Do you share your personally useless information if others may benefit from it?

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Abstract

Information is personally useless if its beholder cannot individually benefit from it further unless she shares it with those who can exploit that information to increase their mutual outcome. We study sharing such information in a non-strategic and non-competitive setting, where selfish and cooperative motives align. Although sharing information is cost-free and results in expected mutual payoff, almost all of the subjects show some negative sensitivities toward sharing information, and it is more severe in the introvert subjects. The subjects' level of cooperation, sensitivity to the fairness of opportunities, and fairness of outcomes do not explain this monetarily irrational behavior. However, computational modeling suggests that this irrationality arises because of high selfishness and excessive subjective value of personally useless information, in the face of low other-regarding motives, that necessitate over-attainable personal benefit to drive sharing. Interestingly, other-regarding element and sensitivity to the value of information are correlated with the subjects' belief about others' cooperation in Public Goods Game and their extraversion in Big5 personality traits, respectively. These results point at the necessity of cognitive interventions to attenuate the subjective value of personally useless information to increase sharing in favor of more benefits for others and self, especially for introvert subjects and those that perceive others less cooperative.

Significance statement

As hubs of an information network, we attain a large amount of information and share that with others, where this sharing behavior is driven by non-monetary social motives. Surprisingly, we behave very differently when our personally useless information has expected monetary benefit for anonymous receivers, even if we get a share in that benefit; we waste information by not sharing. According to our mechanistic model, assigning a high subjective price to personally useless and fading information, and low other-regarding motive, are the barriers for monetarily rational sharing. It means, even personally useless and expiring information gains value in socially beneficial settings that can hinder sharing for mutual benefit. It is more severe in introverts, and those assume others less cooperative.

We have stepped into the information era, and so the quest to keep ourselves being informed of a vast number of diverse topics occupies a major portion of our time and effort¹⁻⁴. While the thirst for ecologically beneficial information is understandable, surprisingly, these days, we eagerly look for personally useless or non-instrumental information as well⁵⁻⁸. Besides, we share much information with others, especially through social networks, and most of that can be categorized as non-relevant to our direct economic benefit^{9,10}. Different reasons are put forward to rationalize this information seeking and sharing habits^{4,10}. However, it is less known about our information sharing behavior if receivers potentially gain direct monetary benefit from it.

Imagine that you are a technical analyst in the stock market with no budget today for trading. What will be your technical analysis information sharing strategy with others? Do you anonymously share it with potential receivers for no monetary return? How much benefit percentage from the receiver's profit motivates you to share? Assume that you are checking your twitter and you suddenly read a post that is irrelevant to you. Do you hesitate to share the post with others if you know that it might help them to gain some financial benefits? Imagine that you have a fading out research idea with some preliminary but not yet publishable results, and do not have funding to pursue it in due time. How do you rationalize not sharing your idea with another colleague in return for mutual scientific collaboration and benefit?

We call such information personally useless, for the beholder, in the sense that holding the information does not result in an external benefit for her. Sharing for any amount of benefit is rational in such settings if the sharing is cost-free.

Personally useless information and money share a fundamental property; both of them are valuable only in social interactions. However, sharing money and sharing information differ in the sense that we lose our money by sharing it in exchange for social and personal values while we keep our information after sharing. A wide range of studies has shown that a considerable portion of the

population participates in charities^{11–14}. Similar behavior is widely observed in the laboratory experiments of the dictator game, where the dictators share the money with others^{15–17}; that is against monetary benefit maximization. These altruistic behavior show that people have social preferences which can be emerged in favor of social norms, reciprocity, or other motives^{18–23}. Considering the fact that people pay the cost of losing their money in charities, which is not the case in information sharing, one may expect a higher tendency for participation in cost-free information charity, where we share our personally useless information with potential beneficiaries. The expectation is higher for limited lifetime information.

If we assume that monetary information is similar to money, we can expect the same mechanistic processes for sharing monetary information and money. For example, one can hypothesize that people do not share their personally useless information since they think it is not fair to provide an opportunity for someone else while they have not had the same opportunity²⁴. On the other hand, people might take fairness of outcomes considerations into account when they share information^{16,25}. Self and other-regarding motives are among other factors that can influence the sharing process²⁶. Another explanation for sharing personally useless information might relate to the level of cooperation or subjects' beliefs about others' cooperation^{27,28}.

Our information sharing strategy is complex and multifactorial. For example, Wittenbaum et al.²⁹ showed that information sharing is a motivated process in a way that group members decide what information to be shared and how to mention it to particular members of the group. People also might inform others in order to present themselves, i.e., as a form of discussing their own traits, preferences, and emotions while it activates regions associated with reward in the brain^{30,31}. Another possibility is that people share information to display their prosociality or trustworthiness^{19,32,33}. In addition, individuals can share information to improve others' well-being³⁴ or simply because they enjoy others' good fortune^{35,36}. However, Tamir et al.³⁷ claimed that information sharing is intrinsic and is associated with reward circuits in the brain, even in costly

situations and where people are anonymous and altruistic motives disappear. In their study, shared information did not have any benefit for the receivers. Therefore, taking the mentioned factors into account, one may speculate that people should exhibit a higher tendency for sharing when receivers can potentially gain monetary benefit from that information, even if the sender has no benefit in that.

Obviously, sharing information is counter optimal in many cases. For example, when the environment is strategic and competitive, sharing information worsens the payoff^{38,39}. For example, Crawford and Sobel⁴⁰ proposed a game-theoretical model in which revealing and not-sharing information are linked to alignment and conflict in the interest of players. The cost of communication also negatively affects the information-sharing behavior. Duffy et al.⁴¹ showed that high communication cost is associated with smaller language. Competition and limited resources seem to influence the information sharing intentions as well negatively. Here we investigate personally useless information sharing behavior when the task is non-strategic and non-competitive, the information has a single sharing chance, resources are unbounded, information sharing is non-costly, it increases expected payoff of receivers, and subjects can gain benefit from that payoff.

We designed a two-player game (see Methods) in which only one of the players could always share her information (Active Subject or ActSub). The other player was passive in all of the trials. All 70 subjects were playing the role of ActSub. We made a cover story to make the subjects believe that they have been in the position of information giver randomly. Each trial began with ActSub's turn, and some white squares (9 or 3) were shown on the screen that only one of them had a reward. The trials were independent of each other, and the place of the reward changed in each trial randomly. After choosing a square, ActSub would either win or lose. In "win" conditions, ActSub acquired the exact location of the reward and could report this information to her confederate (Passive subject or PasSub). However, in the "lose" conditions, ActSub was given some information about the possible places of the reward that could share with PasSub. Therefore, in the "lose"

conditions, she could increase the probability of PasSub's winning, but she could not make it 100%; see Fig.6. If ActSub decided to share her information, ActSub would either take a benefit (20% or 50%) from PasSub's current trial reward (if the PasSub won, both would take benefit. Otherwise, none of them would benefit from sharing information) or would take nothing from sharing information (0% benefit). The amount of benefit was determined by the experimenter in each trial and was randomly chosen from one of the three benefit percentages.

Figure 1 a) The trend of the game for one trial is shown. ActSub can see the whole screen, but PasSub can only see her own side. We changed the side of the PasSub for every new subject. 1. ActSub has to choose a white square with a mouse. 2. ActSub result is shown to her, and some information is delivered to her as a result of her choice. At this time, she is asked if she wants to share her information. She will take this decision by pressing one of the two keyboard buttons (D or A). These buttons changed for shared and not-shared decisions for every two subjects so that the PasSub side and the buttons had all four possible

combinations. The percentage of benefit is also shown in this state. We wrote all of the texts in the Persian language. In this example, the percentage of benefit is 20% (درصد سهم: ۲۰٪). The squares were smaller in the original experiment, and we magnified them here for better visualization. 3. PasSub has to choose a square with a mouse. If ActSub decides not to share her information, PasSub will play the same game that ActSub did and has to choose a square from one of the white squares. Otherwise, If ActSub shares her information, PasSub will play the game with the new information that ActSub has acquired and has to choose a square from one of the green squares. 4. PasSub result is shown. If the PasSub chooses the right square, PasSub will succeed and earns 100 scores. If the percentage of benefit is more than zero, ActSub will take that amount from 100 scores. In this example, ActSub will take 20 scores, and PasSub will take 80 scores out of 100. Every 100 scores are 10000 Rials of Iran's currency. Otherwise, PasSub will fail, and none of them earns anything from PS's choice. b) The probability of a win for ActSub is always 1/9 or 1/3 in each trial. If ActSub does not share her information, the probability of a win for PasSub will also be 1/9 or 1/3, respectively. If ActSub shares her information, the probability of a win for PasSub will be one of the five conditions depicted in the figure.

Results

A naive assumption is that the subjects in our task always share their personally useless information since sharing information not only imposes no cost but also may result in income for them in 66% of trials. Sharing information in all trials reduces the decision process load as well. The question is what percentage of the subjects follow the naive assumption and what is the information-sharing strategy for those who do not follow it.

Role of win and lose

For a pure reward maximizer, the sharing strategy should be invariant with respect to the history of the subject's gain in the current trial. To test this, we calculated the average frequency of sharing in the win and lose conditions. The subjects were significantly less generous in sharing when they gained self-exploited full information; average sharing was 37% ($-/+0.038$) against 55% ($-/+0.033$) in uncertain information cases (two-sided paired t-test, $t\text{-stat}=-6.92$, $P\text{-value} < 1e-8$, significance level=0.05).

The sensitivity of ActSub to her benefit percentage

If subjects want to minimize their decision load, they must be extremist; either share or not share in all trials. Analysis of sharing frequency of all subjects revealed that their average sharing is 26% ($-/+0.037$) when their benefit is zero. Therefore, decision load minimization is not the case, at least for

all subjects. The ratio of information sharing frequencies in 50% and 0% benefit cases is in favor of labeling the subjects as partially gain seekers; their average sharing is 74% (± 0.033) in 50% benefit cases while it is 26% in 0% benefit condition (two-sided paired t-test, $t\text{-stat}=11.88$, $df=69$, $P\text{-value} < 1e-17$, significance level ~ 0.01 with Bonferroni correction). Interestingly, in the 50% benefit case, when the subjects have a fully fair percentage of their partner's reward, they do not always share their personally useless information. In 20% benefit case, the subjects share information in 54% (± 0.043) of trials, which is significantly lower than the same statistic in 50% benefit condition (two-sided paired t-test, $t\text{-stat}=-6.05$, $df=69$, $P\text{-value} < 1e-7$, significance level ~ 0.01 with Bonferroni correction). This observation is against assuming the subjects as pure gain seekers. The subjects shared information further less in 0% benefit condition in comparison with 20% condition, (two-sided paired t-test, $t\text{-stat}=-8.66$, $df=69$, $P\text{-value} < 1e-11$, significance level ~ 0.01 with Bonferroni correction). In contrary to the naive assumption, the results indicate that the subjects' utility function for information sharing is not a pure income maximization while information sharing has not cost. The task is neither cooperative nor competitive, and sharing results in probable income in 2/3 of the cases.

The question which arises here is that why subjects do not share their personally useless information and what drives this dissociation in their behavior between different benefit percentages?

Level of cooperation and tendency of sharing information

One possible reason that one might share her information in our setting is the level of cooperation, i.e., the more subjects cooperate in a public good, the more they are willing to share their personally useless information. In order to investigate this possibility, we took a public goods game (PGG) study from 30 subjects (from various ranges of sharing personally useless information) who participated in our first task. The hypothesis that sharing personally useless information is related to

the level of subjects' cooperation was ruled out, Fig.3.a, ($\text{corr}=0.12$, $\text{p-value}=0.50$). Furthermore, we analyzed the relation between sharing information in each benefit percentage (and also the difference between sharing in benefit percentages), with the level of subjects' cooperation in PGG. Again, we did not observe any significant correlation between the frequency of sharing in any of the benefit percentages and the level of cooperation in PGG.

Another explanation for not sharing personally useless information is the subjects' beliefs about the level of others' cooperation. To test this, we recorded the subjects' beliefs about the levels of three other participants' cooperation in the PGG and used its mean, which we call it "average belief about others' cooperation." The results indicate that there is no significant correlation between the "average belief about others' cooperation" and the tendency of sharing information in our first task, Fig.3.b, ($\text{corr}=0.17$, $\text{p-value}=0.36$).

However, by analyzing the relation between the "average belief about others' cooperation" and the tendency of sharing information in each benefit percentage, we saw that there is a significant correlation between the tendency of sharing information in 0% benefit and the "average belief about others' cooperation," Fig.3.c, ($\text{corr}=0.39$, $\text{p-value}=0.03$). It means that there is a relation between the subjects' belief about how much others are cooperative toward them, and giving free information to a confederate in the information-sharing task.

In addition, there is a negative correlation between their "average belief about others' cooperation" and the difference between sharing information in 50% and 0% benefit ($\text{corr}=-0.49$, $\text{p-value}=0.005$). It means that the more subjects want to take benefit from their confederate and the less they want to give free information to them, the less they think others cooperate in PGG.

Fairness of opportunity or information gain (IG) and the tendency of sharing information

The information gain (IG) varies from 0.4 to 2.19 in our task (see Fig1) and can also be seen as the fairness of opportunity since there is a difference between the probability of winning for ActSub and the probability of winning for PasSub if the Actsub decides to share. Therefore, if a subject is sensitive to the opportunity that has been given to him relative to the opportunity that has been provided for another person, the subject has to share less if the IG gets larger. We calculated the average frequency of sharing (we call it the tendency of sharing information) in each information gain condition. In lose conditions (IGs: 0.4, 0.8 and 1.5), there is not a significant difference between average frequency of sharing in different IG conditions (one way ANOVA, $F\text{-stat}=0.14$, $df=2$, $p\text{-value}=0.86$). Besides, the task complexity for ActSubs, which is 3 or 9 square cases, does not affect the subjects' sharing behavior when they succeed; i.e., the sharing frequency is 37% in both win conditions (two-sided paired t-test, $t\text{-stat}=-0.40$, $P\text{ value}=0.68$, significance level=0.05).

Personality traits and the tendency of sharing information

Another possible explanation for sharing information is that it might be related to the subjects' personality traits. Our analysis showed that there is a positive correlation between sharing information and extraversion, i.e., the more extraverts the subject is, the more she is inclined toward sharing personally useless information ($\text{corr}=0.29$, $p\text{-value}=0.027$). However, there was not any significant correlation between the tendency of sharing information and any other Big 5 factors.

GLM model on sharing information

In order to analyze the results further, we fitted a GLM model to our task structure and analyzed subjects' sensitivities to different conditions in our task (for further reading, see supplementary materials and methods, GLM model). There were three key factors that could potentially influence subjects' behavior in our task: (i) benefit percentage, (ii) The Information Gain (

$IG = \log(P(\text{PasSub wins} | \text{info shared}) / P(\text{PasSub wins} | \text{info not shared}))$ which is the increase in the probability of PasSub's winning in the condition that ActSub decides to share relative to the condition that ActSub decides not to share, (iii) "win" condition. Table.1 shows the mean and standard deviation of the fitted parameters to the subjects. Also, it represents what percentage of subjects have negative/positive sensitivity toward each variable in our GLM model.

As it can be seen in Fig. 2 (which is the mean frequency of shared trials in each condition of the task) and as the GLM model describes (Parameter β_1), a considerable number of subjects have a negative tendency toward sharing personally useless information, and there are subjects who do not follow the naïve assumption discussed earlier. Furthermore, we found no correlation between the sensitivity to IG or fairness of opportunities (GLM model parameter β_2) and the tendency of sharing information, Fig.3.d.

In another series of retrospective analyses, we investigated the role of the previous trial's envy, guilt, and regret on subjects' decisions. The analyzes showed that these factors were not responsible for the sharing decision (sensitivity to retrospective guilt and the tendency of sharing information: $\text{corr}=0.19$, $\text{p-value}=0.10$, sensitivity to retrospective regret and their tendency of sharing information: $\text{corr}=-0.13$, $\text{p-value}=0.29$, retrospective envy and sharing personally useless information: $\text{corr}=-0.08$, $\text{p-value}=0.50$).

Table. 1 Standardized parameters of the GLM model for each subject

Parameter	mean	SD	Positive sensitivity	Not sensitive	Negative sensitivity
β_0 (intercept)	-5.07	28	~14%	~36%	~50%
β_1 (benefit percentage)	0.31	0.8	~75%	~25%	0%
β_2 (information gain)	-0.2	0.9	~7%	~76%	~17%
β_3 (win)	-5.28	24	~2%	~58%	~40%

Figure 2 The average frequency of sharing responses is shown with details in the pool of data. We had three different benefit percentages for ActSub (0%, 20%, and 50%), and for each benefit percentage, we had five different IGs. Two of these IGs are win conditions, and 3 of them are the conditions in which the ActSub has failed. The IGs are sorted for the win and lose conditions separately. Standard errors of sharing frequencies among the subjects are depicted in each of the 15 conditions.

Figure 3 information sharing and behavioral factors a) tendency of sharing information and subjects cooperation in Public Goods Game (PGG) b) tendency of sharing information and subjects' beliefs about others cooperation in PGG c) tendency of sharing information in zero benefit and subjects' belief about others cooperation in PGG d) tendency of sharing information and sensitivity to the fairness of opportunities

A mechanistic approach to subjects' information sharing tendencies

Here, we use two kinds of famous social preference models to explore the mechanism by which subjects tend to share their information.

One might assert that fairness of outcomes forms people's decisions toward sharing personally useless information, i.e., the subjects prefer the 50% benefit percentage. To test this hypothesis, we fitted the Fehr-Schmidt¹⁶ model. In this model, the information giver's utility function reduces if her confederate's gains more than her by sharing information (prospective envy), or the subject's outcome becomes more than her confederate's outcome by sharing information (kindness, if the subject has negative sensitivity to this condition).

On the other hand, one can simply reject the fairness of outcome hypothesis and proclaim to the extent that subjects have self and other-regarding behavior⁴²; they share personally useless information that can have monetary benefits for them as well as others. To test these two competing hypotheses, we fitted these two models to our data and compared them to each other (for further reading, see supplementary methods, computational modeling).

The mean BIC of these two models are depicted in Fig.4.a (red and blue lines). The self and other-regarding model can capture sharing behavior better. However, the self and other-regarding concept did not have a good prediction solely. Therefore, we used three other variants of the model (yellow lines and green line in Fig.4.a) based on the observed behavior of the subjects and the literature of information value. The two yellow models are the self and other-regarding models plus change in the utility function in the “Win” condition that was mentioned earlier. We can add the “Win” conditions in two different ways. First, we can assume that the “Win” condition affects the sharing process independently, and therefore, it can be added as a bias to the model (the upper yellow line in Fig.4.a). The second way is that we can assume that subjects’ self and other-regarding motives change with induced emotions^{43,44} (lower yellow line in Fig.4.a). In this context, the “Win” condition can be considered as a happy induced emotion that can change the self and other-regarding motives. This second proposition had a better model fitting index, and therefore we proceeded with this model. The last parameter that is consistent with our observed data and also the literature is something that we call “value of information.” As we mentioned earlier, subjects sharing tendency is positively correlated with their level of extraversion. Furthermore, if we assume that information has intrinsic value in people’s minds⁴, we can add the “value of information” parameter to the model. We did this by adding the winning probability if the information giver decides to share the information (p_2 in Fig.1.b), that is, the information that the subject can provide for the information receiver. In this context, the more p_2 is, the more becomes the winning probability for information receiver and thus the information becomes more valuable (we also used

other variants of this variable in the model but this variable had the best prediction and fitting results).

We also used two different models from the literature, Bolton-Ockenfels⁴⁵ and Krajbich et al.⁴⁶ that did not have good predictions in comparison with the fairness of outcomes and self and other-regarding models. For further reading, see supplementary materials, computational modeling.

Thus, the proposed model for sharing personally useless information is the combination of self and other-regarding behavior plus changes in these parameters with induced emotion as well as the value of information. Fig.4.b and c show the model recovery part for this proposed model in each of the 15 conditions and in all of the trials, respectively. The proposed model prediction is good in general as well as almost in each of the conditions (except condition 14 because of lack of data).

$$1) U(share) = (W_{self} + W_{self_change} \times Win) \times Payoff_{self}(share) + (W_{other} + W_{other_change} \times Win) \times Payoff_{other}(share) + W_{Inf} \times P_2$$

$$2) U(Not\ share) = (W_{self} + W_{self_change} \times Win) \times Payoff_{self}(Not\ share) + (W_{other} + W_{other_change} \times Win) \times Payoff_{other}(Not\ share)$$

$$3) Pr(share) = \exp(U(share)/\tau) / (\exp(U(share)/\tau) + \exp(U(Not\ share)/\tau))$$

Figure 4 Model comparison and model recovery is depicted a) Mean BIC of models have been compared. The first model from above (the red line) is the Fehr-Schmidt model that is based on the fairness of outcomes. Kindness or envy drive subjects' decisions in this context. The next model (the blue line) is Hutcherson et al. model that assumes subjects consider their opponent as well as their payoffs to take social decisions. Thus, self and other-regarding behavior drive subjects' decisions in this context. The remaining three models (yellow ones and the green one) are based on the Hutcherson et al. model. Both of the yellow models take the “win” condition into account. The first yellow model from the above assumes that the “win” condition influences subject decisions separately. However, the second yellow model assumes that the “win” condition induces emotion in subjects, and therefore, their social preferences change. The last model (the green line) that is the winning model, is similar to the second yellow model, except it assumes that subjects take the value of information into account, i.e., if information has a higher probability of winning compared to other information, it has a higher value. b) Model simulation in the 15 conditions of the task. Red dots and error bars (SEMs) indicate model simulations, whereas black bars with blue error bars indicate subjects' behavior. c) Predicted behavior of subjects vs. real behavior of subjects.

Equations 1 to 3 show the proposed computational model. The mean fitted standardized parameters with their SEM are shown in Fig.5. The sixth parameter, temperature, which shows randomness in the choice, is not shown in Fig. 5 for better illustration (mean=170.99, SEM=17.61). The mean self-regarding parameter is positive when subjects are in the “Lose” conditions, and the mean other-regarding parameter is slightly negative. As the model suggests, when subjects win, their other-regarding behavior increases and their self-regarding behavior decreases on average.

However, the net value of these changes (selfish motives change+other-regarding motives change) is negative, and since self and other-regarding parameters are in alignment together in our task, it leads subjects to share less. In addition, subjects on average have a negative tendency toward the value of information; they share less when the probability of winning for the other person increases, i.e., their information is more valuable. In Fig. 5, the model parameters have been calculated for the subject with high variance in their behavior since we did not have enough data for the subject at the two ends of the sharing spectrum (almost always sharing subjects or almost never sharing subjects) to fit the model and therefore we had outliers in parameters of the model when we tried to fit the model for these subjects. However, the patterns in the model parameters remain the same without removing the low variance subjects (for the criterion of selecting always sharing subjects and almost never sharing subjects, see supplementary materials, subjects types).

Furthermore, there is a significant positive correlation between the model parameter $w_{information}$ and subjects extraversion (corr=0.46, p-value=0.0019); the more subjects are extravert, the easier they give high probability information. Also, the subjects' other-regarding behavior in the lose condition in the computational model is positively correlated with their belief about others' level of cooperation in the Public Goods Game (corr=0.48, p-value=0.012). We observed a negative correlation between their other-regarding parameter in the win condition and their extraversion (corr=-0.41, p-value=0.0057).

Figure 5 Proposed model parameters' mean and SEM plus correlation with PGG and Big5 personality traits. a) mean and SEM of model parameters. Note that $w_{self_win} = w_{self_lose} + w_{self_change}$ and $w_{other_win} = w_{other_lose} + w_{other_change}$. b) there is a positive correlation between sensitivity to the probability of PasSub's winning and subjects extraversion. c) positive correlation between subjects' other-regarding behavior in the lose condition and their belief about others' cooperation in Public Goods Game (PGG).

Discussions

We live in an era that information-sharing is one of the most prominent means to remain connected with others. Although most of the shared information has no impact on our choices, i.e., categorized as non-instrumental information, we share more than billions messages⁴⁷ in social networks on a daily basis. Also, experimental researches show that we eagerly seek and share such information^{5,37}. The pandemic of sharing useless information suggests that such information has no monetary value for its distributors. Nevertheless, sometimes our personally useless information can be of monetary usage for others. Getting aware of this fact, do we still freely share our personally useless and short-lifetime information?

We investigated sharing personally useless information behavior when others can benefit from it in an information-sharing task. In our task, the subject first faced an n-choice reward-seeking problem and either found the goal and got a reward or failed and received nothing. Then, the subject gained some personally useless trial-specific information (short-lifetime information); complete or partial information about the goal position in the win and lose conditions, respectively. The subject could share that information with her anonymous confederate (who would face the same n-choice reward-seeking problem) and get a defined percentage (0, 20 or 50 percentages) of her confederate's reward in that trial.

The first observation was that the subjects' behavior was substantially different from the common passionate free-information-sharing one. Although information sharing was cost-free and beneficial for their confederates in almost 90 percent of the trials, the subjects did not show altruistic behavior. The surprising point was that the subjects shared less when their confederates would benefit the most.

Sharing information was not only cost-free but also was potentially beneficial for the beholders in 2/3 of the trials. Therefore sharing even in all conditions could be rationalized in terms of expected

reward maximization and decision load minimization. However, some of the subjects were highly inclined toward not sharing; unexpectedly, they preferred to waste their personally useless and short-lifetime information by not sharing it. More importantly, some of the subjects did not share even in the seemingly fair division of outcome, i.e., 50% of the benefit.

In order to explain these surprising results, we proposed a computational model based on self and other-regarding behavior as well as the subjective value of information. Furthermore, the model assumes that subjects' self and other-regarding motives are not fixed, i.e., they can change by inducing emotions in the win condition. In terms of model recovery, the model had good prediction at the general level as well as in each condition. Besides, the parameter recovery for the model was acceptable (see supplementary materials, parameter recovery).

Based on this model, subjects can be reluctant to share information if their other-regarding motive or their sensitivity to the value of information (how much the subject increases her confederate's winning probability) is negative. On the other hand, the model predicts sharing more if their selfishness and prosocial behavior are positive.

Interestingly, according to model-free analysis and computational modeling, the subjects assumed a significant value for their personally useless information. The more the value of this information (benefit percentage) was, the less (the more) subjects wanted to share. These findings support the view that even personally useless and very lifetime-short information has value in subjects' minds^{5–8}. This assertion was also corroborated by looking at the subjects' behavior and the computational model in zero benefit conditions. If we assume that the subjects' other-regarding behavior had been the only driver of their behavior when their benefit was zero, we should expect the subjects to share more in the win condition relative to the lose case. However, this was in contradiction with the behavioral data; the subjects shared less in the win condition. High sensitivity to the subjective

value of information explains this observation; assigning value to useless belongings blocks prosocial behavior.

When the subjects lost, selfishness was the main drive for sharing. In contrast, other-regarding did not have a significant effect on sharing in the lose condition (mean=-0.25, SEM=0.25, two-sided t-test, p-value=0.32). Therefore, the subjects shared more when their expected profit from sharing compensated their subjective value of information better and avoided sharing their personally useless information otherwise despite being expired. In other words, the result of computational modeling rationalizes the observed monetary irrational behavior. That is, high personal monetary benefit is needed to compensate low other-regarding motives and high subjective value for personally useless and fast-expiring information. It suggests cognitive interventions for decreasing the subjective value of information when monetary compensation for sharing is limited or costly.

The subjects had certain information just in their personal win trials, and in those trials, they shared less; compared to probabilistic information cases. This is surprising since we expect the subjects to share more as sharing certain information leaves no doubt in their confederates' win, and consequently, their own benefit is guaranteed. The higher tendency to avoid sharing can be attributed to both satisfactions from self-win followed by a change in behavior or to the nature of sharing certain information, i.e., giving a free lunch to others. If certain information had an independent role in preventing subjects from sharing, then we should expect a significant change in the value of information in the win condition. In order to test this, we added another parameter to our computational model named "change in the value of information". The model parameters pattern remained the same as the former model, and the "change in the value of information" was not significantly different from zero (mean=0.09, SEM=0.19, two-sided t-test, p-value=0.65). It means that certain information did not have a role different from the role of information value. Instead, the results pointed at a significant drop in the self-regarding motive as the possible cause of lower sharing in the win condition.

The change in self and other-regarding motives might be related to incidental emotions, i.e., emotions that are not related to the actual choice problem, claiming that happy emotions can increase people's prosocial behavior and decrease their selfishness^{44,48}. Therefore, we expect the self (other) regarding parameter to decrease (increase) in the win situation, which was the case in our computational modeling. However, one may expect an increase in sharing information when subjects become more prosocial and less selfish, which is in contrast with our behavioral results; the subjects shared less when they won. We resolve this contradiction by looking at the subjects' behavior as well as the model parameters and the task structure. The task structure aligns selfish and other-regarding motives together; sharing always helps the subjects and their confederates (except in zero benefit when sharing only helps the confederate). Therefore, the net value of the decrease in selfishness (negative impact on sharing) and an increase in prosocial behavior (positive impact on sharing) change the sharing performance. That net value was negative in our win cases; i.e., drop in the selfishness was significantly larger than the increase in the prosocial motives. This observation suggests that inducing happy emotions does not necessarily increase individuals' monetary contribution in society when they benefit directly or indirectly from their contributions. This issue should be studied in more detail in future studies.

Sharing information was positively correlated with the subjects' level of extraversion. According to the modeling results, the subjects with low levels of extraversion had more negative sensitivity to the value of information; introverts shared less when the information value was higher while extraverts were not sensitive to the information value. One possible explanation for this correlation is that more extravert subjects might be less reluctant to give information. Therefore, in their mind, there is no difference between sharing a high probability versus low probability information. However, further investigations are needed to study this hypothesis.

We observed that sharing is not linked to the fairness of opportunities as well as with the subjects' level of cooperation. Excluding certain information and zero benefit percentage cases, there were

some subjects who had negative sensitivity to the fairness of opportunities. However, the results were not generalizable to the whole population.

Experimental results showed that sharing in zero benefit condition and the subjects' belief about other's cooperation in the public goods game were positively correlated. Our modeling linked this behavior to higher other-regarding parameter; there was a positive correlation between the other-regarding parameter and the subjects' beliefs about others' cooperation in the public goods game. These observations corroborate the idea that subjects' beliefs about others' cooperativeness can be the mediator of their other-regarding behavior^{27,28}. We also observed a significant correlation between the subjects' other-regarding parameter in the win condition and their extraversion that needs to be explored more in future studies.

The GLM results revealed that around 15% (50%) of the subjects were biased toward sharing (not-sharing) their information, while no significant bias was observed in 35% of the subjects. This heterogeneity in automaticity of sharing decisions suggests that, in contrast to Tamir et al. 's claim³⁷, sharing information has not been an intrinsic behavior in most of the subjects in our setting.

One may argue that the subjects had been sensitive to their own and their confederates' accumulated rewards. To examine this, we added these two parameters to the model, and that assumption was rejected. The same happened to the difference of these accumulated rewards. The reason would be either lack of strong competitiveness feeling or not calculating the accumulated reward at all by the subjects. In addition, we ruled out the role of other retrospective factors such as envy, regret, and guilt of the previous trial.

The current study has some possible extensions. First of all, the underlying neural mechanism of information sharing in our task is not clear. Tamir et al. ³⁷ used an information-sharing task in which subjects had to give up money to inform others and used fMRI techniques to investigate the underlying associated brain areas during the information sharing process. They found that informing

others is intrinsic and is associated with the reward circuits. Interestingly, in our non-costly information sharing environment, we observed that some of the subjects shared highly with relatively short reaction times while some others refused to share their information again with relatively short reaction times. Hence, it is important to study the underlying brain mechanism of the subject's behavior at the two ends of the sharing spectrum in order to see whether sharing information for those who almost never share is intrinsic as well or not.

Furthermore, personally useless information and money conceptually have some similarities since both of them are only valuable in social interactions. That being said, we should be aware that we lose our money by sharing it, contrary to information. Therefore, one may expect a higher tendency to share information relative to money. It could be of great worth to compare money allocation with information sharing framings and investigate the role of costs and intrinsic information sharing as well as their underlying neural mechanisms.

Finally, it is not clear if nature or nurture have caused the intrinsic biases toward giving or not giving the information. Further research is needed to investigate whether intrinsic biases are related to genetics or not. In parallel, cross-cultural studies are needed to investigate social preferences toward sharing personally useless information among different cultures⁴⁹.

Methods

Participants

Seventy students from the University of Tehran (34 females & 36 males, age between 18-32 years old with the mean of 22.5) participated in the experiment. The subjects were paid 150K Rials for participation, and an additional payment ranged between 150K-300K Rials. The additional payment was their score in 20 randomly chosen trials. Informed consent was obtained from all subjects, and the study was approved by the ethics committee of the University of Tehran.

Task

The experiment consisted of 250 trials. All participants were Active (they acquired information, and they had to decide whether to share information or not, see below) and their pair, Passive subjects who could not share information, was chosen from one of the four pre-determined persons and randomly assigned to each participant. We made a cover story in order to make the subjects believe that the role of being Active or Passive subject is assigned randomly to the participants. We did not use the “Active subject” or “Passive subject” in front of the participants in order to prevent them from any bias. In our cover story, Active subjects (ActSub) believed that the passive subjects (PasSub) would be paid based on the same process. Each trial was a two-player game (ActSub and her confederate, PasSub) that began with the ActSub’s turn. ActSub and her confederate could not see and talk to each other before and during the task. Subjects were provided a written instruction about the task. Having read the instruction, subjects played a training phase consisted of 5 trials and asked their questions about the task after this phase. In the game, using a mouse, ActSub had to choose one of the 3 or 9 white squares presented on the screen. Only one of the squares was associated with reward (Fig. 1a).

Subjects were aware that the place of the reward changes in each trial randomly. ActSub could observe the PasSub’s screen, but PasSub could not see ActSub’s screen, and ActSub was aware

of that (Fig. 1a). Contrary to the dictator game in which people are given an amount of money, people obtained information by themselves in our task. If the ActSub selected the rewarding square, she would win, and the color of the selected square would change to green. Otherwise, the ActSub would fail, and as a result, the selected square, as well as some other non-rewarding squares, would become red, and the remaining squares turned to green. The green squares meant that the reward is behind only one of them.

At this time, the ActSub was asked to push Key A if she decided to share the acquired information with the PasSub (called shared-condition), in return of a percentage of benefit (0%, 20% or 50%, which was shown on the screen) of PasSub's possible gain, and to push Key D otherwise (called non-shared-condition). For half of the subjects, the actions of these two keys were reversed. We call this number 'ActSub's benefit percentage,' and it means that the ActSub gains benefit from her confederate's score in that specific trial if the ActSub gives the information to the PasSub and PasSub succeeds as a result of that. In the shared-condition, PasSub had a higher probability of a win, compared to ActSub, and in the non-shared situation, the PasSub would play the original game. PasSub had no freedom to reject the share offer.

Depending on how many white squares would turn to green, we had three different conditions for nine squares trials and two different conditions in three squares trials. Fig.1b illustrates these different conditions. The probability of a win for ActSub (P_1) was always 1/9 or 1/3 in each trial, and PasSub had the same win probability in non-share-conditions. In the shared-condition, PasSub's win probability (P_2) would be 1, 1/2, or 1/4, depending on how many squares had turned to green. We define information gain (IG) as $\log(P_2/P_1)$ for shared-condition; see Fig. 1b. We had three different ActSub's benefit percentages (0%, 20%, and 50%) and five different information gains summing up to 15 different decision conditions for the ActSub.

DETAILS OF ANALYSIS

RT analysis

We removed RTs that were more than 10 seconds in order to make the shape of the logarithm of RT distribution of all subjects normal. 36 trials out of 17500 trials were removed As a result. The mean RT before removing these trials was 1.51s, and the mean RT after removing these trials became 1.48s. We also excluded five subjects in t-test analysis since they had less than ten shared or not-shared trials in order to conduct a t-test to compare shared and non-shared trials. The results are robust to the selection of this minimum number of trials in shared and not-shared decisions.

Comparing shared percentage in different conditions of the task

We used a two-sided paired t-test, Wilcoxon signed-rank test, and one way ANOVA to analyze the difference between sharing in different conditions of our task.

We used the maximum likelihood method in order to fit the model parameters to subjects' behaviors.

Data Availability

All data on which the findings of the papers are based are available at [10.6084/m9.figshare.7931135](https://doi.org/10.6084/m9.figshare.7931135).

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Author contributions

All authors contributed to the design of experiment, the analysis of the results, and the writing of the paper. A.Y. also contributed to the running of the experiments.

Competing interests

The authors claim no competing financial interests.

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Supplementary Materials

This PDF file includes:

Materials and Methods
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I. Materials and methods

a. Additional tasks

i. Public goods game

30 subjects of those who previously participated in our main task participated in PGG study one year and a half after the task. The task was a one-shot game with 4 participants. Each participant was given 8 thousand Tomans in Iranian currency (~80 cents) to play with in the game. The task was taken internet-based. The money the subjects allocated to the public good, were doubled and shared between participants equally. After finishing the task, we asked the subjects about their beliefs on how much other three participants has shared in the game. Furthermore, we asked them two questions to be sure they have understood the game.

ii. personality traits

We took Big 5 personality traits questionnaire one year after task completion. Since some of the subjects were not available anymore after this time, we could collect the data from 53 of those 70 subjects participated in our first study. If we assume that the subjects' personality traits do not have huge changes in one year, the subjects behavior in our first task and their personality traits must be correlated in case sharing personally useless information is a personality trait.

b. computational modeling

i. different models of social preference

Computational model

A simple utility-based model can be built upon the utility that ActSub expects from sharing information:

$$U(\text{share}) = P(\text{win}_{\text{PasSub}} | \text{share}) \times U_{\text{benefit}}(\gamma \times \text{reward}_{\text{PasSub's success}}) \quad (1)$$

Where $U(\text{share})$ is the expected utility of sharing, $P(\text{win}_{\text{PasSub}} | \text{share})$ is the PasSub's win probability if ActSub shares information, U_{benefit} is ActSub's utility of its confederate's reward when γ is the benefit percentage. In this modeling, $U(\text{Not Share}) = 0$. Hereafter we use identity function for U_{benefit} . The decision-making model is a Boltzmann machine:

$$\Pr(\text{share}) = \frac{e^{U(\text{Share})/T}}{e^{U(\text{Share})/T} + e^{U(\text{Not share})/T}} \quad (2)$$

A pure expected utility maximizer is anticipated to share when $U(\text{share}) > 0$. However, since $\gamma \geq 0$, $P(\text{share}) = 1$ not only results in expected benefit maximization but also reduces the decision making load. T is the temperature and is fitted during model fitting process.

In this model, the active subject does not consider any social value and is assumed to be selfish. However, widely used models of social preferences include confederate's expected utility as well.

The Fehr-Schmidt model¹⁶

This model is based on inequity aversion:

$$U(\text{share}) = U_{\text{ActSub}}(\text{share}) - \beta \times \max\{0, U_{\text{ActSub}}(\text{share}) - U_{\text{PasSub}}(\text{share})\} - \alpha \times \max\{0, U_{\text{PasSub}}(\text{share}) - U_{\text{ActSub}}(\text{share})\} \quad (3)$$

where $\alpha \geq \beta$ and $0 \leq \beta < 1$

$$U_{\text{ActSub}}(\text{share}) = P(\text{win}_{\text{PasSub}} | \text{share}) \times (\gamma \times \text{reward}_{\text{PasSub's success}}) \quad (4)$$

$$U_{\text{PasSub}}(\text{share}) = P(\text{win}_{\text{PasSub}} | \text{share}) \times ((1 - \gamma) \times \text{reward}_{\text{PasSub's success}}) \quad (5)$$

$U(\text{Not Share})$ is calculated likewise by setting $\gamma = 0$, and replacing $P(\text{win}_{\text{PasSub}} | \text{share})$ by $P(\text{win}_{\text{PasSub}} | \text{not share})$ in (4) and (5).

Bolton-Ockenfels model⁴⁵

This model is also relying on inequity aversion. However, the sensitivity to inequity is measured by a single parameter in contrast with the previous model:

$$U(share) = U_{ActSub}(share) - \beta \left(\frac{U_{ActSub}(share)}{U_{ActSub}(share) + U_{PasSub}(share)} - \frac{1}{2} \right)^2 \quad (6)$$

Other variable and parameters are defined as the same as the previous model.

Krajbich et al. model⁵⁰

This model is based on how much a person cares about her confederate, and it is represented in the model by the parameter α . The formulation is as the following:

$$U(share) = U_{ActSub}(share) + \alpha U_{PasSub}(share) \quad (7)$$

It is obvious that if the parameter α is negative, the player 1 cares negatively about player 2 and vice versa for the condition in which α is positive. Other conditions are defined as the same as the previous models.

Hutcherson et al. model²⁶

This model is also based on how much a person cares about the other person. However, they have added another degree of freedom to the model that represents how much a person cares about herself:

$$U(share) = W_{self} U_{ActSub}(share) + W_{other} U_{PasSub}(share) \quad (8)$$

Similar to the previous models, other conditions are defined.

Initially, we fitted these models to our data and selected the best model (Hutcherson et al.'s model) in terms of mean BIC.

ii. three variants of the selected model

After selecting the winning model, we used model prediction to see if Hutcherson et al.'s model could predict the behavior or not. The result showed that the model could not capture subjects' behavior solely, especially in the win conditions. Therefore, before inserting information value to the model, we used examined three hypotheses about the mechanistic model of changing behavior in the win condition.

1. win condition as a bias in the model

In this version, we assumed that the win condition is an independent psychological phenomenon and affects subjects utility of sharing as the following:

$$U(\text{share}) = W_{\text{self}} U_{\text{ActSub}}(\text{share}) + W_{\text{other}} U_{\text{PasSub}}(\text{share}) + W_{\text{other}} \times \text{Win} \quad (9)$$

In this model, Win is a dummy variable and equals to 1 if the subject has won and is zero otherwise.

2. win condition changes the ActSub payoff

In this version, the utility for share and not share decisions is calculated as the equation (8).

However, there is a difference in calculating the $U_{\text{ActSub}}(\text{share})$:

$$U_{\text{ActSub}}(\text{share}) = P(\text{win}_{\text{PasSub}} | \text{share}) \times \left(\gamma \times \text{reward}_{\text{PasSub's success}} \right) + \text{Win} \times \text{reward}_{\text{ActSub's success}} \quad (10)$$

Win is a dummy variable similar to the former version.

3. win condition changes subjects self and other-regarding motives

In this variant of the model, we changed the self and other-regarding parameters in the share and not share utilities as the following:

$$U(\text{share}) = (W_{\text{self}} + W_{\text{self_change}} \times \text{Win}) \times \text{Payoff}_{\text{self}}(\text{share}) + (W_{\text{other}} + W_{\text{other_change}} \times \text{Win}) \times \text{Payoff}_{\text{other}}(\text{share}) \quad (11)$$

The results showed that the last version that win condition changes subjects self and other-regarding motives fits better to the data. Therefore, we continued with this model.

iii. criteria for selecting the subjects' model parameters

Since some subjects had a low variance behavior in their sharing intentions, i.e., almost always shared or almost never shared, we could not have an accurate fitting of the parameters in these clusters (see supplementary results, subjects' types). Therefore, for calculating correlations between model parameters and Big5 (or PGG behavior), and reporting the model parameters, we removed the subjects with low variance in their behavior (standard deviation less than 0.2), based on the subjects' standard deviation histogram and the individuals' standard deviations depicted on figure below.

Figure 6 Standard deviation of subjects (vertical axis) vs. subjects sharing intentions. The colors represent different clusters of sharing behavior that has been explained in the next part. Standard deviation less than 0.2 removes dark blue (almost always share) and black (almost never share) clusters only.

ii. Supplementary results

a. Subjects' types

Clustering the subjects

To find similarity and diversity in the subjects' behavior, we calculated the percentage of shared trials in each of the 15 conditions and used these 15 features to cluster the subjects. Since the number of features was large in comparison with our sample size (70 subjects), we used a hierarchical clustering method. The algorithm used for computing the distance between clusters was unweighted average distance, and the distance metric was cityblock. We had four single-member clusters, which we considered them as outlier clusters in the clustering section.

Fig. 7 shows the average frequency of sharing for all subjects in 15 information sharing conditions. Now the question is if the subjects can be clustered with respect to their sharing behavior. The hierarchical clustering resulted in the formation of 6 distinct groups; see Fig. 7a. The characteristic behavior of the groups can be described as:

1. Almost never share information (3males, 8 females)
2. Negative sensitivity to information gain and interest in higher benefit percentage (12 males, 8 females)
3. Negative attitude to provide certain win condition and interest in higher benefit percentage (8 males, 1 female)
4. Mostly share information except in zero benefit condition (4 males, 7 females)
5. Mostly share information except in certain win condition (3 males, 2 females)
6. Mostly share information (4 males, 6 females)

Fig.7 **a** Hierarchical clustering. Ten clusters are formed, and 4 of the clusters were single-member ones. The rest 6 clusters are analyzed. **b** The average percentage of shared responses is shown with details for the biggest cluster. We had three different benefit percentages for ActSub (0%, 20%, and 50%) and for each benefit percentage we had five different IGs. Two of these IGs are win conditions, and 3 of them are the conditions in which the ActSub has failed. The IGs are sorted for win and lose conditions separately. In this cluster, the percentage of sharing decreases with increasing the IG. **c** Percentage of each cluster in the population.

b. regression analysis

GLM model

In our GLM model, we first included the general factors in our task structure, then, we added parameters such as guilt, envy of previous trial and regret to our model separately.

i. General factors

$$U_{diff} = \beta_0 + \beta_1 s + \beta_2 \log\left(\frac{P_2}{P_1}\right) + \beta_3 z \quad (10)$$

In the proposed model, the probability of sharing is calculated from the following formula:

$$\Pr(\text{share}) = \frac{e^{U_{diff}}}{1 + e^{U_{diff}}} \quad (11)$$

The parameter β_0 represents the intrinsic biases of subjects about sharing information. Parameter β_1 measures sensitivity to ActSub's benefit percentage and parameters β_2 and β_3 are sensitivity to IG and sensitivity to win conditions respectively. In this model, Z is one for win conditions and zero otherwise, s can be 0, 0.2, or 0.5 and $\log(P_2/P_1)$ can be derived from the conditions mentioned in Fig. 1b.(in the main text) It is worth to be mentioned that we used different combinations of variables p_1 and p_2 in our model such as linear combination, multiply, and the ratio of p_2 to p_1 but the best-fitted model was the model that used $\log(P_2/P_1)$. It should be noted that variables z and $\log(P_2/P_1)$ have a strong correlation. In order to eliminate the effect of correlation between these two variables, we used the Gram-Schmidt orthogonalization method and used the orthogonalized vector of $\log(P_2/P_1)$. The parameters of modeling were very close to the former parameters. Thus, we continued without orthogonalization.

As can be seen, the intercept of the model increases with increasing the tendency of information sharing. If we define this intercept as subjects' intentions toward sharing information, almost 50% of the subjects have negative intentions. Parameter β_1 corresponds to subjects' sensitivity to the percentage of benefit. There is not any subject with negative sensitivity to the percentage of benefit, and almost 75% of the subjects have positive sensitivity. It means that the subjects are more willing to share their information if they get more. The parameter β_2 represents the subjects' sensitivity to the information gain (IG) or fairness of opportunities. Most subjects are not sensitive to IG, but some have negative sensitivity; that means their tendency of sharing information decreases if IG increases. The subjects with significant sensitivity to IG are mostly laid on the left part of X-axis in fig. 5, where the sharing tendency is lower. The last parameter, β_3 , is the subjects' sensitivity to win conditions and is negative in almost 40% of the subjects; they decide to share less when they win and have certain information for their confederate.

Fig. 8 GLM parameters are fitted for each individual and have been normalized to their standard error. The horizontal axis is the tendency of sharing information and the vertical axis in each figure is one of our model's parameters. Each data point represents an individual, and its color and sign correspond to its cluster. The subjects with model parameters below/above the lower/higher red lines have negative/positive sensitivity to that variable. As it can be seen for β_1 , no individual has negative sensitivity to the percentage of benefit.

ii. envy of previous trial, guilt, and regret

In our GLM model, we added the conditions in which the behavior of subject in the previous trial, might have had an effect on the current trial in the form of guilt, regret, or envy. These retrospective variables were equal to 1 if there was such a condition in the previous trial and were equal to zero otherwise. We added these variables separately to the GLM model since they had correlation with each other and couldn't be added to the model simultaneously. In this kind of retrospective analysis, if a subject has not shared the information in the trial $n-1$ and PasSub has failed, the subject might have guilt (because of not sharing) and this may affect her behavior in the trial n . In this analysis, we first assessed subjects' sensitivities to guilt and then calculated the correlation between sensitivity to guilt and the tendency of sharing information. The analysis showed that there is not a significant correlation between retrospective guilt and tendency of sharing information ($\text{corr}=0.19$, $\text{p-value}=0.10$). In the same analysis, we calculated the subjects' sensitivities to regret. Again, in this retrospective context, subjects' behavior in trial $n-1$ might lead them to be regretful in trial n , if they have not shared, PasSub has won, and benefit percentage has not been zero in trial $n-1$. In other words, if they could have won something but they haven't because they have not shared in the previous trial, they must be regretful. There was not a significant correlation between subjects' sensitivity to regret and their tendency of sharing information ($\text{corr}=-0.13$, $\text{p-value}=0.29$). Furthermore, from Fehr-Schmidt model⁵¹, envy arises if the payoff of the other person gets more than the payoff of self. From this point of view, retrospective envy happens when PasSub's payoff has been more than ActSub's payoff in the previous trial. However, our analysis again showed that retrospective envy is not correlated with sharing personally useless information ($\text{corr}=-0.08$, $\text{p-value}=0.50$).

c. Reaction time Analysis

We calculated each ActSub's mean RT in shared and not-shared trials; see Fig. 9a. The horizontal axis represents the frequency of sharing information in all trials. According to Fig. 9b, there is a significant difference between RTs in shared and not-shared trials at the two ends of the sharing behavior spectrum; i.e., for those who either rarely (cluster 1) or mostly (cluster 6) share. Those who preferred to keep/share their useless information were faster in their not-shared/shared decisions. That is, sharing/not-sharing is the faster decision for those who mostly/rarely contribute their information. In contrast, there was no significant difference in RTs of shared and not-shared decisions of the other subjects; those who were more sensitive to the benefit percentage and the information gain. In addition, those subjects had a longer RT in both their shared and not-shared decisions, compared to the faster decisions of mostly and rarely sharing subjects.

Fig. 9 **a** mean RT in shared and not-shared conditions. The horizontal axis is the percentage of shared information in 250 trials for each subject. Each dot represents a subject, and its color and sign indicate its cluster. Outliers are represented with multiplication signs. The five dots with red circles around them are the subjects who have less than ten trials of one of the shared or not-shared responses, and as a result, they are not included in a t-test. **b** t-statistics for the difference between mean RT in shared responses and mean RT in not-shared responses. Outliers are represented with multiplication signs. Note that below the lower red line, the mean RT for not-shared responses is significantly greater than mean RT for shared responses. The pattern is reversed for the data above the upper red line.

d. parameter recovery for the proposed model

After finding the low variance subjects, we did the parameter recovery for the subjects who had a noticeable variance in their behavior. Figure 10, shows these subjects.

Figure 10 parameter recovery for the model parameters. The vertical axis is the recovered parameters and the horizontal axis is the fitted ones.