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Groups disguise lying better

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Groups Disguise Lying Better*

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Abstract

This study experimentally examines the lying behavior of individuals and two-person groups, using a dice-rolling experiment developed by Fischbacher and Föllmi-Heusi (2013). We found strong evidence of lying in both individuals and groups, but partial lying (not lying to the maximum extent possible) is more pronounced under group decisions. Furthermore, from the experimental data, we estimated the preference parameter(s) of existing models for lying aversion. The results reveal that groups are more sensitive to the social image concern of not being perceived as a liar and have a lower cost of lying than individuals.

Keywords: Lying, group decision, experiment

JEL Classification: C72, C91, C92, D63

1 Introduction

Informational asymmetries are commonly observed in many social and economic situations. In such situations, there is a possibility that an agent with private information has an incentive to deceive other agents by sending a wrong message to increase his/her own

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payoff. Examples of this include accounting fraud, manipulating quality checking data by a for-profit firm, welfare fraud by an individual or by a small group of people, medical malpractice by a hospital or a doctor, and promises made by politicians in campaigns. Against a background of its bad influence on society, economists have recently started to experimentally investigate the characteristics of lying behavior (Gneezy, 2005; Mazar et al., 2008; Fischbacher and Föllmi-Heusi, 2013).

Experimental evidence suggests that people often lie, but not to the maximum extent possible. Fischbacher and Föllmi-Heusi (2013) developed an ingenious design to study lying behavior in which subjects privately rolled a six-sided dice and reported the number to the experimenter. Since payment was made according to the reported dice number, subjects had an incentive to lie to the number that yields the higher earnings. Although we are unable to observe that subjects actually lie at an individual level, a pattern of lying behavior can be inferred from the distribution of the reported numbers by comparing them to the uniform distribution which is expected under full honesty. They found that, while the number that yields the maximal payment was most reported, the fraction of people reporting the number that yields the second highest payment was also substantially higher than 1/6, which they referred to as partial lying. Others have reported similar findings (Abeler et al., 2019).

Using the dice-rolling experiment, we experimentally study the lying behavior of individuals and two-person groups and identify the difference. In real-life situations, decisions are often made by a group. Political, monetary policy, and some business decisions are all made by small groups in which two or more individuals interact freely. Unethical behavior, such as lying, deception, and cheating, is also sometimes made by a group of people, institution, organization, and so on. Economists and social psychologists have accumulated experimental evidence on how and why group behavior is different from individual behavior in various strategic situations (Bornstein, 2008; Charness and Sutter, 2012; Kugler et al., 2012). Our study provides further evidence on differences in behavior between groups and individuals.

In the dice-rolling experiment, a pure payoff maximizer would always report the number that yields the highest monetary payoff, irrespective of the actual rolled number.

This behavior cannot explain the observed lying pattern. Several possible explanations have been proposed and examined to explain why people exhibit partial lying: people feel guilty if they disappoint others by lying (Charness and Dufwenberg, 2006); they have a preference for keeping promises per se (Vanberg, 2008); it is an attempt to maintain a favorable self-image (Fischbacher and Föllmi-Heusi, 2013; Mazar et al., 2008), adhere to social norms (Rauhat, 2013), or care about social image concerns (Gneezy et al., 2018). It is unclear how these preferences shift when groups are formed, and thus it is difficult to say a priori whether groups would be more or less likely to lie than individuals. Therefore, this question can only be answered empirically. Previous experimental research on group versus individual lying behavior found that groups do the same as, or are somewhat more inclined to lie than individuals (Sutter, 2009; Cohen et al., 2009; Chytilová and Korbel, 2014; Muehlheusser et al., 2015; Kocher et al., 2018).

The important difference that distinguishes our experimental design from previous studies is that each group consists of two friends who know each other well, whereas previous studies investigate the behavior of randomly formed groups.[1] There are two reasons why we adopted groups of friends. First, it is means of facilitating discussion within a group. To reach a decision, subjects may need to discuss matters which include delicate or unethical content. Subjects may hesitate to do so if their group member is someone who they have just met for the first time. Furthermore, a lack of communication or social skills may affect the decision of randomly formed groups. The second reason is due to practical relevance. Cheating behavior observed in many real-life situations is by a small group of acquaintances, not strangers. This design allows us to study the decisions by groups which are closer to reality.

We found that the distribution of reported numbers was significantly different from the uniform distribution for both individuals and groups. The lying pattern of individuals is in line with previous findings. Groups were more inclined to disguise their lies in several ways: (1) the fraction of the number with the highest monetary payoff was not significantly different from 1/6; (2) the number with the third highest monetary payoff was

[1] The exception is Chytilová and Korbel (2014) who investigate the effects of friendship ties of high school students on lying behavior.

reported most frequently; and (3) four dice numbers with higher monetary payoffs were reported more frequently than 1/6, whereas it was two dice numbers for individuals.

Another contribution of this study is that we compare the preference of individuals and groups for lying aversion by estimating the preference parameter(s) of the existing models from the experimental data. As noted above, since it is unclear a priori how the preference for lying aversion would shift under group decisions, it is important to evaluate them a posteriori. We focused on two models which include social image concerns: the model with perceived size of the lie from Dufwenberg and Dufwenberg (2018) and the model with cost of lying and likelihood to be perceived as a liar from Khalmetski and Sliwka (2019).

We found that under Dufwenberg and Dufwenberg's (2018) model, sensitivity to the size of the lie they are perceived to take is similar between individuals and groups. Under the model of Khalmetski and Sliwka (2019), groups are significantly more sensitive to the likelihood that they are perceived as liars, and have, on average, a lower cost of lying than individuals. Furthermore, we examine how well these theories capture the observed lying patterns. Both models fit better with the individual data than the group data. The model in Khalmetski and Sliwka (2019) fits better with the group data than the model in Dufwenberg and Dufwenberg (2018), whereas we are unable to conclude which model fits better with the individual data.

The paper is organized as follows. Section 2 presents our experimental design that allows us to analyze the lying behavior of individuals and groups. Section 3 reviews existing studies on group versus individual lying behavior. Section 4 reports the results of the experiment and statistical tests. Section 5 reports how the preferences for lying aversion are different between individuals and groups under the models. Section 6 provides conclusions to the findings.

2 Experimental Design

Our experiment uses a variant of a well-known paradigm for studying lying behavior, developed by Fischbacher and Föllmi-Heusi (2013) (henceforth, F&FH), in which subjects privately roll a six-sided dice, and report the number they have observed. The payments were made based on the reported numbers as follows: JPY600 for one, JPY700 for two, JPY800 for three, JPY900 for four, JPY1,000 for five, and JPY500 for six.[2] The payments were made in recompense for completing a questionnaire. Under self-interested preferences, a player will choose to report five, thus gaining the maximum amount of payment, regardless of the actual number on the dice.

There are two treatments in our experiment: individual treatment and group treatment. In each experimental session for both treatments, only two subjects participated. They are friends who know each other well. First, they received and read the consent form approved by the Institutional Review Board at the Kochi University of Technology and signed their agreement. Following this, each received an envelope which included the questionnaire, and they were directed to move to two different rooms to complete the form in private. The questionnaire was about the relationship between the subject and his/her friend with whom they attended the session.[3] After completing the questionnaire, the subjects returned to the room where the experimenter waited. The procedures that follow distinguish our experiments between the individual and group treatments.

In the individual treatment, each subject received another envelope which included a six-sided dice and a copy of instructions that explained the procedure of determination for the payment.[4] They were again directed to move to two distinct rooms and asked to follow the instructions provided and return to the room where the experimenter waited. Since the subjects were asked to open the envelope after entering the room, they could not communicate with their friend on the decision of a report.

In the group treatment, two subjects received an envelope and were directed to move to one room with their friend, and asked to follow the instructions. They had to jointly report one number and were aware that each would be paid according to the reported number.

[2]JPY100 translates to about USD0.885 at the exchange rate at the time the experiments took place.

[3]Supplementary Appendix A describes the details of the questionnaire and reports the results of statistical tests comparing the answers between the individual and group treatments. Most answers (all except for Q2 of part 2) were not significantly different between treatments. This indicates that the gender and affiliation compositions and friendship ties are similar between treatments, and that the difference in behavior can be attributed to the difference in treatments.

[4]See Supplementary Appendix C for details of the instructions.

In both treatments, subjects were allowed to roll the dice more than once in order to check whether the dice was balanced. However, they were strictly requested to fill out the number at the first throw. After filling out the number on the sheet, they put it back into the envelope and handed it to the experimenter to get paid. The rooms where the subjects rolled the dice were far from the room where the experimenter waited and thus subjects were easily aware that the conversation within a group could not be overheard, and that they were not being directly monitored by the experimenter.

All experimental sessions were conducted from October to November 2018 at Kochi University of Technology. The subjects were recruited from Kochi University of Technology and University of Kochi through crowd-based subject pool software, Sona Systems.[5] In total, 154 subjects participated in this experiment, of which 52 and 102 subjects participated in the individual and group treatments, respectively (and hence we have 52 and 51 throws). Each experimental session ended in around 10 minutes. None of the subjects participated in more than one session.

3 Related Literature

Before proceeding to the experiment's results, we will briefly review the existing studies on group versus individual lying behavior.

Muehlheusser et al. (2015) compared the lying behavior of two-person groups to that of individuals. Groups were randomly formed, and group members played the dice-rolling task in a booth that ensured complete privacy of decision making. They found no significant difference in lying behavior between individuals and groups.[6] One minor difference in experimental design from this study is that, in their experiment, 228 subjects were gathered at a time, and sequentially performed the dice-rolling task. It took about two hours for a whole experiment to be completed.

Kocher et al. (2018) examined the behavior of randomly formed three-person groups in which subjects could communicate with their group members via anonymous real-time

[5] https://www.sona-systems.com

[6] They found a significant difference in behavior when the data were divided according to gender composition.

chat. They found significant evidence that groups lie more than individuals, irrespective of payoff commonalities. The important difference of their design from ours is that the outcome of the dice-roll (shown at the screen display in front of the subjects) was known by the experimenter so the subjects could not disguise their lie. As a result, partial lying was a rare occurrence.

Chytilová and Korbel (2014) conducted a field experiment with adolescents in which subjects were paid in sweets. They found that, with younger students (from 11 to 13 years old), three-person groups lie more than individuals, whereas with older students (from 14 to 16 years old), there was no significant difference in lying behavior between individuals and groups. They also tested whether the process of group formation matters. Comparing randomly formed groups to groups that were formed of their own accord, they found that quickly formed groups and randomly formed groups lie to the same extent, and that slowly formed groups exhibited no evidence of cheating.

Sutter (2009) studied lying behavior of individuals and groups in the sender-receiver game developed by Gneezy (2005) in which the sender sends a message about the consequences of a given action to the receiver, and the receiver then decides to choose one of two actions which determines the payoffs of both the sender and receiver. He found that group senders chose the true message more often than individual senders. However, by eliciting the subject's belief about the receiver's action, he discovered that group senders expect the receiver not to follow the message and to choose the alternative action which, in turn, yields a higher payoff for the sender. Cohen et al. (2009) found that when the senders knew that the receiver was certain to follow the message, group senders lied more.

4 Results

Figure 1 shows the distribution of reported dice numbers where the percentage for six is placed leftmost to be the increasing order in payoff. Table 1 reports average payoff and the share of subjects who reported the corresponding number (in percent).

The average payoffs are 3.46 and 3.27 in the individual and group treatments, respec-

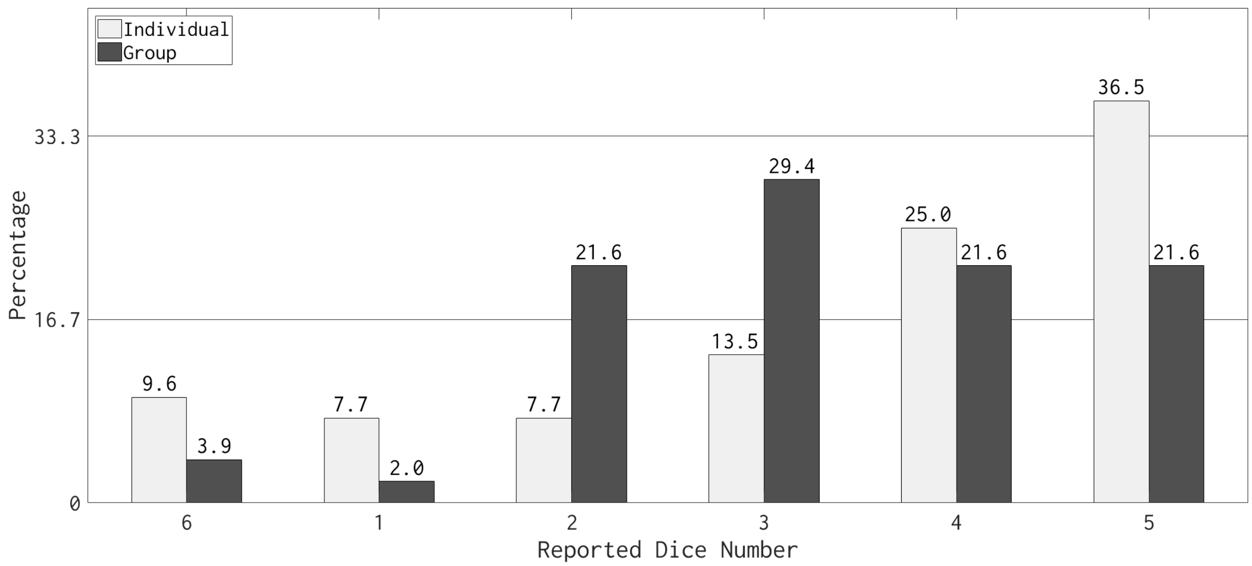

Figure 1: Distribution of reported dice numbers

Table 1: Average payoff and distribution of reports

		Dice number (percentage)					
	$\bar{\pi}$	6	1	2	3	4	5
Individual (N = 52)	3.46	9.62	7.69^{-}	7.69^{-}	13.46	25.00^{+}	36.54^{+++}
Group (N = 51)	3.27	3.92^{--}	1.96^{---}	21.57	29.41^{++}	21.57	21.57

Note: $\bar{\pi}$ indicates the average payoff with rescaling of the payoff to $\pi = 0$ for reporting six and $\pi = x$ for reporting $x \in \{1, \cdots, 5\}$. Plus and minus sign show the significance of a one-sided binomial test indicating that the observed relative frequency is larger (smaller) than 1/6: $^{+}$ ($^{-}$) = 10% level, $^{++}$ ($^{--}$) = 5% level, $^{+++}$ ($^{---}$) = 1% level.

tively, when rescaling the payoff so that $\pi = 0$ for reporting six and $\pi = x$ for reporting $x \in \{1, \cdots, 5\}$. The difference is not significant ($p = 0.208$, the two-tailed Wilcoxon rank-sum test).

The distribution of the individual treatment has a similar behavioral pattern to that of F&FH and the vast majority of studies that have used the same paradigm (Abeler et al., 2019).[7] It differs significantly from the uniform distribution that would result when all subjects report honestly ($p = 0.000$, the chi-square goodness-of-fit test). The distribution has a significant increasing trend in payoff at the 10% level ($p = 0.072$, $\rho = 0.812$, Spearman's rank correlation). Three and lower numbers are reported less frequently than the expected true value of 1/6 (16.7%), with the fraction of one and two being significantly less than 1/6 at the 10% level ($p = 0.119$ for six, $p = 0.061$ for one and two, and $p = 0.332$ for three, one-sided binomial test). The fractions of four and five are significantly above 1/6 (at the 10% level for four ($p = 0.077$) and 1% level for five ($p = 0.000$)).

The distribution of the group treatment is also significantly different from the uniform distribution ($p = 0.000$, the chi-square goodness-of-fit test), but it has quite different characteristics from that of the individual treatment. The increasing trend in payoff is not significant ($p = 0.183$, $\rho = 0.638$, Spearman's rank correlation). Only numbers six and one are reported less frequently than 1/6 ($p = 0.012$ for six, and $p = 0.004$ for one). Number three is reported most frequently and significantly above 1/6 ($p = 0.012$). Numbers two, four, and five are above but not significantly different from 1/6 ($p = 0.226$ in all cases).

Consequently, we observed several differences in behavior between individuals and groups. The hypothesis that two distributions of reports came from the same population is rejected at the 5% level ($p = 0.041$, the chi-square test). The fractions of two and three are significantly higher in the group treatment than in the individual treatment at the 5% level ($p = 0.046$ for two, and $p = 0.048$ for three, the chi-square test). Conversely, number five is significantly less frequently reported in the group treatment than in the individual treatment at the 10% level ($p = 0.095$). When combining the frequencies of six and one,

[7]When comparing to the baseline treatment of F&FH, we could not find a significant difference in payoff ($p = 0.965$, the two-tailed Wilcoxon rank-sum test), frequency of a given number ($p = 0.897$ for one, $p = 0.404$ for two, $p = 0.860$ for three, $p = 0.731$ for four, $p = 0.823$ for five, and $p = 0.391$ for six, the chi-square test), and frequency of all numbers ($p = 0.895$, the chi-square test).

they are significantly lower in the group treatment than in the individual treatment at the 10% level ($p = 0.071$).[8]

In summary, these observations suggest the following characteristics in group lying behavior compared with individuals:

- *Groups also tell a lie.*

  Though the average payoff was lower in the group treatment, our findings do not suggest that groups are more likely to report honestly. Note that six and one are the numbers that make subjects feel tempt to misreport. Groups reported these numbers less frequently than individuals. This indicates that groups might have lied with the same or greater frequency than individuals.

- *Partial lying is more pronounced.*

  Income-maximizing liars (who lie to five) decreased, and partial liars (who lie to non-maximal payoffs) reported four and lower numbers (two and three) as well. As a result, the range to which groups lie became broader, since the numbers with relative frequency above 1/6 are from two to five in the group treatment, whereas in the individual treatment these are only four and five. This indicates that groups are more likely to disguise their lie.

5 Theories of Lying Aversion and Preference of Groups

This section compares the preferences for lying aversion between individuals and groups by estimating the model parameters of the existing models from our experimental data. We also address how well these theories explain the behavioral pattern of individuals and groups. Among the many theories of lying aversion, we focus on the models proposed by Dufwenberg and Dufwenberg (2018) and Khalmetski and Sliwka (2019).

Dufwenberg and Dufwenberg (2018) (henceforth, D&D) incorporate disutility from the size of the lie perceived by the audience (e.g., experimenter). Khalmetski and Sliwka

[8]When testing these numbers separately, the differences are not significant ($p = 0.251$ for six, and $p = 0.176$ for one).

(2019) (henceforth, K&S) consider the cost of lying and disutility from the probability that the agent is perceived as a liar by the audience. These studies characterize the unique equilibrium under certain assumptions, which permits us to conduct the estimation easily. Furthermore, Abeler et al. (2019) clarify that, among 14 classes of model of lying aversion, the model with a cost of lying and social image concerns, like that of K&S, is one of those not falsified by a meta study using 90 experimental studies (decisions by more than 40,000 subjects) and by a series of new experiments conducted by them.[9] Though the model of D&D is not examined in the analysis of Abeler et al. (2019), it also explains the characteristics of the experimental data in the F&FH setting very well.

In this section, we rename the dice number of six as zero so that an agent privately observes a state (an integer number) $\omega \in \{0, 1, \ldots, 5\}$. He/she then reports an integer number $x \in \{0, 1, \ldots, 5\}$ to the audience. Let $p[\omega|x]$ be the probability that the audience thinks that the true state is ω when x is reported, with $p[\omega|x] \in [0, 1]$ for all ω, and $\sum_{\omega'} p[\omega'|x] = 1$. We next proceed to the details of two models and their equilibrium prediction.

5.1 Model with Perceived Size of the Lie

D&D analyze an agent with the following utility function:

$$u(x) = ax - \theta \sum_{\omega'} p[\omega'|x] a(x - \omega')^+,$$

where $a > 0$ and $(x - \omega')^+ = \max\{x - \omega', 0\}$. The first term ax is the monetary payoff by reporting x. The agent feels disutility from the audience's expectation about the amount of money taken by lying, $\sum_{\omega'} p[\omega'|x]a(x - \omega')^+$. The parameter $\theta \geq 0$ measures the agent's sensitivity to this reputation.

Let $s : \{0, \ldots, 5\} \to \Delta\{0, \ldots, 5\}$ be a behavioral strategy, and $s(x|\omega)$ denote the probability that s assigns to x after the agent observes ω. S denotes the agent's set of strategies. $s \in S$ is a sequential equilibrium if for $\omega, \omega', x \in \{0, \ldots 5\}$, we have $p[\omega|x] \in [0, 1]$, $\sum_{\omega} p[\omega|x] = 1$,

[9] Another class of models that is not falsified by the experimental data is the model with audience's belief about the agent's cost of lying, which is not examined in this study.

and the following two conditions: (a) $s(x|\omega) > 0 \Rightarrow x \in \operatorname{argmax}_{x'} u(x')$, and (b) $\sum_\omega s(x|\omega) > 0 \Rightarrow p[\omega'|x] = \frac{\frac{1}{6}s(x|\omega')}{\sum_\omega \frac{1}{6}s(x|\omega)} = \frac{s(x|\omega')}{\sum_\omega s(x|\omega)}$.[10]

D&D show that the sequential equilibrium $s \in S$ with the properties that

(1) if $x < \omega$, then $s(x|\omega) = 0$,

(2) if $\omega < 5$, then $s(5|\omega) = 1 - \varepsilon_5$ where $\varepsilon_5 \in (0,1)$, and

(3) if $\omega < x < 5$, then $s(x|\omega) = (1 - \varepsilon_x)\prod_{x+1 \le k \le 5} \varepsilon_k$ where $\varepsilon_k \in (0,1)$,

is uniquely determined for all $\theta > 2$.[11] Condition (1) means that the agent never lies downward. Conditions (2) and (3) indicate that the probability that the agent lies to x is the same for all $\omega < x$, which D&D call *uniform-cheating*. Since $s(\omega|\omega) = \prod_{\omega+1 \le k \le 5} \varepsilon_k$ for $\omega < 5$, and $\varepsilon_k \in (0,1)$, all numbers are reported with positive probability.

In any sequential equilibrium with the above properties, we have

$$1 - \varepsilon_x = \frac{2}{x(\theta - 2) + \theta} \tag{1}$$

for $x \in \{1, \cdots, 5\}$. This condition comes from the insight that, since all numbers will be reported with positive probability, the utility following any choice must be the same in equilibrium. Actually, the utility in equilibrium must be zero because $u(0) = 0$ (see section 3.4 and the proof of proposition in section 3.3 in D&D). Let $q_x(\theta)$ be the probability that

[10] Since subjects in our experiment received a monetary payoff of $ax + b$ ($a > 0$) when they reported $x \in \{0, 1, \ldots, 5\}$, it is appropriate to formulate the agent's utility function as

$$\tilde{u}(x) = ax + b - \theta \sum_{\omega'} p[\omega'|x]a(x - \omega')^+.$$

However, since b is constant, the agent's optimization problem

$$\max_{x \in \{0,\ldots,5\}} \quad ax + b - \theta \sum_{\omega'} p[\omega'|x]a(x - \omega')^+$$

is equivalent to

$$\max_{x \in \{0,\ldots,5\}} \quad ax - \theta \sum_{\omega'} p[\omega'|x]a(x - \omega')^+.$$

Therefore, equilibrium prediction under the model with $\tilde{u}(x)$ is equivalent to the one under the D&D model.

[11] D&D analyze a more general case where the number of states is $K \ge 1$ instead of 5, and the probability of each state occurring is not uniform.

the agent reports $x \in \{0, \ldots, 5\}$ in equilibrium in the D&D setting. Then, we have

$$q_x(\theta) = \sum_{\omega \le x} \frac{1}{6} s(x|\omega) = \begin{cases} \frac{1}{6} \prod_{1 \le k \le 5} \varepsilon_k & \text{if } x = 0 \\ \frac{1}{6}[x(1-\varepsilon_x)+1] \prod_{x+1 \le k \le 5} \varepsilon_k & \text{if } x \in \{1, \ldots, 4\} \\ \frac{1}{6}[5(1-\varepsilon_5)+1] & \text{if } x = 5. \end{cases}$$

Using (1), we obtain the equilibrium distribution of reports. The following claim holds.

Claim 1. *The equilibrium distribution of reports in the D&D model, $q_x(\theta)$, has the following properties:*

(i) (a) When $\theta \to 2$ (from above), $q_5(\theta) \to 1$, and $q_x(\theta) \to 0$ for $x \in \{0, \ldots, 4\}$. (b) When $\theta \to \infty$, $q_x(\theta) \to 1/6$ for all x.

(ii) (a) $q_5(\theta)$ is strictly decreasing in $\theta > 2$. (b) $q_0(\theta)$ and $q_1(\theta)$ are strictly increasing in $\theta > 2$. (c) For $x \in \{2, 3, 4\}$, there exists $\theta > 2$ such that $q_x(\theta) > 1/6$.

(iii) $q_x(\theta)$ is strictly increasing in x for all $\theta > 2$.

Proof. See Supplementary Appendix B. □

(i) describes results on limits of θ. (a) says that, when θ is sufficiently close to two (from above), the behavior is equivalent to the income-maximizing behavior. In contrast, we will show that (b) holds by proving that, when $\theta \to \infty$, $s(\omega|\omega) \to 1$, indicating that the agent always tells the truth as θ becomes sufficiently large. (ii) describes how the probability of reporting each number varies with θ. (a) indicates that when θ increases, partial lying and/or truth-telling are more revealed. (b) states that the two lowest numbers (zero and one) are reported more frequently when θ increases. (c), combined with (i), says that the fractions of reporting two, three, and four increase in some range of θ, decrease in the other range. Finally, (iii) means that higher numbers are reported more frequently for all $\theta > 2$.

5.2 Model with Cost of Lying and Likelihood to be Perceived as a Liar

K&S consider an agent with the following utility function:

$$u(x) = x - c \cdot I(x, \omega) - \eta \sum_{\omega' \neq x} p[\omega'|x],$$

where $x \in \{0, \ldots, 5\}$ is the monetary payoff by reporting x, $c > 0$ is a fixed cost of lying, $I(x, \omega)$ is the indicator function taking one if $x \neq \omega$ and zero otherwise, $\sum_{\omega' \neq x} p[\omega'|x]$ is the likelihood that the audience thinks that the agent has told a lie when x is reported, and $\eta > 0$ captures the sensitivity to this reputation.[12] The cost of lying c is assumed to be distributed according to a strictly increasing continuous cdf $F(c)$ with $F(0) = 0$. Furthermore, $F(5 + \eta) < 1$ is assumed, which ensures that in any equilibrium, all numbers are reported with positive probability.

We again define sequential equilibrium under this setting. Let $s : \{0, \ldots, 5\} \times \mathbb{R}_+ \to \Delta\{0, \ldots, 5\}$ be a behavioral strategy, and $s(x|\omega, c)$ denote the probability that s assigns to x after the agent observes ω and c. $s \in S$ is a sequential equilibrium if for $\omega, \omega', x \in \{0, \ldots, 5\}$, we have $p[\omega|x] \in [0, 1]$, $\sum_\omega p[\omega|x] = 1$, and the following two conditions: (a) $s(x|\omega, c) > 0 \Rightarrow x \in \mathrm{argmax}_{x'}\ u(x')$, and (b) $\sum_\omega \int_0^\infty s(x|\omega, c) dF(c) > 0 \Rightarrow p[\omega'|x] = \frac{\int_0^\infty s(x|\omega', c) dF(c)}{\sum_\omega \int_0^\infty s(x|\omega, c) dF(c)}$.[13]

[12] Gneezy et al. (2018) analyze a more general utility function and examine the model prediction experimentally.

[13] Since our subjects receive monetary payoff of $ax + b$ ($a > 0$), it is appropriate to formulate the agent's utility function as

$$\hat{u}(x) = ax + b - \hat{c} \cdot I(x, \omega) - \hat{\eta} \sum_{\omega' \neq x} p[\omega'|x]$$

where $\hat{c}, \hat{\eta} > 0$. Note that, since b is constant, the agent's optimization problem

$$\max_{x \in \{0, \ldots, 5\}} \quad ax + b - \hat{c} \cdot I(x, \omega) - \hat{\eta} \sum_{\omega' \neq x} p[\omega'|x]$$

is equivalent to the problem

$$\max_{x \in \{0, \ldots, 5\}} \quad ax - \hat{c} \cdot I(x, \omega) - \hat{\eta} \sum_{\omega' \neq x} p[\omega'|x].$$

Furthermore, since $a > 0$, it is also equivalent to the problem

$$\max_{x \in \{0, \ldots, 5\}} \quad x - \frac{\hat{c}}{a} \cdot I(x, \omega) - \frac{\hat{\eta}}{a} \sum_{\omega' \neq x} p[\omega'|x].$$

Let $\eta = \frac{\hat{\eta}}{a}$. Then, $\eta > 0$. Furthermore, we assume that $c = \frac{\hat{c}}{a}$ is distributed according to a strictly increasing continuous cdf $F(c)$ with $F(0) = 0$ and $F(5 + \eta) < 1$. Then, this situation is equivalent to the one under the

K&S show that there are many payoff equivalent equilibria that yield the same distribution of reports. More precisely, they show that, given $\eta > 0$ and $F(\cdot)$, there exists a constant $\rho \in (\max\{0, 5-\eta\}, 5)$ such that, in any equilibrium, for all $x \geq m(\rho)$ where $m(\rho) = \min\{x \in \{1, \ldots, 5\} | x > \rho\}$,

$$x - \eta \sum_{\omega' \neq x} p[\omega' | x] = \rho,$$

and ρ is uniquely determined by the equation,

$$\sum_{\omega=0}^{m(\rho)-1} F(\rho - \omega) = \sum_{x=m(\rho)}^{5} \left(\frac{x - \rho}{\eta - x + \rho} \right) \tag{2}$$

(see Proposition 1 and Theorem 1 in K&S).[14] Let $q_x(\rho)$ be the probability that the agent reports $x \in \{0, \ldots, 5\}$ in equilibrium in the K&S setting. K&S show that

$$q_x(\rho) = \begin{cases} \dfrac{\eta}{6(\eta - x + \rho)} & \text{if } x \geq m(\rho) \\ \frac{1}{6}(1 - F(\rho - x)) & \text{if } x < m(\rho) \end{cases}$$

(see Proposition 2).[15]

K&S show that agents who observe $\omega < m(\rho)$ either report the true state or lie to a number $x \geq m(\rho)$, and that agents who observe $\omega \geq m(\rho)$ always report honestly (see Proposition 1 in K&S). When η increases, $m(\rho)$ weakly decreases and the probability that an agent lies strictly decreases (see Proposition 5 in K&S). In other words, higher social image concerns enlarge the set of numbers that agents misreport, while they reduce the fraction of liars. Furthermore, when η becomes sufficiently large, all numbers besides zero are reported by liars (see Proposition 6 in K&S). When the distribution of the cost of lying F increases in the sense of first-order stochastic dominance, $m(\rho)$ weakly increases and the probability that an agent lies strictly decreases (see Proposition 7 in K&S). In other words, a higher cost of lying decreases the range of numbers reported by liars and decreases the

K&S model.

[14] K&S analyze a more general case where the number of states is $K \geq 2$, instead of 5.

[15] K&S also show that, under the assumption of uniform-cheating where $s(x|\omega, c) = s(x)$ for any $\omega < m(\rho)$, $x \geq m(\rho)$, and $c < \rho - \omega$, there is a unique sequential equilibrium (Proposition 3).

fraction of liars. Finally, as under the D&D model, the higher the value of x the higher is the likelihood that x is reported for any η and $F(\cdot)$ (see Proposition 2 in K&S).

5.3 Estimation Strategy

We will perform the maximum likelihood estimation. Let n_x be the frequency of report $x \in \{0 \ldots, 5\}$ observed in the experiment, and q_x be the equilibrium probability of reporting x in the model. Then, the log-likelihood function is given as:

$$LL = \sum_x n_x \log q_x.$$

We will find $\theta > 2$ that maximizes the LL in the estimation of the D&D model.

In the estimation of the K&S model, we assume that the cost of lying is distributed as a gamma distribution with the shape parameter $\alpha > 0$ and scale parameter $\beta > 0$. The application of gamma distribution provides a plausible explanation for the distribution of the cost of lying. It is likely that: some non-negligible fraction of people have a small cost of lying; the majority of people feel some extent of cost; and a small fraction of people feel extremely high cost. Gamma distribution allows the distribution with these characteristics. Since gamma distribution with α and β as free parameters becomes quite flexible, we fix β to be two in the estimation process, which is equivalent to the chi-square distribution with degree of freedom 2α. Therefore, we will find $\eta > 0$ and $\alpha > 0$ that maximize the LL in the K&S model.

5.4 Results

Table 2 reports the estimated parameters. Although ρ is not a parameter to be estimated in the K&S model, we report its values because it is an important factor to characterize the lying behavior. Figures 2 and 3 display the distribution of reports from our experiment (black) and the percentages predicted under the models with estimated parameter(s) (gray for the D&D model and white for the K&S model, respectively).

We first look at the results of the D&D model. The estimated θs are 3.912 for individuals

Table 2: Estimated parameters

	D&D		K&S			
	θ	LL	η	α	ρ	LL
Individual	3.912	−86.471	2.928	1.569	3.405	−84.723
	(0.704)		(1.441)	(0.537)		
Group	3.937	−84.281	8.223	0.276	1.400	−82.154
	(0.690)		(1.938)	(0.242)		

Note: Numbers in parentheses represent standard deviation.

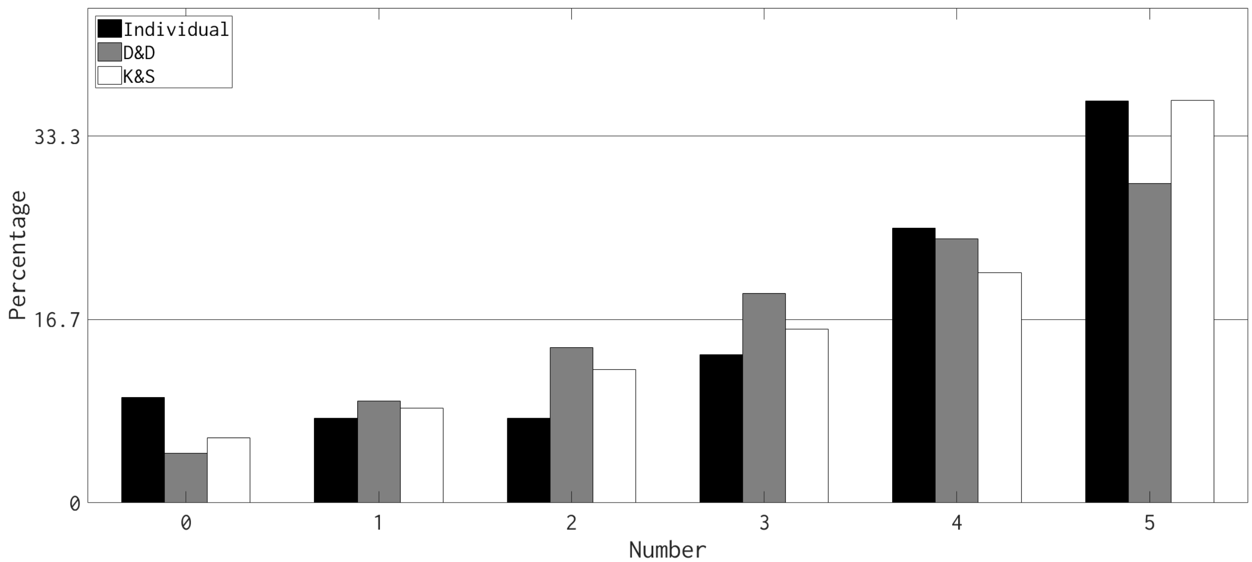

Figure 2: Comparison between theory and data (individual treatment)

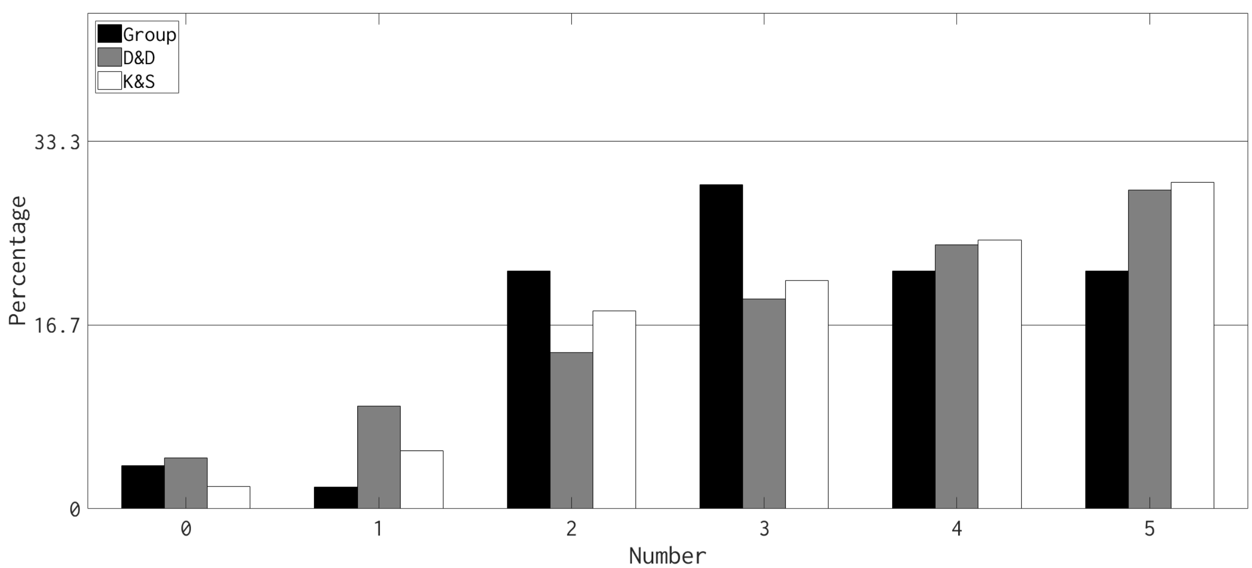

Figure 3: Comparison between theory and data (group treatment)

and 3.937 for groups. Recall that when θ is sufficiently close to 2, the behavior is equivalent to the income-maximizing behavior (see (i) of claim 1). Therefore, both individuals and groups are, to some extent, sensitive to the amount of money on which they are perceived to cheat. The θ for groups is not significantly different from that for individuals ($p = 0.971$, t-test, and $p = 0.971$, likelihood ratio test), indicating that sensitivity to the perceived size of the lie is similar between individuals and groups under the D&D model. Since a higher θ results in more partial lying, we might expect that the estimated θ for groups becomes strictly higher than that for individuals, but it is not the case. One reason is that a higher θ also leads to higher fractions of zero and one, which is a worse fit with the data of groups (see (ii) of claim 1).

In contrast, in the K&S model, the parameter values are quite different between individuals and groups. The value of η for groups (8.223) is significantly higher than that for individuals (2.928) ($p = 0.009$, t-test, and $p = 0.002$, likelihood ratio test). This indicates that, under the K&S model, groups are more sensitive to the social image concerns not to be viewed as a liar. This observation is consistent with the theoretical finding that higher social image concerns (higher η) have an effect which leads agents to deviate to lower numbers.

The values of α are 1.569 and 0.276 in the individual and group treatments, respectively. The α for groups is significantly lower than that for individuals ($p = 0.000$, t-test, and $p = 0.009$, likelihood ratio test). The average values for the cost of lying are calculated as 3.138 and 0.552 in the individual and group treatments, respectively.[16] Hence, the cost of lying takes, on average, smaller values in the group treatment. Theoretically, a lower cost of lying also has the effect that lower numbers are reported by liars, indicating that the fractions of lower numbers become greater than 1/6, which is consistent with our findings.

As noted in section 5.2, agents who observe $\omega < m(\rho)$ either report the true state or lie to a number $x \geq m(\rho)$, and agents who observe $\omega \geq m(\rho)$ always report honestly. Since $m(\rho) = \min\{x \in \{1, \ldots, 5\} | x > \rho\}$, estimated $m(\rho)$ is four in the individual treatment and two in the group treatment. This is again consistent with the finding that the lowest number whose fraction is above 1/6 is four in the individual treatment, while it is two in the group

[16]The mean of gamma distribution is calculated by $\alpha\beta$.

Table 3: Performance of the D&D model

	Goodness-of-fit		Payoff (percentage)					
	SSE	*SAE*	0	1	2	3	4	5
Individual	0.016	0.271	4.53^{-}	9.27	14.11	19.04	24.02	29.04
Group	0.028	0.356	4.60	9.34^{+}	14.16^{-}	19.04^{--}	23.96	28.90

Note: Plus and minus sign show the significance of a one-sided binomial test indicating that the predicted probability under the D&D model is larger (smaller) than the observed relative frequency: $^{+}$ ($^{-}$) = 10% level, $^{++}$ ($^{--}$) = 5% level, $^{+++}$ ($^{---}$) = 1% level.

treatment.

5.5 Performance of the Models

Here, we assess how well the theories examined here capture the behavioral characteristics of our experimental data. In the individual treatment (Figure 2), the predicted distributions adhere to the experimental data very well for both models. In the group treatment (Figure 3), some predicted numbers depart from the experimental data. These discrepancies are partly caused by the increasing trend of the distribution of reports in payoff under both models, whereas the distribution of the experimental data has a peak at three.[17]

Table 3 reports two types of measure for goodness-of-fit of the model and predicted probabilities of reports in the D&D model. For the goodness-of-fit measure, we used the sum of squared errors (*SSE*) and sum of absolute errors (*SAE*) between the observed and predicted values. The *SSE* and *SAE* are defined as:

$$\begin{aligned} SSE &= \sum_x (r_x - q_x^*)^2, \text{ and} \\ SAE &= \sum_x \left| r_x - q_x^* \right|, \end{aligned}$$

where r_x is the relative frequency of report $x \in \{0, \ldots, 5\}$, and q_x^* is the predicted probability of x under the model with estimated parameter(s).[18] For both measures, the values are

[17] Recall that the equilibrium probabilities of report x are strictly increasing in x for any parameter value(s) under both models.

[18] These two measures have a different preference for the goodness-of-fit. The *SSE* often prefers small

Table 4: Performance of the K&S model

	Goodness-of-fit		Payoff (percentage)					
	SSE	*SAE*	0	1	2	3	4	5
Individual	0.006	0.156	5.92	8.63	12.13	15.80	20.91	36.60
Group	0.018	0.284	2.02	5.29	17.98	20.69^{-}	24.37	29.64

Note: Plus and minus sign show the significance of a one-sided binomial test indicating that the predicted probability under the K&S model is larger (smaller) than the observed relative frequency: $^{+}$ ($^{-}$) = 10% level, $^{++}$ ($^{--}$) = 5% level, $^{+++}$ ($^{---}$) = 1% level.

smaller in the individual treatment than in the group treatment, indicating that the D&D model fits better with the individual data than the group data. The chi-square goodness-of-fit test reveals that the observed frequencies of groups are significantly different from the equilibrium prediction under the D&D model at the 10% level ($p = 0.062$), whereas those of individuals are not ($p = 0.164$). In the individual treatment, the model significantly underpredicted the frequency of zero at the 10% level ($p = 0.076$, one-sided binomial test). For all the other numbers, the difference between the predicted and observed percentages is not statistically significant ($p = 0.440$ for one, $p = 0.129$ for two, $p = 0.198$ for three, $p = 0.498$ for four, and $p = 0.150$ for five). In the group treatment, the model significantly overpredicted the frequency of one, and underpredicted that of two and three ($p = 0.058$ for one, $p = 0.094$ for two, and $p = 0.044$ for three).[19]

Table 4 reports the goodness-of-fit of the K&S model. Again, both *SSE* and *SAE* are smaller in the individual treatment than in the group treatment, indicating that the K&S model is a better fit with the individual data than the group data. The chi-square goodness-of-fit test reveals that the observed frequencies of both individuals and groups are not significantly different from equilibrium prediction under the K&S model ($p = 0.442$ for individuals, and $p = 0.138$ for groups). In the individual treatment, the K&S model neither under- nor overpredicted the frequency for all numbers ($p = 0.202$ for zero, $p = 0.502$ for one, $p = 0.221$ for two, $p = 0.392$ for three, $p = 0.290$ for four, and $p = 0.554$ for five). In

errors for many categories to big errors for a few categories, compared with *SAE*. For example, consider case A in which $r_x - q_x^* = 0.1$ for all x, and case B in which $r_0 - q_0^* = 0.3$ and $r_x - q_x^* = 0$ for $x \in \{1, \ldots, 5\}$. Then, the *SSE* prefers case *A*, whereas *SAE* prefers case B.

[19] The p-values of the binomial test for the other numbers are $p = 0.542$ for zero, $p = 0.407$ for four, and $p = 0.158$ for five.

Table 5: Information criteria

	Individual		Group	
	AIC	*BIC*	*AIC*	*BIC*
D&D	174.94	176.89	170.56	172.49
K&S	173.45	177.35	168.31	172.17

Note: The AIC is given as $-2LL^* + 2m$, and the BIC is given as $-2LL^* + m \log(N)$, where LL^* is the maximized log-likelihood, m is the number of parameters in the model, and N is the number of observations.

the group treatment, the model significantly underpredicted the frequency of three at the 10% level ($p = 0.086$).[20]

Finally, we address the question of which model fits better with the experimental data. Comparing Tables 3 and 4, the K&S model outperforms the D&D model in many respects. For both the individual and group data, the SSE and SAE scores are smaller in the K&S model than in the D&D model. In the chi-square goodness-of-fit test for the group data, the prediction under the D&D model significantly differs from the observed data, whereas the prediction under the K&S model does not.[21] The number of rejections in the binomial tests for a given number is lower in the K&S model than in the D&D model.

However, a model with many parameters generally becomes flexible, meaning that it fits the observed data better than the models with fewer parameters. To compare the performance between models with different numbers of parameters, penalized-likelihood information criteria are widely used. We used the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). The AIC is given as $-2LL^* + 2m$, and the BIC is given as $-2LL^* + m \log(N)$, where LL^* is the maximized log-likelihood, m is the number of parameters in the model, and N is the number of observations. The model with the smaller information criterion is preferred.

Table 5 reports the AIC and BIC. For the individual data, we are unable to draw conclusions on which model is better. Based on AIC, the K&S model fits better with the data, whereas based on BIC the D&D model fits better. In contrast, for the group data, the

[20]The p-values of the binomial test for the other numbers are $p = 0.320$ for zero, $p = 0.227$ for one, $p = 0.314$ for two, $p = 0.381$ for four, and $p = 0.134$ for five.

[21]For the individual data, the predictions under both the D&D and K&S models do not significantly differ from the observed data.

K&S model fits better than the D&D model based on both *AIC* and *BIC*.

6 Conclusions

We compared the lying behavior of groups and individuals in the dice-rolling task developed by Fischbacher and Föllmi-Heusi (2013) and clarified the differences. The experimental data suggest that groups are more likely to disguise their lie: the fractions of reporting five which results in the maximum monetary payoff is significantly lower, and the range of numbers whose fraction is above 1/6 is broader in the group treatment than in the individual treatment. These findings have important welfare implications. On the one hand, an average size of ill-gotten profit becomes lower for groups, but on the other hand, it becomes harder to infer whether a group is lying or not from observing a lower report, which suggests that detecting an act of dishonesty by a group is costly.

We further compared the preference of groups and individuals for lying aversion by estimating the model parameter(s) of the models by Dufwenberg and Dufwenberg (2018) and Khalmetski and Sliwka (2019). Under the model of Dufwenberg and Dufwenberg (2018), the sensitivity to the perceived size of the lie is statistically similar between groups and individuals. Under Khalmetski and Sliwka's (2019) model, groups are statistically more sensitive to the likelihood that they are perceived as a liar and have a lower psychological cost of lying than individuals. These findings help us to understand the reason why the lying behavior of groups is different from that of individuals. It would also be important to measure the sensitivity to the preference for lying aversion not examined in this study. This is left for future work.

Finally, we observed that the models examined here failed to capture the characteristics of group lying behavior that the distribution of reports have a peak at three. This discrepancy partly comes from the theoretical results that, under both models, the number with higher monetary payoff is reported more frequently for any parameter value(s). This finding may provide a new direction for the improvement of the models for lying aversion.

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Supplementary Appendix to "Groups Disguise Lying Better"

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Contents

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A Questionnaire

Table A1 reports the results of the questionnaire and statistical tests that examine the difference between treatments. Part (1) asks each subject's gender and affiliation. We report the number and its share (in parentheses) of groups which consisted of two females, one female and one male, and two males in the gender entry; and the number and its share (in parentheses) of groups which comprised two, one, and no economics/management student(s) in the affiliation entry. Part (2) asks about the relationship between the subject and the friend with whom he/she attended the experiment. We report the average and the standard deviation (in parentheses) of answers. All answers in part (2) may be correlated within a group. In order to perform the statistical tests, we processed the data in the following way. In Q1 and Q4, we performed the Wilcoxon rank-sum test (WRS test) with the average answer within a group being the unit of observation. In Q2, Q3, Q7, Q8, Q9, and Q10 using a seven-point Likert scale, we reported two results of the Wilcoxon rank-sum test. In one test, the unit of observation is the minimum of the answers within a group, while in the other, it is the maximum. In the chi-square test of Q5 and Q6, we counted one if both subjects in a group answered yes, and zero otherwise.

Table A1: Results of questionnaire and statistical tests

		Treatment		p-value of
		Individual	Group	statistical test
(1) Please tell us about yourself.				
Gender:	Two females	6 (23.1%)	16 (31.4%)	0.748
	One female and one male	4 (15.4%)	7 (13.7%)	(χ^2 test)
	Two males	16 (61.5%)	28 (54.9%)	
Affiliation:	Two Economics/Management students	7 (26.9%)	24 (47.1%)	0.234
	One Economics/Management student	2 (7.7%)	3 (5.9%)	(χ^2 test)
	No Economics/Management student	17 (65.4%)	24 (47.1%)	
(2) Please answer the following questions regarding the friend with whom you came today.				
Q1. How long have you known each other? ( ) years		2.22 (1.52)	2.26 (3.15)	0.257 (WRS test)
Q2. Have you ever made any decision in accordance with your friend's decision, or changed your choice as a result of your friend's influence? Likert scale: 1 (Not at all), 7 (Very much)		4.33 (1.28)	4.83 (1.41)	min: 0.248 max: 0.017 (WRS test)
Q3. Have you ever been helped or supported by your friend? Likert scale: 1 (Not at all), 7 (Very much)		6.00 (1.03)	6.12 (0.95)	min: 0.714 max: 0.664 (WRS test)
Q4. How frequently do you meet your friend in a week? ( ) days		4.80 (1.65)	4.48 (1.66)	0.295 (WRS test)
Q5. Do you usually have meals or enjoy leisure activities together? 1 (Yes), 0 (No)		0.88 (0.26)	0.88 (0.31)	0.529 (χ^2 test)
Q6. Do you plan to continue to meet after graduation? 1 (Yes), 0 (No)		0.92 (0.18)	0.91 (0.24)	0.844 (χ^2 test)
Q7. How close do you feel toward your friend? Likert scale: 1 (Not at all), 7 (Very much)		6.13 (0.95)	6.25 (0.96)	min: 0.493 max: 0.499 (WRS test)
Q8. How do you think your friend answered Q7? Likert scale: 1 (Not at all), 7 (Very much)		5.56 (1.04)	5.61 (1.11)	min: 0.674 max: 0.448 (WRS test)
Q9. How much do you trust your friend? Likert scale: 1 (Not at all), 7 (Very much)		6.25 (0.71)	6.32 (0.89)	min: 0.855 max: 0.126 (WRS test)
Q10. How do you think your friend answered Q9? Likert scale: 1 (Not at all), 7 (Very much)		5.27 (1.29)	5.50 (1.15)	min: 0.292 max: 0.571 (WRS test)

B Equilibrium Lying Behavior of the D&D Model

This section provides proof of the claim for the characteristics of equilibrium lying behavior of the model with the perceived size of the lie in Dufwenberg and Dufwenberg (2018).

Claim 1. *The equilibrium distribution of reports in the D&D model, $q_x(\theta)$, has the following properties:*

(i) (a) When $\theta \to 2$ (from above), $q_5(\theta) \to 1$, and $q_x(\theta) \to 0$ for $x \in \{0, \ldots, 4\}$. (b) When $\theta \to \infty$, $q_x(\theta) \to 1/6$ for all x.

(ii) (a) $q_5(\theta)$ is strictly decreasing in $\theta > 2$. (b) $q_0(\theta)$ and $q_1(\theta)$ are strictly increasing in $\theta > 2$. (c) For $x \in \{2, 3, 4\}$, there exists $\theta > 2$ such that $q_x(\theta) > 1/6$.

(iii) $q_x(\theta)$ is strictly increasing in x for all $\theta > 2$.

Proof. (i)(a) It suffices to show that, when $\theta \to 2$ (from above), $s(5|\omega) \to 1$ for all $\omega < 5$. Under the equilibrium,

$$1 - \varepsilon_x = \frac{2}{x(\theta - 2) + \theta} \tag{1}$$

is satisfied for all $\theta > 2$ and $x \in \{1, \ldots, 5\}$ (see section 3.4 and the proof of proposition in section 3.3 in D&D). Since $s(5|\omega) = 1 - \varepsilon_5$ for $\omega < 5$ from the construction of the strategy, we have $s(5|\omega) \to 1$ as $\theta \to 2$ for all $\omega < 5$.

(b) It suffices to show that, when $\theta \to \infty$, $s(\omega|\omega) \to 1$ for all ω. First, note that since there is no downward lying from the construction of the strategy, we have $s(5|5) = 1$. Since $s(\omega|\omega) = \prod_{\omega+1 \leq k \leq 5} \varepsilon_k$ for $\omega < 5$, we have $s(\omega|\omega) \to 1$ as $\theta \to \infty$.

(ii)(a) It immediately follows from the observation that $q_5(\theta) = \frac{1}{6}[5(1 - \varepsilon_5) + 1]$, and that $1 - \varepsilon_5 = \frac{2}{5(\theta-2)+\theta}$ is strictly decreasing in $\theta > 2$.

(b) For $q_0(\theta)$, it immediately follows from the observation that $q_0(\theta) = \prod_{1 \leq k \leq 5} \varepsilon_k$, and that $\varepsilon_k = 1 - \frac{2}{k(\theta-2)+\theta}$ is strictly increasing in $\theta > 2$ for all $k \in \{1, \ldots, 5\}$.

Differentiating $q_1(\theta) = \frac{1}{6}(2-\varepsilon_1)\prod_{2\le k\le 5}\varepsilon_k$, we have

$$\begin{aligned} q_1'(\theta) &= \frac{1}{6}[-\varepsilon_1'\varepsilon_2\varepsilon_3\varepsilon_4\varepsilon_5 + (2-\varepsilon_1)\varepsilon_2'\varepsilon_3\varepsilon_4\varepsilon_5 + \\ &\quad +(2-\varepsilon_1)\varepsilon_2\varepsilon_3'\varepsilon_4\varepsilon_5 + (2-\varepsilon_1)\varepsilon_2\varepsilon_3\varepsilon_4'\varepsilon_5 + (2-\varepsilon_1)\varepsilon_2\varepsilon_3\varepsilon_4\varepsilon_5'] \\ &> \frac{1}{6}\Big(-\varepsilon_1' + \sum_{2\le k\le 5}\varepsilon_k'\Big)\prod_{2\le l\le 5}\varepsilon_l, \end{aligned}$$

in which the inequality comes from the fact that $2-\varepsilon_1 > \varepsilon_x$ for all x. Since $\varepsilon_x > 0$, it suffices to show that $-\varepsilon_1' + \sum_{2\le k\le 5}\varepsilon_k' > 0$. Since $\varepsilon_x' = \frac{2(x+1)}{[x(\theta-2)+\theta]^2}$, we have

$$\begin{aligned} -\varepsilon_1' + \sum_{2\le k\le 5}\varepsilon_k' &= -\frac{1}{(\theta-1)^2} + \sum_{2\le k\le 5}\frac{2(k+1)}{[k(\theta-2)+\theta]^2} \\ &> -\frac{1}{(\theta-1)^2} + \sum_{2\le k\le 5}\frac{2(k+1)}{[5(\theta-2)+\theta]^2} \\ &= \frac{12\theta-16}{(\theta-1)^2(3\theta-5)^2} > 0, \end{aligned}$$

for $\theta > 2$.

(c) It is easy to see that

$$\begin{aligned} q_2(20) &= \frac{1}{6}\Big(3-2\cdot\frac{27}{28}\Big)\cdot\frac{36}{37}\cdot\frac{45}{46}\cdot\frac{54}{55} = \frac{1}{6}\cdot\frac{1312200}{1310540} > \frac{1}{6}, \\ q_3(5) &= \frac{1}{6}\Big(4-3\cdot\frac{6}{7}\Big)\cdot\frac{15}{17}\cdot\frac{9}{10} = \frac{1}{6}\cdot\frac{1350}{1190} > \frac{1}{6}, \text{ and} \\ q_4(3) &= \frac{1}{6}\Big(5-4\cdot\frac{5}{7}\Big)\cdot\frac{3}{4} = \frac{1}{6}\cdot\frac{45}{28} > \frac{1}{6}. \end{aligned}$$

(iii) Since $\varepsilon_k \in (0,1)$ for all $k \in \{1,\ldots,5\}$, we have

$$q_0(\theta) = \frac{1}{6}\prod_{1\le k\le 5}\varepsilon_k < \frac{1}{6}\prod_{2\le k\le 5}\varepsilon_k < \frac{1}{6}[(1-\varepsilon_1)+1]\prod_{2\le k\le 5}\varepsilon_k = q_1(\theta).$$

From (1), we have

$$x(1-\varepsilon_x)+1 = \frac{1}{1-\frac{2}{\theta}\frac{x}{x+1}} < \frac{1}{1-\frac{2}{\theta}\frac{x+1}{x+2}} = (x+1)(1-\varepsilon_{x+1})+1,$$

for $x \in \{1, \ldots, 4\}$. It follows that, for $x \in \{1, 2, 3\}$,

$$\begin{aligned} q_x(\theta) = \frac{1}{6}[x(1-\varepsilon_x)+1] \prod_{x+1 \le k \le 5} \varepsilon_k \quad &< \quad \frac{1}{6}[x(1-\varepsilon_x)+1] \prod_{x+2 \le k \le 5} \varepsilon_k \\ &< \quad \frac{1}{6}[(x+1)(1-\varepsilon_{x+1})+1] \prod_{x+2 \le k \le 5} \varepsilon_k = q_{x+1}(\theta). \end{aligned}$$

Finally,

$$q_4(\theta) = \frac{1}{6}[4(1-\varepsilon_4)+1]\varepsilon_5 < \frac{1}{6}[4(1-\varepsilon_4)+1] < \frac{1}{6}[5(1-\varepsilon_5)+1] = q_5(\theta).$$

□

C Translated Instructions

Thank you for responding to the survey. **The amount of reward that the two of you receive (individual treatment: the amount that you receive) for today's questionnaire survey will be determined by the number that comes up on a dice.**

Please choose the representative – either you or your friend – and throw the dice in the envelope only once. The reward for each person will be determined by the number that comes up. It does not matter which one of you throws the dice (the two of you will receive the same amount). (Individual treatment: Please throw the dice in the envelope only once. Your reward will be determined by the number that comes up.) Please check the amount in the table below.

Number	Reward per person
1	600 yen
2	700 yen
3	800 yen
4	900 yen
5	1000 yen
6	500 yen

Throw the dice and write down the number that comes up.

Answer:

After the initial throw of the dice, you may throw it several times to make sure that it is not loaded. **However, in the above box, write only the number that comes up first.**

After writing down the number, please put this sheet in the envelope and give it to the person in charge. Thank you so much for your cooperation in today's survey.