forms for an overview of experimental procedures in the treatment, being asked to sign the forms once they agree to participate. After we observe each subject's consent, the experimenter provides oral instructions to all subjects in that session with neutral terminologies, confirming that they understand each procedure without any bias. First, the subjects engage in an SVO game for approximately 15 minutes, making choices that reflect their SVOs. Second, 15 minutes are dedicated to the ambiguity responses game and subjects make some decisions under ambiguity. Finally, the public bads prevention game is conducted, taking time between 35 and 45 minutes, depending on treatments. The session ends by paying an experimental reward to each subject in the session and it takes approximately 5 to 10 minutes. As mentioned, subjects earn 500 JPY from the SVO game, 500 JPY from the ambiguity responses game, 2000 JPY from the public bads prevention game and 3000 JPY in total on average.

3 Experimental results

Table 2 presents the summary statistics of experimental results for cooperative choices, the number of subjects and observations across treatments. It can be confirmed that 400 subjects are employed, each of which provides 10 observations, and thus, 4000 observations are generated in total. Overall, the number of cooperative choices is identified to be 1402 by pooling all the observations across treatments, meaning that the overall percentage of the choices is $35.10 \ \left(\approx \frac{1402}{4000}\right)$. We see that the percentages of cooperative choices appear to differ across treatments (42 % in Base, 32.30 % in Amb, 21.50 % in Amb_info, 44.30 % in WAmb and 33.70 % in WAmb_info), implying some possibility that ambiguity and sharing information influence cooperative choices made by subjects. To statistically check the possible influence, a 2×5 contingency table is created for the percentages of subjects' choices per treatment, taking cooperative and noncooperative ones to be

Table 2: Summary statistics of experimental results for cooperative choices, the number of subjects and observations across treatments

	Base	Amb	Amb_info	WAmb	WAmb_info	Total
Cooperative choices (= Blue choices)						
# of the choices	420	258	161	310	253	1402
% of the choices	42.0	32.3	21.5	44.3	33.7	35.1
SD	0.493	0.468	0.411	0.497	0.473	0.477
# of subjects	100	80	75	70	75	400
Observations	1000	800	750	700	750	4000

in rows as well as five treatments to be in columns. The Pearson χ^2 test is conducted to examine the associations between cooperative choices and treatments with the null hypothesis that the frequency distributions of cooperative choices do not differ across all treatments. The result rejects the null hypothesis at 1 % ($\chi^2(4) = 111.56$), demonstrating an existence of associations between the frequencies of cooperative choices and treatments. Overall, table 2 and the Pearson χ^2 test corroborate some dependence of cooperative choices on ambiguity and sharing information under the treatments in a coherent manner.

Figure 1 displays percentages of cooperative choices over 10 rounds under different treatments. In figure 1a, the cooperative choices under Amb, ranging from 27.50 % to 36.30 %, consistently remain lower than Base, ranging from 31.00 % to 48.00 %. In figure 1b, cooperative choices under WAmb range from 35.70 % to 52.90 %, which is similar to or slightly higher than Base. Additionally, sharing the information, as shown in both figures 1a and 1b, leads to a consistent decrease in cooperation. Specifically, the ranges under Amb_info and WAmb_info are 17.30 % to 29.30 % and 28.00 % to 42.70 %, respectively, being lower than the corresponding ones under the treatments without sharing information (Amb and WAmb) over the rounds. The tendency suggests that sharing information about subjects' conjectures to thresholds may negatively influence cooperative choices in the presence of ambiguity. Overall, the impact of ambiguity on cooperative choices is nonmonotonic as cooperation decreases under Amb and increases under WAmb in comparison to Base, and sharing the information consistently diminishes cooperative choices in each of ambiguity levels.

Figure 1: Percentages of cooperative choices over 10 rounds across treatments

(a) Info sharing under ambiguity

(b) Info sharing under wide ambiguity

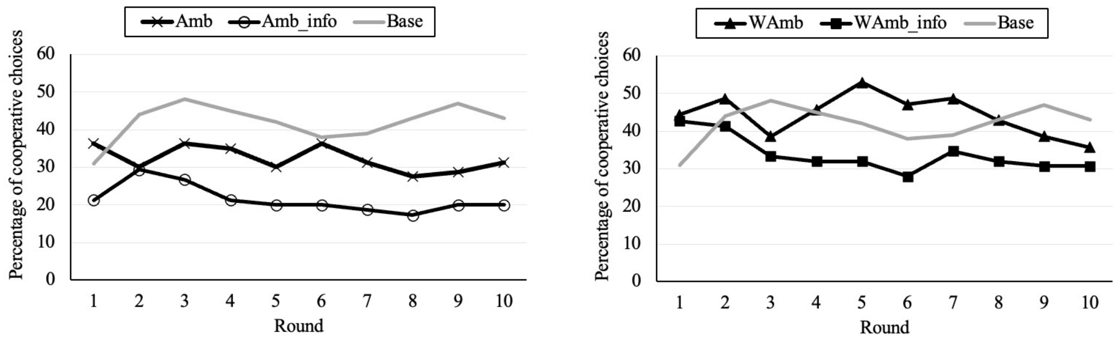
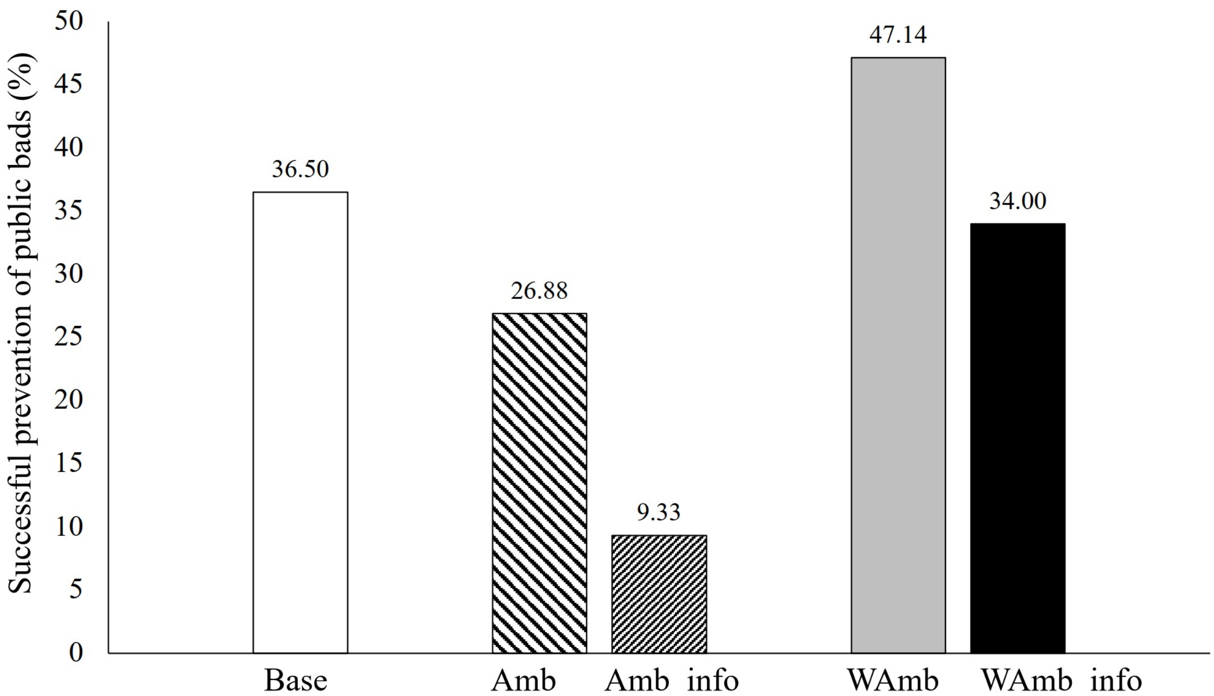


Figure 2 illustrates percentages of successful public bads prevention across treatments. Recall that the threshold is fixed at 2 in Base, while a threshold in each round is selected according to the threshold-generating algorithms with the expected value of 2 in Amb and WAmb (see footnote 1). Therefore, the percentages of successful public bads prevention should become close with one another among treatments as far as the sample size is large and subjects make choices in a similar fashion. However, the percentages are identified to be different from each other (see figure 2). In Base, 36.50 % of groups successfully prevent public bads, and the percentage reduces to 26.87 % under Amb and further to 9.33 % under Amb_info. In contrast, the percentage rises to 47.14 % under WAmb and falls to 34.00 % under WAmb_info. These changes across treatments indicate that both the introduction of ambiguity and sharing the information influence successful public bads prevention, and notably, sharing information reduces the successful prevention by approximately 17.50 % and 13.00 % as compared to Amb and WAmb, respectively.

Table 3 presents the percentages of cooperative choices by subjects' characteristics of SVOs and ambiguity responses among treatments. It reveals that cooperative subjects consistently make more cooperative choices than individualistic subjects over all treatments. The cooperation rates of such cooperative subjects in Base, Amb, Amb_info, WAmb and WAmb_info are 21.20 %, 25.50 %, 19.30 %, 15.10 % and 22.40 %, which are higher than individualistic subjects, respectively. Ambiguity responses do not indicate a clear pattern of cooperative choices, while sharing informa-

Figure 2: Percentages of successful public bads prevention across treatments



tion consistently reduces cooperative choices compared to the corresponding treatments without it regardless of the subjects' characteristics of SVOs and ambiguity responses. Cooperative and individualistic subjects do not take cooperative choices under Amb_info as compared to Amb, and a similar trend is confirmed between WAmb_info and WAmb. Ambiguity neutral and averse subjects also show a reduction in cooperative choices under Amb_info and WAmb_info as compared to Amb and WAmb, respectively. In summary, table 3 illustrates that cooperative subjects consistently exhibit higher cooperation than individualistic subjects and sharing information reduces cooperation regardless of subjects' SVOs and ambiguity responses.

Table 4 presents the estimation results associated with the marginal effects of independent variables on the probability for a subject to make a cooperative choice via probit and random-effects probit regressions. The dependent variable is a binary choice made by each subject, taking on 1 if the subject makes a cooperative choice (Blue choice), otherwise 0 (the base group is Yellow choice). Model 1 and Model 3 include treatment dummy variables of Amb, Amb_info, WAmb

Table 3: Percentages of cooperative choices by SVO and ambiguity responses

	Base	Amb	Amb_info	WAmb	WAmb_info
SVO game					
Cooperative	51.2% (42)	45.8% (31)	35.8% (12)	55.8% (19)	47.6% (21)
Individualistic	30% (35)	20.3% (40)	16.5% (52)	40.7% (42)	25.2% (44)
Competitive	32% (6)	50% (1)	20% (2)	37.5% (4)	75% (2)
Unidentified	47.7% (17)	37.5% (8)	31.1% (9)	36% (5)	33.8% (8)
Ambiguity responses game					
Ambiguity neutral	48.3% (36)	26.6% (26)	25.2% (27)	46.4% (28)	29.2% (25)
Ambiguity averse	38.4% (64)	35% (54)	19.4% (48)	42.9% (42)	36% (50)

The number of subjects is given in parentheses

and WAmb_info as independent ones where the base group is the baseline treatment, i.e., "Base". Model 2 and Model 4 additionally include rounds from 1 to 10, SVOs and ambiguity responses as independent variables (see the notes of table 4 for the definition of each independent variable) and these models are estimated for the purpose of robustness check. We have also tried to include some interaction terms of independent variables, confirming that the primary results do not change. Thus, we decide not to include the results. Since each subject provides 10 observations over 10 rounds in our experiment, the data possess a panel-data structure where a cross-sectional unit is a subject and a time unit is a round. Therefore, a random-effects probit regression is employed, accounting for some time-invariant factors, such as SVOs and ambiguity responses, as well as some time-variant factors, such as rounds, on top of treatment dummy variables (Wooldridge, 2010).

The regression results from table 4 indicate that cooperation under Amb and Amb_info is lower than Base, with probabilities ranging from 7.60 % to 10.90 % for Amb, and from 14.50 % to 20.80 % for Amb_info, significant in all models at 1 % to 5 % levels. The results demonstrate that threshold ambiguity reduces cooperative choices, consistent with existing studies (Dannenberg et al., 2015, Kishishita and Ozaki, 2020) and that sharing information about this ambiguity further decreases cooperation. Conversely, WAmb increases cooperation with probabilities ranging from 0.80 % to 7.00 %, while WAmb_info decreases it from 4.10 % to 9.20 % compared to Base but not significant in all models. The findings suggest that wide ambiguity might enhance cooperation, supported by research such as Rocha et al. (2020) and De Jaegher (2020), and sharing information

Table 4: Marginal effects of the independent variables on the probability for a subject to make a cooperative choice (Blue choice)

	Probit		Random-effects probit	
	Model 1	Model 2	Model 3	Model 4
Treatment (Base group = Baseline)				
Amb	−0.098***	−0.076***	−0.109**	−0.087**
	(0.023)	(0.022)	(0.047)	(0.044)
Amb_info	−0.205***	−0.145***	−0.208***	−0.148***
	(0.022)	(0.022)	(0.044)	(0.044)
WAmb	0.023	0.070***	0.008	0.053
	(0.024)	(0.024)	(0.051)	(0.049)
WAmb_info	−0.083***	−0.041*	−0.091*	−0.048
	(0.023)	(0.023)	(0.048)	(0.046)
Round[a]		−0.005*		−0.005**
		(0.003)		(0.002)
SVO[b](Base group = Individualistic)				
Cooperative		0.209***		0.216***
		(0.017)		(0.035)
Competitive		0.094**		0.110
		(0.040)		(0.080)
Unidentified		0.130***		0.138***
		(0.025)		(0.049)
Amb. responses[c](Base group = Ambiguity averse)				
Ambiguity neutral		0.009		0.004
		(0.015)		(0.031)
Observations		4000		

***,**,*significant at 1%, 5% and 10% levels, respectively.
Standard errors are reported in the parenthesis.
Each marginal effect is calculated according to the estimated parameters via maximum likelihood estimations and the associated likelihood functions in each model, holding the other independent variables fixed at the sample means.

[a] Round refers to each of the ten times the decision making of a subject.

[b] SVO refers to a subject's social value orientation, taking on 0, 1, 2 or 3 if the subject is individualistic, cooperative, competitive or unidentified, respectively.

[c] Ambiguity responses refer to a subject's decision making under different levels of ambiguity, taking on 1 if the subject is ambiguity neutral, otherwise 0.
For the robustness check, merging the competitive and unidentified subjects does not change the qualitative results.
The LR χ^2 statistics are 115.25 and 270.35 in models 1 and 2 of the probit regression, respectively, and they are significant at 1% level.
The Wald χ^2 statistics are 26.76 and 72.17 in models 3 and 4 of the random-effects probit regression, respectively, and they are significant at 1% level.

about the wide ambiguity also decreases cooperative choices. Thus, the overall findings illustrate nonmonotonic responses as ambiguity levels rise, where cooperation initially decreases and then increases. Furthermore, the magnitudes of coefficients reveal that the reductions of cooperative choices under Amb_info are nearly double compared to those under Amb. Similar trends are observed when comparing WAmb_info to WAmb, with WAmb exhibiting a positive trend in making cooperative choices that turns negative under WAmb_info. These findings suggest that sharing the information can discourage cooperation at each level of ambiguity.

Table 4 illustrates the marginal effects of other independent variables on cooperative choices, without treatments. The round variable shows a decline in making cooperative choices over the 10 rounds of decision significant at 5 % to 10 % levels. It indicates a 0.50 % decline in the probability of making cooperative choices per round, underscoring a slight but consistent decrease in cooperation over time, consistent with prior study (Andreozzi et al., 2020). SVO variables indicate that cooperative subjects are more likely to make cooperative choices than individualistic ones, with probabilities ranging from 20.90 % to 21.60 % significant at 1 % level. This finding aligns with the literature suggesting cooperative subjects are generally more cooperative (De Cremer and Van Lange, 2001, Gintis et al., 2003, Emonds et al., 2014). Additionally, ambiguity neutral subjects show a slight but statistically insignificant increase in cooperative choices ranging from 0.40 % to 0.90 % compared to ambiguity averse subjects. These analyses illustrate a consistent decrease in cooperative choices as rounds progress, cooperative subjects are more likely to engage in cooperation than individualistic ones, and ambiguity responses show no significant impact on cooperation.

The subsample analyses in table 5 illustrate the impact of sharing the information on cooperative choices by comparing Amb with Amb_info (table 5a) and WAmb with WAmb_info (table 5b). Table 5a shows that Amb_info reduces cooperation, with probabilities ranging from 5.10 % to 10.80 % compared to Amb, significant in three models at 1 % to 5 % levels. Table 5b indicates that WAmb_info also decreases cooperation, with probabilities ranging from 9.90 % to 10.90 % compared to WAmb, significant in all models at 1 % to 10 % levels. These findings underscore a more adverse effect on cooperation under WAmb_info than Amb_info. They suggest that sharing information about threshold conjectures under wide ambiguous situations, such as climate change, could deepen confusion about necessary levels of cooperation. This confusion can hinder effective coordination and reduce cooperative efforts.

The main results from figures 1 and 2, along with tables 4 and 5, present the impact of threshold ambiguities and sharing information about the ambiguities on cooperation. Figure 1 and figure 2 indicate that sharing the information leads to few cooperative choices and success rates in public bads prevention under both Amb and WAmb treatments. The regression results from table 4 demonstrate that ambiguity and sharing the information reduce cooperation, notably under Amb and Amb_info treatments compared to Base. In contrast, WAmb enhances cooperation, and WAmb_info decreases cooperation compared to Base, but these results are not significant in all models. Table 5 further demonstrates through subsample analyses that sharing the information diminishes making cooperative choices under both Amb and WAmb. The analyses also suggest a more adverse effect of sharing the information under WAmb than Amb.

In contemporary world, transformation into a digitally connected society is rapidly progressing (Rometty, 2016, Ranjith et al., 2021). This transformation is leading us into what is commonly referred to as an era of digital democracy where sharing any information is easy to do through devices (Helbing and Pournaras, 2015, Turner, 2018). In such environments, people can anonymously share any type of information across various platforms without accountability and responsibility. While such sharing contributes to information disseminations and communications among people as a positive side, it presents some new challenge as a negative side. Some studies argue that sharing unverified and irresponsible information impedes overall welfare of people in societies (Mario and Daria, 2016, Kennedy, 2019). In particular, as some global challenge involving threshold ambiguity, such as climate change, intensifies, it is claimed that the degree of ambiguity will widen and sharing information worsens the situations (Petr et al., 2016, Lampert, 2020, Koundouri et al., 2022). In this context, our study is considered the first to document that allowing people to anonymously and freely share information about ambiguous thresholds without accountability and responsibility worsens the situations in public bads prevention. Given this state of affairs, it shall be

Table 5: Marginal effects of subsample analyses in probit and random-effects probit models

(a) Marginal effects of sharing info under Amb

	Probit		Random-effects probit	
	Model 1	Model 2	Model 3	Model 4
Treatment (Base group = Amb)				
Amb_info	−0.108***	−0.060***	−0.098**	−0.051
	(0.022)	(0.023)	(0.046)	(0.045)
Round		−0.007*		−0.007**
		(0.004)		(0.003)
SVO (Base group = Individualistic)				
Cooperative		0.229***		0.236***
		(0.028)		(0.056)
Competitive		0.125		0.167
		(0.086)		(0.172)
Unidentified		0.162***		0.172**
		(0.040)		(0.078)
Amb. responses (Base group = Ambiguity averse)				
Ambiguity neutral		0.009		−0.011
		(0.024)		(0.047)
Observations	1550			

(b) Marginal effects of sharing info under WAmb

	Probit		Random-effects probit	
	Model 1	Model 2	Model 3	Model 4
Treatment (Base group = WAmb)				
WAmb_info	−0.106***	−0.109***	−0.100*	−0.099*
	(0.026)	(0.025)	(0.053)	(0.051)
Round		−0.010**		−0.009***
		(0.004)		(0.004)
SVO (Base group = Individualistic)				
Cooperative		0.207***		0.205***
		(0.030)		(0.061)
Competitive		0.167**		0.197
		(0.065)		(0.133)
Unidentified		0.032		0.049
		(0.045)		(0.089)
Amb. responses (Base group = Ambiguity averse)				
Ambiguity neutral		−0.065**		−0.058
		(0.027)		(0.054)
Observations	1450			

***,** and *significant at 1%, 5% and 10% levels. Standard errors are in the parenthesis.
The LR χ^2 statistics are 23.00 and 105.45 for models 1 and 2 in Table 5a, and 17.00 and 71.36 in Table 5b of the probit regressions. All are significant at 1 % level.
The Wald χ^2 statistics are 4.48 and 30.72 for models 3 and 4 in Table 5a, and 3.53 and 22.43 in Table 5b of the random-effects probit regressions. They are significant at 1 % to 10 % levels.

recommended to reconsider and implement some rules and guidelines under platforms along with consensus among people in relation to anonymity, accountability and responsibility for sharing some information regarding the ambiguity, when everybody can easily publicize her conjectures during an era of digital democracy under rapid development of information technologies.

4 Conclusion

Public bads prevention problems, such as climate change, require people to cooperate above a certain threshold which is ambiguous and varies in many situations. In that case, people conjecture and share some information about the threshold. This research examines how people's cooperative choices are influenced by ambiguity and sharing information about the conjectures in public bads prevention, hypothesizing that sharing the information does not necessarily contribute to cooperation. We conduct a laboratory experiment with 400 subjects under five treatments each of which differs in ambiguity as well as in presence or absence of sharing the information. We find that (i) the percentages of cooperative choices are nonmonotonic, decreasing and then increasing over ambiguity levels and (ii) sharing the information tends to uniformly discourage cooperation, and the negative impact becomes prominent as the ambiguity levels rise. The result demonstrates an adverse effect between sharing information and threshold ambiguity on cooperation, being in sharp contrast with the literature. Overall, this study suggests that how or what information is shared among people should be carefully reconsidered for resolving any public bads problem involving threshold ambiguity, as everybody is able to easily publicize her conjectures during an era of digital democracy.

This study has limitations and opens avenues for future research. The research is limited to sharing information about threshold conjectures by announcing and displaying them on a common screen. Investigating other methods, such as discussions or text chats, could provide deeper insights into how different methods of sharing the information influence cooperation. Additionally, the study does not explore how sharing information influences decision making processes.

Future research could examine the reasons behind the observed adverse effects on cooperation, considering psychological aspects and the role of institutions and social networks. Lastly, this study does not identify potential strategies to mitigate the effects of sharing the information. Future research should explore specific rules or platforms that could help minimize these negative impacts of sharing information, particularly regarding ambiguous thresholds, to promote coherent actions and enhance cooperation. Despite these limitations, the study sheds light on the impact of sharing information about threshold conjectures on cooperation, laying the groundwork for more comprehensive lab and field experiments in the future.

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