Interdependent utilities: How social ranking affects choice behavior

Nadège Bault
Institut des Sciences Cognitives, CNRS, France

Giorgio Coricelli
Institut des Sciences Cognitives, CNRS, France

Aldo Rustichini
Department of Economics, University of Minnesota

We gratefully acknowledge financial support from the Human Frontier Science Program (HFSP, RGP 56/2005) to G.C. and N.B.; and the National Science Foundation (SES-0452477) to A.R.

Abstract

Organization in hierarchical dominance structures is ubiquitous in animal societies, so a strong preference for higher positions in social ranking is likely to be an important motivation of human social and economic behavior. We report and test experimentally a theoretical model predicting that emotions associated with social gains (gloating) and losses (envy), are stronger than their private counterparts (relief and regret). The asymmetry between gains and losses also reverses: while for private outcomes losses loom larger than gains, in the social domain gains loom larger than losses. The relatively larger weight assigned to social gains affects deeply economic behavior: faced with a weaker competitor, subjects adopt a more risky and dominant behavior.

In the postal code lottery run in the Netherlands your ticket is linked to your postal code (*1*). The lottery is very popular and this is perhaps due to the strong regret you would feel if you had not bought the ticket and your code was selected. However, a second strong emotion may be operating: if your code is selected, your neighbors who had bought the ticket will win the lottery, and envy would be added to regret.

We study here the link between these two emotions. Recent research on the neural basis of regret (*2, 3*) suggests that this emotion has an important role in learning to evaluate our actions: the counterfactual thinking (*4*) (``I would have been better off by choosing the other option") keeps a record for future use of the outcome of our past choices compared to the available alternatives. Envy may have a similar role, operating as the social correspondent of regret (``I would have been better off by choosing the option he chose"). However, with envy we also keep track of our social status (*5, 6*): this suggests an additional reason for envy and its opposite, the joy of winning or gloating.

Concern for status is strong motivation for human behavior (*6*-*9*). For example a major determinant of workers' effort is how their income is ranked within their firm (*10*) . More generally, happiness and well-being are strongly affected by the comparison between the individual's own income and the income of others (a reference group), such as people with the same educational level, or people living in the same neighbor (*11*). Income related comparisons might reduce subjective well-being (*12*). Thus, life satisfaction strongly depends on our relative ranking in the society.

Here we disentangle experimentally and theoretically *(A theory of interdependent utilities* (*13*)) the learning and ranking motivation for these social emotions. We show that the ranking motivation adds to the learning one, so that the social emotions have stronger effects than their private counterparts, they operate differently, and they affect our behavior in a deeper and different way.

In our experiment subjects choose among lotteries, and observe the choice that others have made. They are then informed of the outcome of their choice and the choice of others, and have the opportunity in this way of experiencing regret and envy, or their positive counterparts. Two players participated in each experimental session (see Fig. 1 for the design). The sequence of trials was the same for each subject. In each trial subjects were first informed about the condition in which they were going to play, which could be one or two players. They were then presented with two lotteries and they had to choose one of the two. In the one player trial, after his choice the subject was informed of the outcome of the lottery he had chosen and the outcome of the other lottery. In the two players trials after his choice he was informed of the choice of the other subject, which could be the same that he had selected or not. He was then informed of the outcome of the two lotteries: so he would be able to compare his outcome and the outcome of the other. After each trial the subject was invited to rate his subjective feelings on the outcome he had just observed. We also measured the skin conductance responses and heart rate of all participants during the entire experiment.

Depending on the treatment (one or two players), choice of both players (same or different choice) and on the outcome (gain or loss relative to the other lottery's outcome) in every trial six events are possible, each potentially associated with an emotion: relief and regret are the events occurring in the one player trials when the payoff of the subject was larger or smaller than the non chosen lottery, shared relief and shared regret occur in two players trials when both players made the same choice, gloating and envy occur when their choices were different. The last two are the social correspondent of relief and regret since they are based on a social comparison.

As expected, relief, shared relief and gloating received an average positive score, while the other three had a negative rating (see Fig. 2A). Different physiological responses corresponded to positive and negative emotions; for instance, subjects' heart rates were significantly higher for the three positive emotions compared with the negative ones (Wilcoxon Signed Rank Test (WSRT), $Z = 4.283$; $P = .0001$, Fig. 2B). For both positive and negative emotions, those in the two players treatments received a stronger rating (larger in absolute value) than their correspondent in the single player trial. Specifically, gloating was stronger than relief (WSRT, $Z = 4.03$, $P < .001$), and envy was stronger than regret (WSRT, $Z = 2.75$, $P = .0059$). On the other hand, the shared emotions in the two player trials had a weaker rating than their single player correspondent: relief was stronger than shared relief (WSRT, $Z = 4.62$, $P < .0001$), and regret was stronger than shared regret (WSRT, $Z = 4.12$, $P < .0001$).

Comparisons between obtained and un-obtained outcome in the two players trials resulted in an amplification of the emotional responses, as also indexed by a measure of emotional arousal such as the skin conductance responses (SCR) (Fig 2C). Thus the interdependence between the two subjects strengthens the emotional experience when assessing one's choice consequence. The difference of the emotional evaluation between gloating and relief (social *vs.* private gain) was significantly higher (WSRT, P = .046) than the difference between regret and envy (social *vs.* private loss) (Fig. S1). Thus, contrary to the private domain, social gains loom larger than social losses (Fig. 3).

Subjective ratings, SCR and heart rate measurements might simply indicate affective responses with no consequence on behavior. Our model of choice with interdependent utilities (*13*) suggests otherwise: once subjects get acquainted with the idea that the choice of the others will affect, at the moment in which the outcome is communicated, the utility they derive from the outcome, they will also anticipate this effect and keep it into consideration at the moment of choice.

The experiment was designed to analyze this effect, by randomly allocating subjects to two treatments that we may call bold and prudent. In the bold one, subjects were facing the choices of the other as determined by a computer programmed to select the lottery with higher expected value, irrespective of the risk. In the prudent one, the program chose as an extremely risk averse decision maker would choose, by minimizing the variance of the outcomes of the lottery (see Fig. S2). The use of two different criteria implied that the choice of the opponent that subjects were facing differed on a substantial part of the trials, 23 over the 40 two players trials (in which the subject observed the choice of the opponent). The differences occurred at equally distributed points during the session so their cumulative effect might induce over the course of the experiment a different behavior of the subjects in the two groups. A very visible consequence of the difference in policy was that the performance of the opponent was very different for the two groups: the average payoff was $ 4.125 per trial for the bold treatment, instead of the $ 1.875 for the prudent treatment. In other words, the two groups of subjects were facing two different competitors: one group had tough competitors, with high average payoff, the other weaker competitors with relatively lower average earnings.

The model we report (*13*) predicts that if subjects derive more utility from social winning (gloating) than dis-utility from social losses (envy), their behavior in the two environments will be significantly different, and dependent on the behavior of the opponent. The dependence is not based on imitation: Rather than adjusting to the different environment by mimicking the behavior of the other, subjects should behave boldly in the prudent environment, and prudently in the bold one.

The intuitive reason for this effect on behavior (which is formally the asymmetry of the Nash equilibrium, in which players in a game with symmetric payoff choose different actions) becomes clear if we consider the extreme case of two players with a risk-averse utility function who only care about winning. Suppose that the choice they have is between a lottery giving with equal probability $10 and $0, and a certain amount $5. If subjects are risk averse, they would choose the certain amount $5 in the one-player condition. In the two-player condition, a subject who knows that the other is going to choose the certain amount has now an additional incentive to choose the lottery, given by the gloating he enjoys when $10 is the outcome. Suppose that this incentive is enough to make him choose the lottery, and consider now the best course of action of the other player. He can choose the lottery: but since the outcome is the same for both players, the total value he derives from it is equal to the expected utility of the lottery, which by risk aversion is smaller than the utility of the certain amount. In addition the choice of the certain amount gives the additional value from gloating when the opponent gets the $0 amount. Hence his best choice is the certain amount, and the Nash equilibrium is asymmetric. The evidence provided by subjective evaluations and SCR data suggests that subjects are indeed more sensitive to social wins than to social losses, so the condition that subjects like winning more than they dislike losing is satisfied. Therefore we should observe subjects behaving the opposite way than their opponent.

A simple way of measuring this effect is to estimate the separate effect of mean and variance (risk) of the two lotteries in each choice on the probability of the choice. In this very simple model, the choice depends on the difference between the expected value of the two lotteries and the difference between the standard deviation. After subjects become familiar with the task, the estimated coefficients for each of these two variables have the expected sign: a higher expected value increases the probability of choice of the lottery; a higher variance reduces this probability (see Table 1a and Table S1). Results from the regression analysis on choice behavior also show that the subjects were risk averse in the gain domain and risk lovers for loss, as predicted by Prospect Theory (*14*).

There was no significant difference (in the estimated coefficient for the panel data analysis, $P > .10$) in choices made in the initial trials in which the subjects in the two groups observe the same choices of the opponent; but a significant difference appeared in later trials (see Table 1b and 1c, and Fig. S3). Subjects in the bold treatment become relatively more risk averse, while the opposite happens to subjects in the prudent treatment. The difference in behavior also produced a substantial difference in the payoff for the two groups: the average payoff for subjects in the bold treatment was 2.7 dollars per trial, against a 3.26 in the prudent treatment. These values are intermediate between the 4.125 dollars and 1.875 average payments for the two types of computer reported earlier.

What produced this difference in choice behavior? The subjects in the two groups experienced very different relative payoffs, which induced different emotional experiences. These differences can be measured by the frequency of occurrence of the various emotional events, and by the average difference in the payments for the two subjects in that event. For example, the measure for gloating is provided by the difference between the subject's payoff and the opponent's payoff. The only type of event for which the difference is significant is gloating (when we consider number of occurrences or value: see Tables S2-S5), and this difference is large (Fig. S4). Subjects facing a prudent opponent had a proportion of trials in which gloating was experienced that is double (21.4 per cent instead of 11.2) the proportion of the same type of trials for subjects facing a bold opponent ($Z = 5.243$, $P < .001$). The average total dollar value of gloating was 108 dollars for the subjects in the bold treatment, as opposed to 241 for the others ($Z = -5.137$, $P < .001$). For comparison, the difference for envy goes in the opposite direction, but is smaller and non-significant (*P* > .2): 14.4 instead of 16.4 for the frequency of occurrence, and 174 instead of 183 for the difference in value. Shared emotions (shared regret and shared relief) are more common for subjects in the bold treatment.

The cumulated effect of this difference over trials is likely to affect behavior: subjects who experience gloating in the past may be more likely to make risky choices in the future. To test whether past gloating affects behavior, we computed the average value of the difference in payment associated with different events in the first 40 trials (early), and tested the effect they had on choices made in the later trials (late). For example, the mean value of the envy is measured by the mean value of the difference between the opponent's payoff and the subject's payoff in the early envy trials. The past experience affects choice in the later trials: in complete agreement with the data provided by the subjective evaluations, gloating has a strong and significant effect, and reinforces risk loving behavior (*P* = .025 for the estimated coefficient in the panel logit regression: (see Table 2); the marginal effect is 3.1 percentage points to the dollar.

The difference in choice behavior between the two groups of subjects is the joint consequence of the effect of gloating on risk aversion and the difference in the amount of gloating experienced by the subjects. This is the only emotion for which the marginal effect is significant and the difference among the amount experienced by subjects is large. The net effect is the significantly higher level of risk loving behavior in subjects in the prudent treatment. In conclusion, the environment in this experiment influences behavior, the way in which this happens is not by imitation, but by producing the most rewarding behavior in a competitive environment.

Our initial hypothesis was that socially motivated emotions like envy or gloating combine the learning function (that they share with emotions like regret and relief) with the awareness of one's social status. We have seen that indeed both components are relevant. Emotions in the two-player condition were stronger than in the single player: envy was experienced as more negative than regret, and gloating or the joy of winning more positive than relief. This effect takes place even if the interaction between the two subjects was minimal: they were clearly instructed that the payment would not depend in any way on the performance of the other subject.

These social emotions operate differently from the private ones: while regret (private loss) looms larger than relief (private gain) (*2, 3*), gloating (social gain) looms larger than envy (social loss). Emotions also significantly affected choices: subjects that experienced more gloating behaved in a more aggressive way. Indeed, the environment and the consequence experience of social-ranking based emotions dramatically affected subjects' choice behavior.

Behavior based on social comparison (*7-9*) is also found in nonhuman primates. Capuchin monkeys would refuse a previously accepted reward, for a given effort, if another monkey got a better reward (*15*), indicating an early evolutionary origin of the interdependent utilities.

Notes and References

1. M. Zeelenberg, F.G.M. Pieters, *Organ. Behav. Hum. Decis. Process*. **93**, 155 (2004).

2. N. Camille et al., *Science.* **304**, 1167 (2004).

3. G. Coricelli et al., *Nature Neuroscience.* **8**, 1255 (2005).

4. N.J. Roese, J.M. Olson, *What Might Have Been: The Social Psychology of Counterfactual Thinking* (Erlbaum Mahwah, NJ, 1995)

5. A. Ferrer-i-Carbonell, *Journal of Public Economics*. **89**, 997 (2005).

6. . T. Veblen, *The Theory of the Leisure Class*, (The Modern Library, New York, 1934);

7. J. S. Duesenberry, *Income, Saving, and the Theory of Consumer Behavior*, (Harvard University Press, Cambridge, 1949);

8. A. Abel, *American Economic Association Papers and Proceedings*, **80**, 2, 38 (1990);

9.J. Gali, *Journal of Money Credit and Banking*, **26**, 1, 42 (1994)

10. U.Gneezy, A. Rustichini, *Quarterly Journal of Economics*. **115**, 791 (2000).

11. E.F.P. Luttmer, *Quarterly Journal of Economics*. 963 (2005).

12. A.E. Clark, A.J. Oswald, *Journal of Public Economics*. **61**, 359 (1996).

13. Material and methods are available as Supplementary Information.

14. D. Kahneman, A. Tversky, *Econometrica*. **47**, 263 (1979).

15. S.F. Brosnan, F.B.M. de Waal, *Nature*. **425**, 297 (2003).

16. G. Coricelli et al., *Science*. **308**, 1260 (2005).

Figure 1: Experimental Design.

Two subjects participated in each experimental session. They did not know each other before, and they were briefly introduced at the beginning of the session. During the experimental task they were sitting in the same room, each playing on a computer, separated from the other by a panel wall. They were told they were going to make the same sequence of choices, and that their own payment would not depend on the other's choices and outcomes. The two computers were synchronized so that the two players went through the same sequence of trials.

A trial could be a single player or a two player. The subjects knew at the beginning of the trial whether that was going to be a single player or a two player trial. Each lottery was surrounded with one dotted square in case of a one player trial or two dotted square of different color, one color for each player, in case of a two players trial. The subject could choose at any time after the beginning of the trial, by pressing the arrow corresponding to the choice on the keyboard of the computer. After they made their choice, the dots describing the square surrounding the chosen lottery changed into a continuous line while the other dotted square disappeared. In the two player condition, the lottery selected by the subject would be marked with a green square, and the lottery chosen by the other player (possibly the same) would be marked with a yellow square. The other player's choice was displayed always after the subject's choice had been made. After both players had made their choice, the subject would observe an arrow spinning, and stop, on both lotteries. He would then know how much he had won and how much he would have won choosing the other lottery. In the two players condition, the subject would also discover how much the other player had won and would have an opportunity to experience envy, or gloating (in situation where the two players chose a different lottery), depending on his and the other's outcome.

At the end of each trial the subject was invited to indicate his subjective feeling in that moment on a scale from -50 to +50, by choosing a position on a slider. At one extreme, the slider indicated the state "Extremely Positive", at the other extreme "Extremely Negative". The middle position was marked "Neither Positive or negative". At the end of the experiment, subjects were paid an amount of money corresponding to the average payoff of ten randomly selected trials.

Figure 2A: Average subjective evaluations for different events

The bars represent the average value (+ standard error) of the subjective evaluation given by subjects in the different events. Events are classified as follows. If the trial was a single player then the event is classified as regret if the outcome of the non-chosen lottery is larger that that of the chosen one, and relief in the opposite case. If the trial was two players, and subjects had made a different choice, then the event is classified as envy if the outcome of the subject's lottery was smaller that the outcome of the other's lottery, and gloating in the opposite case. If the trail was a two players trial, and the two players had made the same choice, then the event would be shared regret or shared relief.

The pictures around the horizontal axis show the typical screen display seen by the subjects in the different events. For example in the left panel (regret), the subject sees the outcome of the lottery he has chosen (on the left) and the outcome of the lottery he did not choose (on the right). Since the first outcome, 5, is smaller than the second, 20, this event is classified as regret. Envy is rated as more negative than regret, and gloating as more positive than relief. When the subjects chose the same lottery, they shared the negative or positive impact of the resulting emotions (shared regret or shared relief).

Figure 2B: Variation in Heart Rate in each event.

Vertical bars represent the average value (+ standard error) of the subjects' heart rate variation, in beats per minute in the different events. Heart rate is computed for the 3 seconds following the display of the outcome of the lotteries. The variation is then computed by subtracting the heart rate during 2 seconds before the outcome (spinning period) from the computed heart rate. Subjects' heart rate was significantly higher for the positive emotions compared with the negative ones.

Figure 2C: Magnitude of the SCR response and absolute value of the subjective ratings.

The vertical axis reports the absolute value of the subjective ratings. The horizontal axis represents the SCR magnitude after the outcomes of the lotteries were displayed. Data are classified by events for each subject. Dots represent the averages across subjects. The correlation between the two is high (0.883) and significant ($P = 0.016$). Higher SCR magnitude and emotional rating (in absolute value) corresponded to the emotions related with different choice in the two players condition (envy and gloating). Thus the interdependence between the two subjects strengthens the emotional experience when assessing one's choice consequence.

Figure 3. Private vs. social gains and losses

The horizontal axis reports in both panels the difference between the outcome for the counterfactual choice and the outcome of the choice made by the subject. In the left panel the counterfactual choice is the choice that the subject could have made; in the right panel the choice is the choice of the other. The vertical axis reports the utility derived from the comparison of obtained and counterfactual outcome. In private comparisons, losses have a larger effect on utility than gains. In the social comparison the opposite is true. The utility function reported in the left panel is similar to the value function for gains and losses assumed in Prospect Theory ([11]), where also losses loom larger than gains (loss aversion). The function γ (from our *theory of interdependent utilities* (I.U.T (*14*)) refers to the effect on the utility of the counterfactual between the obtained outcome and the outcome of the unchosen lottery in the private domain (one player treatment) (*16*), and the counterfactual between the obtained outcome and the outcome of the other player in the two players treatment.

Table 1: Panel data logit analysis of the choice of subjects.

The tables report the coefficients estimated in the panel data logit regression of the choice made by subjects. The variable difference in expected value is the difference between the expected value of the first and second lottery; the variable risk is the difference between the standard deviation of the first and second lottery.

Table 1a: Choice behavior for the two environments

The estimate for all subjects

Table 1b: Choice behavior in the prudent environment

The same estimate restricted to subjects in the prudent environment

Table 1c: Choice behavior in the bold environment

The same estimate restricted to subjects in the bold environment

Table 2: The effect of experienced emotions on choice behavior.

The table reports the coefficients estimated for the average value of the difference in payment associated with different events in the first 40 trials (early envy and early gloating respectively) on choices made in the last 40 trials. The variables expected value and risk are as in Table 1. The variable risk times loss is equal to the latter when the expected value of the two lotteries is negative: this coefficient captures the loss aversion of subjects. The two last variables are the product of the total value of envy and gloating in the early (first 40) trials times the variable risk.

Figure 1: Experimental design

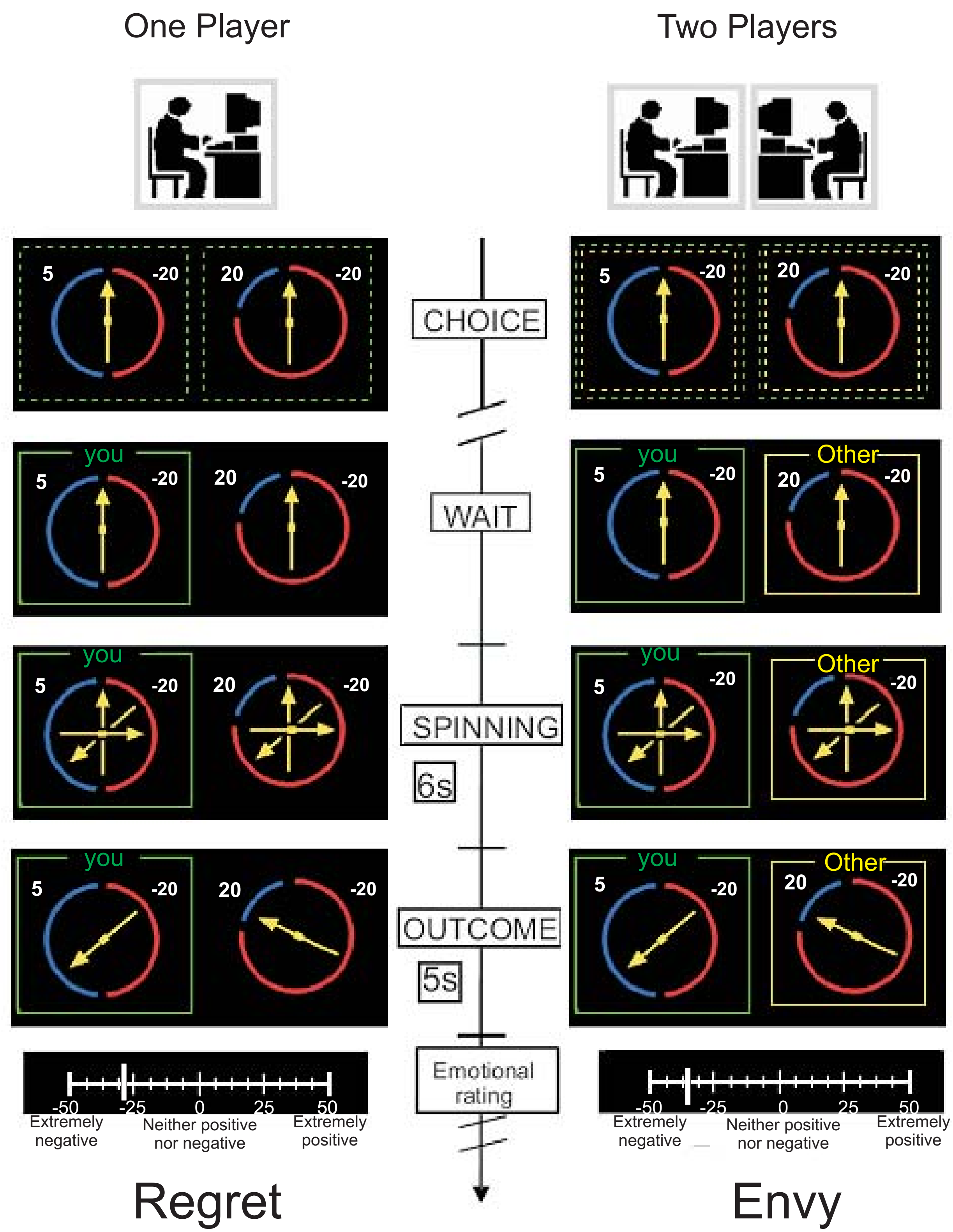
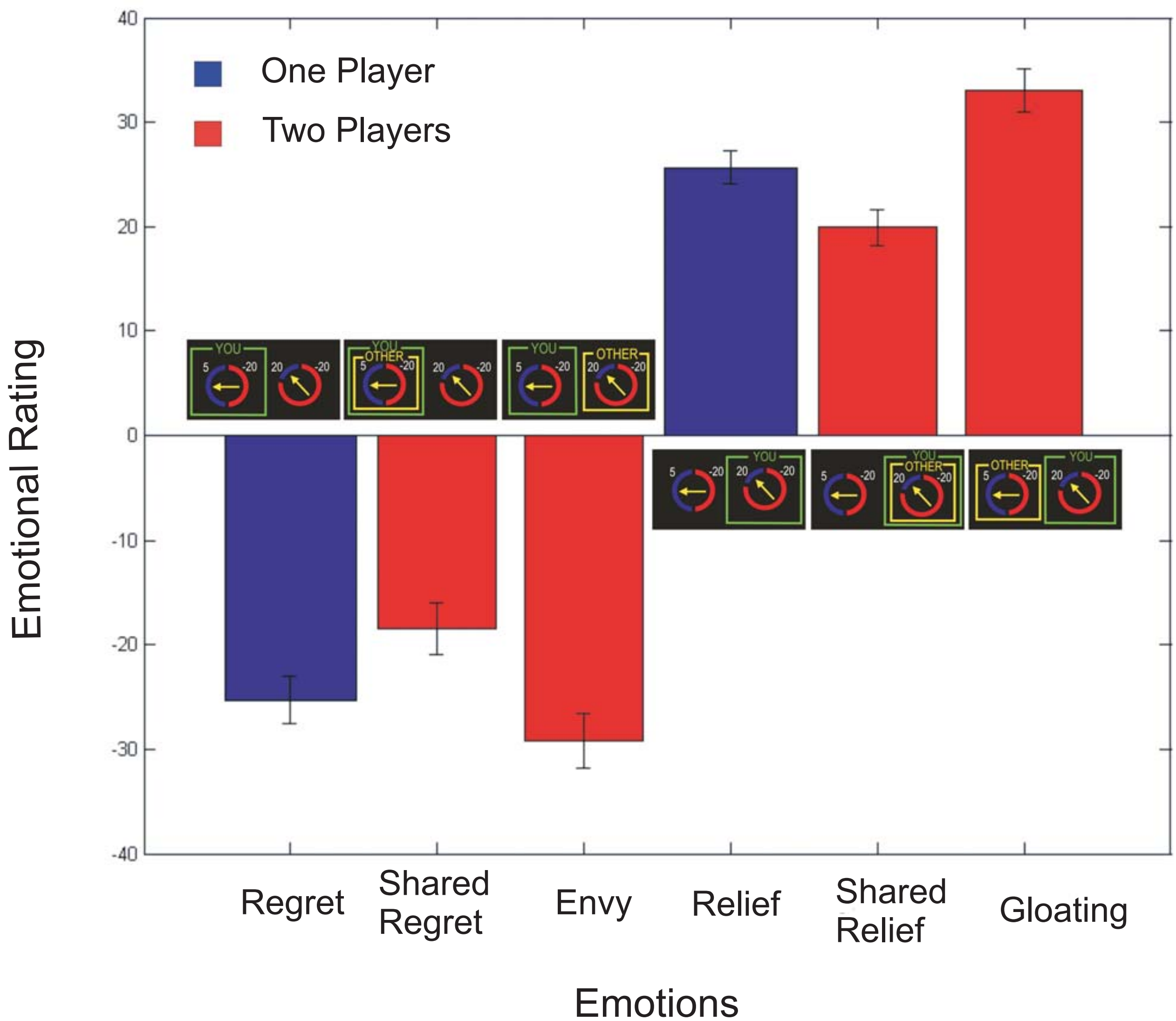
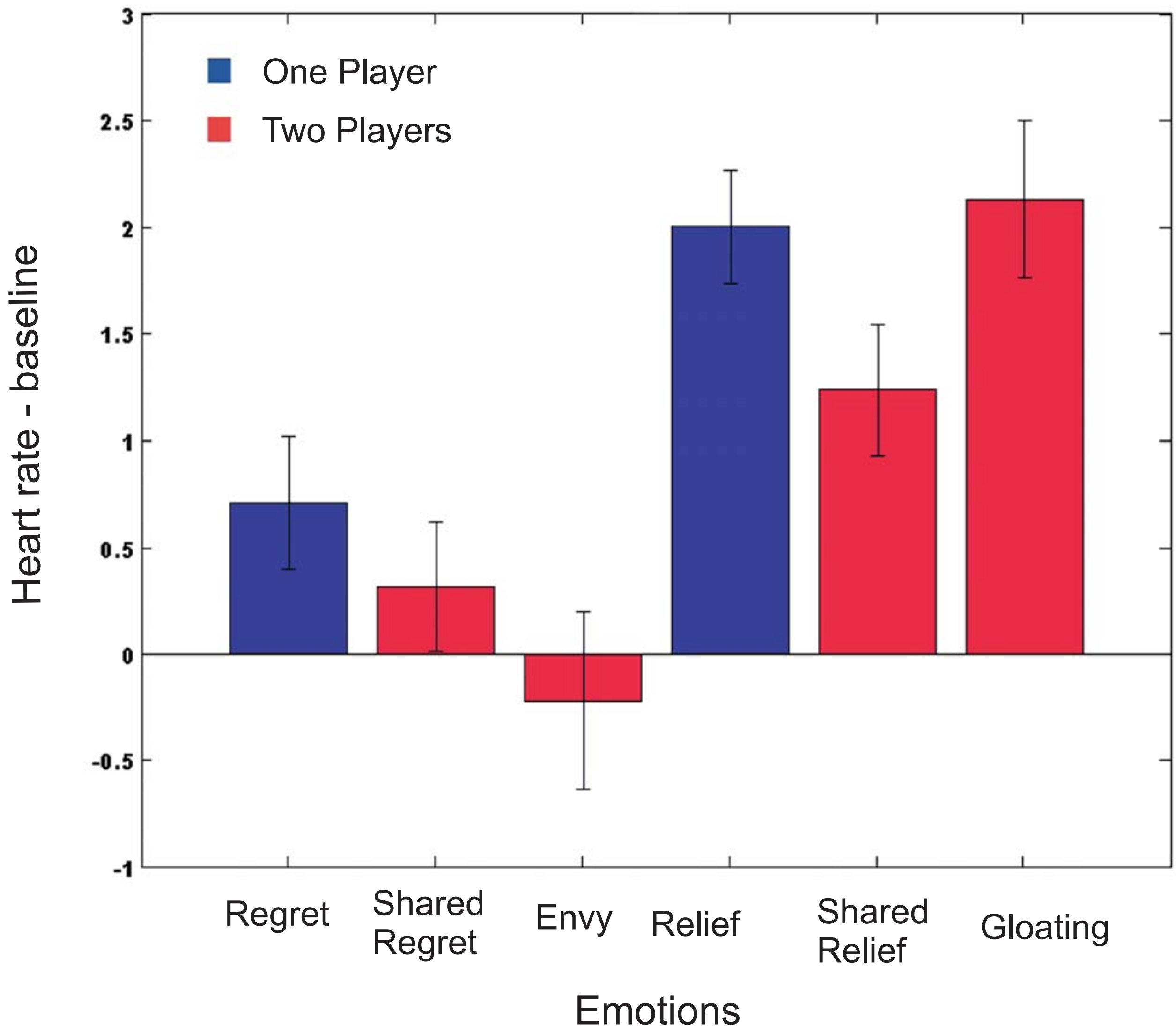


Figure 2: Emotional responses

A

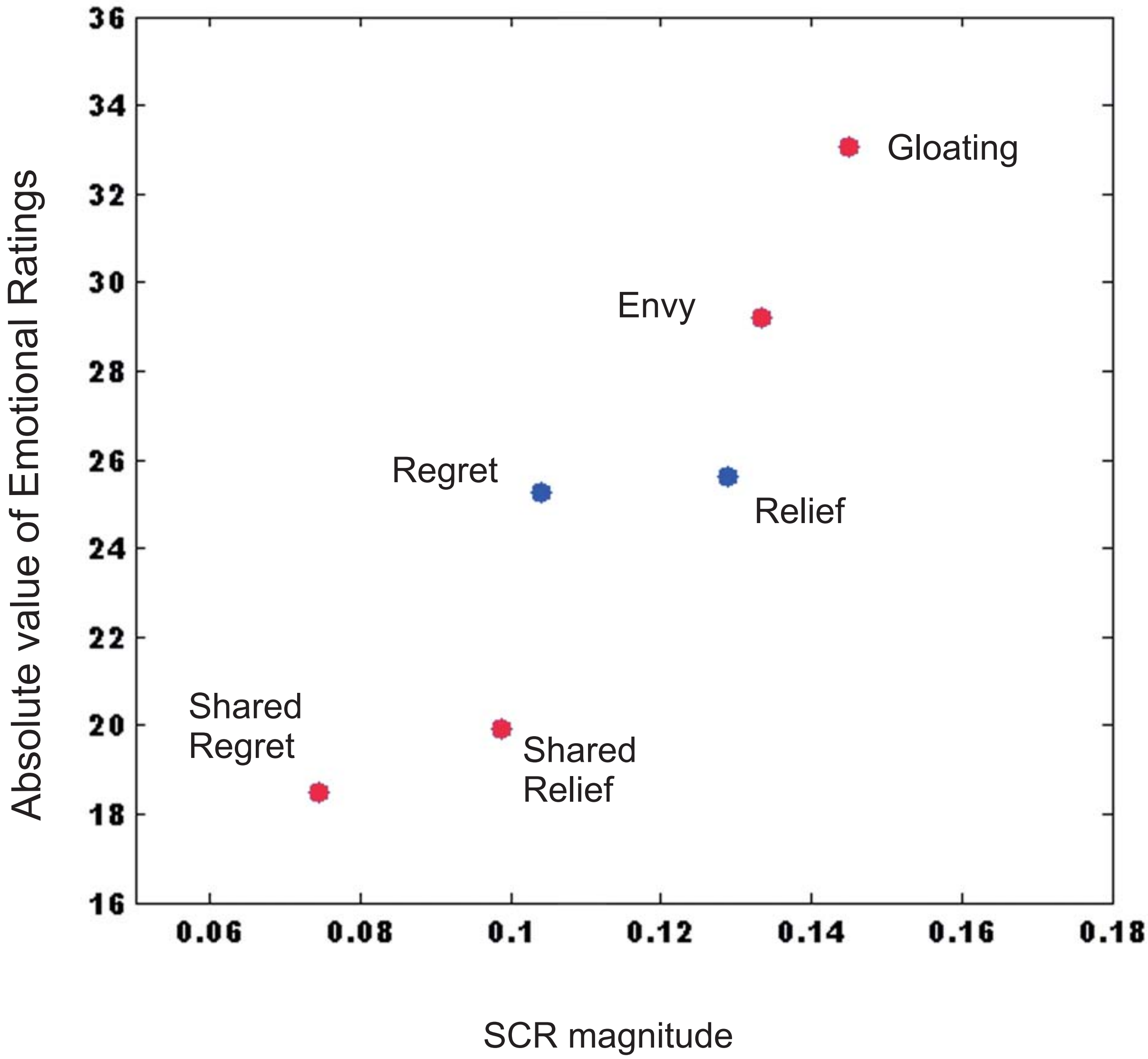


B



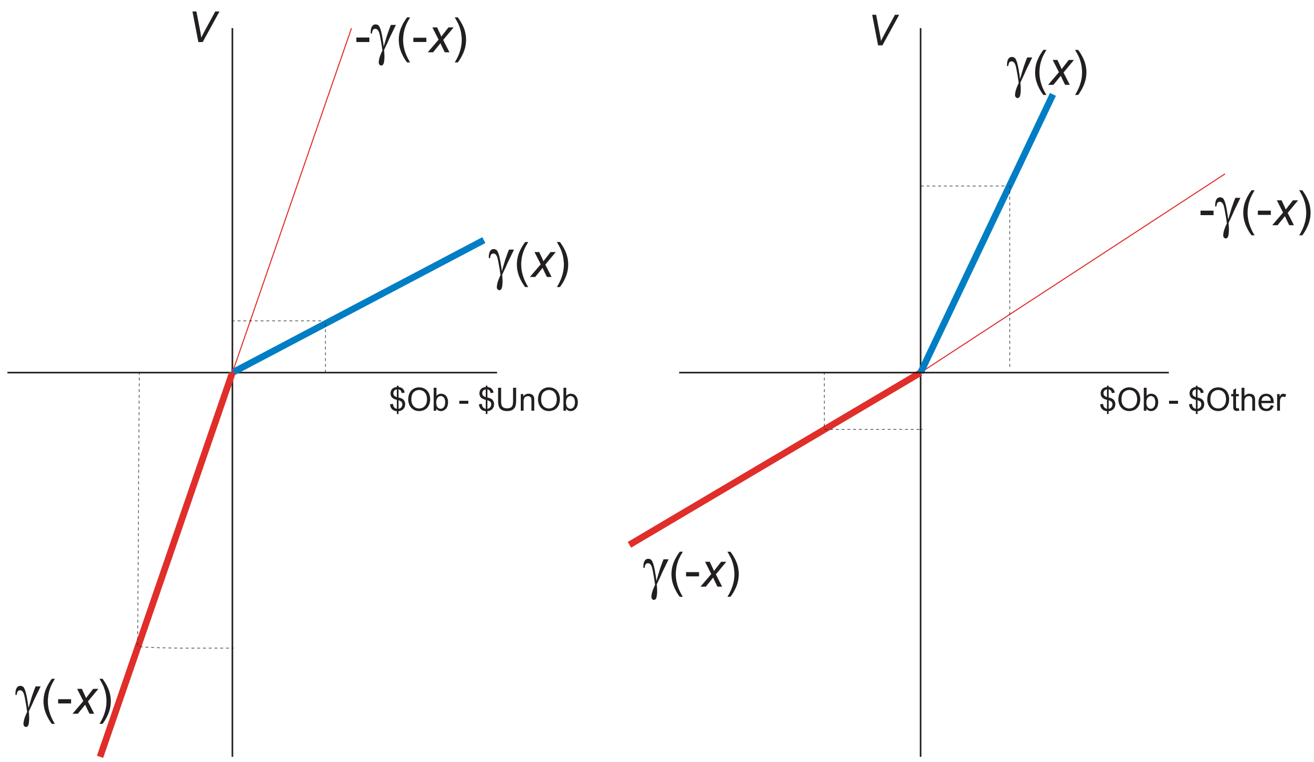
3
2.5
2
1.5
1
0.5
0
-0.5
-1
One Player
Two Players
Heart rate - baseline
Regret
Shared Regret
Envy
Relief
Shared Relief
Gloating
Emotions

C



36
34
32
30
28
26
24
22
20
18
16
Absolute value of Emotional Ratings
Gloating
Envy
Regret
Relief
Shared Regret
Shared Relief
0.06
0.08
0.1
0.12
0.14
0.16
0.18
SCR magnitude

Figure 3: Private vs. Social gains and losses



Private losses loom larger than gains

Social gains loom larger than losses

V=utility function
$Ob=obtained outcome
$UnOb=outcome of the unchosen gamble
$Other=outcome of the other player

Table 1: Choice behavior

a. Choice behavior

Variable name	Coefficient	Standard error	Z	P
Constant	-0.1205	0.0410	-2.94	0.003
expected value	0.2759	0.0123	22.42	<0.001
risk	-0.0308	0.0097	-3.16	0.002
risk*loss	0.0477	0.0147	3.24	0.001

Number of subjects = 42; number of observations = 3360.
Log likelihood = - 1944.3451, Wald chi2(3) = 596.32, Prob > chi2 = 0.000
The dependent variable 'choice' is equal to 1 if subject chose gamble 1 and 0 if subject chose gamble 2.

b. Choice behavior in the prudent environment

Variable name	Coefficient	Standard error	Z	P
Constant	-0.0014	0.1177	-0.01	0.99
expected value	0.2320	0.0296	7.83	<0.001
risk	-0.0086	0.0196	-0.44	0.663

Number of subjects = 42; number of observations = 420. Data from two-player and Late trials (t>40).
Log likelihood = - 251.48, Wald chi2(3) = 64.94, Prob > chi2 = 0.000
The dependent variable 'choice' is equal to 1 if subject chose gamble 1
and 0 if subject chose gamble 2.

c. Choice behavior in the bold environment

Variable name	Coefficient	Standard error	Z	P
Constant	-0.1750	0.1142	-1.53	0.125
expected value	0.1961	0.0284	6.9	<0.001
risk	-0.0483	0.0197	-2.45	0.014

Number of subjects = 42; number of observations = 420. Data from two-player and Late trials (t>40).
Log likelihood = - 253.43, Wald chi2(3) = 60.19, Prob > chi2 = 0.000
The dependent variable 'choice' is equal to 1 if subject chose gamble 1
and 0 if subject chose gamble 2.

Table 2: The effect of experienced emotions on choice behavior

Variable name	Coefficient	Standard error	Z	*P*
Constant	-0.1000	0.0589	-1.7	0.089
expected value	0.2598	0.0169	15.34	<0.001
risk	-0.1700	0.0305	-5.58	<0.001
risk*loss	0.0772	0.0213	3.62	<0.001
early envy on coeff. of risk	0.0415	0.0117	3.54	<0.001
early gloating on coeff. of risk	0.0318	0.0137	2.32	0.021

Number of subjects = 42; number of observations = 1680. Data from Late trials (t>40).
Log likelihood = - 987.1557, Wald chi2(3) = 283.92, Prob > chi2 = 0.000
The dependent variable 'choice' is equal to 1 if subject chose gamble 1 and 0 if subject chose gamble 2.

Marginal effects

```
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
     dev |   .2597972      .01694   15.34   0.000   .226593  .293002       .475
     dsd |  -.1699969      .03049   -5.58   0.000  -.229749 -.110245     -1.675
 dsdloss |   .0772472      .02131    3.62   0.000   .035475   .11902     -1.175
Mvalen~d |   .0414964      .01172    3.54   0.000   .018533  .064459   -2.46383
Mvalgl~d |   .0317848      .01372    2.32   0.021   .004887  .058683   -2.35568
```

Interdependent utilities: How social ranking affects choice behavior

Supplementary Information

Methods

Subjects

Forty two subjects participated in the experiment (29 male subjects). The average age was 21.5 years ($\pm$ 2.01 years). These volunteers gave fully informed consent for the project which was approved by the French National Ethical Committee (*Comité Consultatif de Protection des Personnes dans la Recherche Biomédicale*). Participants were financially motivated, as we report in detail later.

Experimental design

Two subjects participated in each of our experimental sessions, lasting 80 trials. The subjects did not know each other before the experiment, and were introduced to one another at the beginning of the session.

During the experimental task they were sitting in the same room, each playing on a computer, separated by a panel wall. They were told they were about to play together at the same game but that there own gain would not depend on the other's choices. In each trial the subjects had to choose one of two lotteries displayed on the computer screen.

Lotteries

In each trial subjects had to choose between two lotteries. A lottery is a description of two monetary outcomes, indicated by numbers, and the probability of each, indicated as the sector on a circle. Of 80 pairs of lotteries in total, 40 were presented in the single player game, and 40 in the two players game. The set of choices in the two and single player game were identical, but they were presented in a different order. The order was the same for all pairs of subjects. The lotteries consisted entirely of combinations of four possible outcomes: $-20, -5, 5$ and 20. The probabilities of different outcomes were in the set $\{0.2, 0.5, 0.8\}$.

The lotteries were paired so that no one of the two would dominate the other in the first order stochastic dominance. In all choices, the expected value of both lotteries is either positive (in 5 pairs of lotteries) or negative (in the other 5). In 4 out of 10 pairs of lotteries one of the lotteries had a higher expected value while the other one had a lower standard deviation. In the remaining pairs, one lottery had both a higher expected value and a lower standard deviation than the other one. Pairs of lotteries were presented twice in each of the four blocks, once in a one player trial, and once in a two players trial. The order of the trial was randomized inside each block.

Two computer algorithms

During training the participants actually saw their opponent real choices. During the task, choices of the second player were computer simulated in order to control the experimental environment. In addition, this allowed us to consider each participant as an independent observation. No participants reported any doubt about who they were playing with during post-task debriefing.

One of the computers was choosing the lottery with the highest expected value in 90 per cent of the choices. The other was selecting the lottery with the lowest standard deviation. Thus, we had two experimental groups: 21 participants received a bold treatment, interacting with a risk prone opponent; and 21 participants had a more prudent treatment, facing a risk averse opponent.

Choice Task

The subjects knew at the beginning of the trial whether that was going to be a one player or a two players trial. Each lottery was surrounded with one dotted square in case of a one player trial or two dotted square of different color (yellow and green: each color standing for each of the players), in case of a two players trial. The subject could choose at any time after the beginning of the trial, by pressing the arrow corresponding to the choice on the keyboard of the computer.

After they made their choice, the dotted square surrounding the chosen lottery became plain while the other one disappeared. In the two players condition, the lottery selected by the subject would be marked with a green square, and the lottery chosen by the other player (possibly the same) would be marked with a yellow square. The other player choice was displayed always after one's choice had been made. The two players were going through the same trials together, and if one player took longer to chose, the other had to wait.

After both players had made their choice, the subject would then observe an arrow spinning, and stop, on both lotteries. He would then know how much he had won and how much he would have won choosing the other lottery, and have an opportunity for regret or relief. In the two players condition, the subject would also discover how much the other player had won and would have an opportunity for envy, or gloating, depending on his and the other's outcome.

At last, subjects had to evaluate their emotional state regarding to what they had just won or lost. Besides the subjective feeling, we also measured the emotional involvement of the subjects in the different events with a measurement of the Skin Conductance Response (SCR), and the heart rate. Additional information was provided by the response time.

Subjective ratings

At the end of each trial the subject had to evaluate how he/she felt regarding of the amount just won or lost, by choosing a position on a slider on a scale ranging from -50 to +50. At one extreme, the slider indicated the state "Extremely Positive" (*"Extremêment Positif"*), at the other extreme "Extremely Negative" (*"Extremêment Negatif"*). The middle position was marked "Neither Positive nor negative" (*"Ni Positif Ni Negatif"*).

Electrophysiological recording

To access somatic state activation, electrodermal skin conductance responses and heart rate were recorded with a BIOPAC MP35 data acquisition unit (BIOPAC Systems, EU), with a 500 Hz sampling rate. Experimental sessions took place in a noiseless room with temperature set to 20^o c.

SCR recording

Two Ag/AgCl electrodes were placed on the non-dominant hand, after the attachment site had been cleaned with a neutral soap. The tension applied between the 2 electrodes was $0.5V$. As recommended by Dawson et alii ([5]; see also Boucsein, ([3]), responses occurring between 1 second to 3 seconds after stimulus onset and a delay between valley to peak inferior to 5 seconds, were considered. We choose to keep responses with amplitude superior to $0.02\mu S$ since the recording system had a good sensitivity, and scoring was computerized, thus more reliable than hand scoring (see Dawson et al ([5])).

Mean SCR magnitudes were used when averaging size of SCR across trials. In computing magnitude, absences of measurable responses are treated as response with amplitude zero. This allows us to take into considerations all the trials even when no response occurred, and to keep the information of the frequencies of responses as well as their amplitude.

Heart rate

Two electrodes were placed on the chest. Because of the shortness of the decision window, the heart rate variability couldn't be computed during this period.

Non-parametric tests were applied on the data sets since it violated several parametric assumptions, particularly non-normal distribution of the data and high proportion of zero responses (in case of SCR magnitude). We found no evidence of habituation effects across the experimental session.

1 Interdependent Utilities Theory

The relationship between regret and envy is intuitively clear: in both cases, a subject compares the outcome that he has received from the choice he made with what he could have received with a different choice. The only difference between the two emotions is that in the case of regret the different choice is made hypothetically by him, and in the case of envy by someone else. In both cases the crucial element is the counterfactual thought of what could have happened had the subject made a different choice.

We present here a model that makes this intuitive notion precise, and can be used in the statistical estimates of our data. The model is based on the classical setup of Anscombe and Aumann [1], and is developed in detail in Maccheroni, Marinacci and Rustichini ([7]), elaborating on methods in [6], where a precise axiomatic foundation for the utility is presented. The model provides sound behavioral foundation for choice where the utility depends on utilities.

1.1 Choices and consequences

There is a set of states S and a set C of consequences. An act is a function f from the set of states to the set of consequences. For any given act f, the realization of a state s determines the consequence $f(s)$ delivered to the subject. A set of acts F is available to the subject, when he chooses in isolation, or to all subjects when they are informed about the choice and the outcome of others. Each subject has preferences, indicated by $\succeq$, over vectors $(f, (f_i)_{i\in I})$ of the chosen act f and the set $(f_i)_{i\in I}$ of alternative acts that were available to the subject, in the single player environment, or to all the players in the many players environment. The value of the pair for the subject keeps into account both the direct utility from the choice, as well as the relative comparison that will be made, for every state that realizes, between what the subject gets (defined by $f(s)$), and the consequences $(f_i(s))_{i\in I}$ obtained through the alternative acts.

Representation of preferences

The preference $\succeq$ satisfies a specific set of axioms (see [7] for details) if and only if there is a utility function u defined on C, a subjective probability P over S, and a function γ such that $(f, (f_i)_{i\in I}) \succeq (g, (g_i)_{i\in I})$ if and only if $V(f, (f_i)_{i\in I}) \geq V(g, (g_i)_{i\in I})$, where

$$V(f, (f_i)_{i\in I})) = \int_S u(f(s))dP(s) + \int_S \gamma(u(f(s)), u(f_i)_{i\in I}))dP(s)$$

The function V is the sum of two terms. The first is the standard expected utility of the act f: An individual with no regret or envy (that is, with $\gamma = 0$) is an expected utility maximizer. The second term is the expected value of a term which measures the utility (or dis-utility) deriving from the comparison between the realized utility and the utility associated to the relevant alternatives. For both terms the expectation is taken with respect to a subjective probability distribution over the states, indicated by P.

The function γ is increasing in the first term and decreasing in the second (if we give to the vectors with $\#I$ coordinates the point-wise partial order). The second term of this function summarizes the effect of the counterfactual thinking: if a higher utility is associated with alternatives that were not chosen, then the current utility decreases. When the subject is choosing in isolation, the comparison is made between the act he chose and the acts he could have chosen. When he is choosing together with other individuals, the comparison is between the act he chose and the set of choices made by the others. His value is increasing in his utility (that appears in both terms), and decreasing in the utility of the others.

1.2 Preferences and Choices

In our experiment, the set of choices has two elements, denoted by $\{f, g\}$, both in the case of the single player trials and in the two players trials. We consider the value V when the subject chooses f and the alternative is g of the simple form:

$$V((f, g)) = \int_S u(f(s))dP(s) + \int_S \gamma[u(f(s)) - u(g(s))]dP(s) \tag{1.1}$$

In the one-player trials the act g is the act that the subject has not chosen. In the two-player trial, it is the act chosen by the other subject. The function γ is increasing, and $\gamma(0) = 0$. The crucial property of this function is the relative weight of gains and losses.

1.3 Private *vs.* social gains and losses

An important component of Prospect Theory [4] can be informally described as "losses loom larger than gains". This condition can be more precisely stated either as a local condition at the reference point zero that the derivative from the left is larger than the one from the right. More globally, the condition can be states as $v(x) < -v(-x)$ for every x.

In the case of a subject choosing in isolation, this condition has a natural correspondent: the preference exhibits more regret than relief. Several studies of regret suggest that indeed in this case too the negative dominates the positive, and regret looms larger than relief. The evidence we have seen suggests that for social gains and losses, the gain may loom larger than losses. On the basis of the setup we have presented we can extend the analysis of the relative importance of positive and negative emotions to regret and envy.

If x is a consequence, we denote by x also the constant act giving the consequence x in every state. For an event A, and another consequence y, we denote by xAy the act that gives x on A and y in its complement. Consider for simplicity the case in which there is a single other player: $I = \{1\}$.

We say that a preference $\succeq$ exhibits more gloating than envy if $(x_o, xEy) \succeq (x_o, x_o)$ for every event E which has a subjective probability of 50 per cent, and such that the player is indifferent, in isolation, between xEy and x_o. The subject prefers the fair chance of winning some and losing some rather than tying all the times. It is proved in [7] that a preference $\succeq$ exhibits more gloating than envy if and only if the function γ satisfies:

$$\text{for all } x,\ \gamma(x) + \gamma(-x) \geq 0 \tag{1.2}$$

For the case of regret, the formal statement is identical to that given above comparing gloat and envy, with the only difference that the act xEy is the act that the subject could have chosen but did not choose.

We now see what this property of the function γ implies on the behavior of players in social environments, like our two-player treatment.

1.4 The Nash equilibrium set

In the two players trials the subject has to keep into account, at the moment of selecting his lottery, the likely choice of the other player, because his value will be influenced by that choice as well as his own. The appropriate concept in this case is the Nash equilibrium of the game where each subject chooses an act out of the set $\{f, g\}$, and each player receives a payoff given by the function (1.1). The analysis of the equilibria of these game requires that we allow subjects to choose a probability distribution over acts (that is, a mixed strategy). We now analyze the structure of the Nash equilibrium set for this game.

The game is symmetric: if we denote the strategy profile $h = (h^1, h^2) \in \{f, g\}^2$ chosen by the two players, then the pair of payoffs to the two players is the pair:

$$(V(h^1, h^2), V(h^2, h^1))$$

Let p and q denote the probability that the subject and the opponent, respectively, choose the act f in the mixed strategy. The best reply of player 1 to the strategy q of player 2 is denoted $BR^1(q)$, a subset of $[0, 1]$. Since the game is symmetric, $BR^1 = BR^2 \equiv BR$. To characterize the structure of the Nash equilibria we only need to consider the best response to the extreme values of p and q, that is the values $BR(0)$ and $BR(1)$. The graph of the best response function will determine the set of equilibria. For example, if both values are $\{1\}$, then the only equilibrium outcome is (f, f); if $BR(0) = \{0\}$ and $BR(1) = \{1\}$ then there are three symmetric equilibrium outcomes, with outcomes (f, f), (g, g) and a mixed strategy equilibrium.

It is clear that $1 \in BR(0)$ if and only if $V(f, g) \geq V(g, g)$: that is, the choice of f (that is, $p = 1$) is optimal when the other player is choosing g ($q = 0$) if and only if f is at least as good as g when the other is choosing g. Similarly, $1 \in BR(1)$ if and only if $V(f, f) \geq V(g, f)$. The structure of the equilibrium set is completely determined by whether $V(f, g) \geq V(g, g)$ holds or not, and by whether $V(g, f) \geq V(f, f)$ holds or not.

The game may have symmetric equilibria in pure strategies with outcomes (f, f), (g, g) or both, depending on the function γ and on the two acts. For example, $V(f, g) \geq V(g, g)$ and $V(f, f) \geq V(g, g)$ if and only if (f, f) is an equilibrium outcome. The game has a non-symmetric equilibrium in pure strategies if and only if

$$V(f, g) \geq V(g, g) \text{ and } V(g, f) \geq V(f, f) \tag{1.3}$$

An equilibrium in mixed strategies (symmetric) exists if and only if two equilibria in pure strategies exist. Clearly, if $\gamma = 0$ then the only equilibrium is the one where both players choose the same act, the one that maximizes their expected utility.

1.5 Asymmetric Equilibria

Our experimental results suggest that the behavior of our subjects adjusts to an asymmetric equilibrium. In this equilibrium, one of the two players (the computer) is programmed in one treatment to select a safer choice, but with lower return, and in the other treatment to select a more risky but higher return choice. We have seen that the other subject adjusts to the behavior of the opponent by adopting an opposite behavior. In general, the existence of asymmetric equilibria implies restrictions on the function γ, that is on the way subjects' utility varies with the return of the other player. Clearly if such equilibria exist then the function γ is not zero: subjects must care about the outcome of the other. We know more: subjects must enjoy winning than they dislike losing, at least for some values of the utility. To see this, suppose instead that:

$$\text{for all } x, \ \gamma(x) + \gamma(-x) \leq 0 \tag{1.4}$$

With this function the disliking of losing is larger in absolute value than the liking of winning. In this case if $V(f, g) > V(g, g)$ implies that $V(f, f) > V(g, f)$, and then an asymmetric equilibrium does not exist, since the condition (1.3) is not satisfied.

Functions γ for which the condition (1.4) does not hold, so that asymmetric equilibria are possible, are easy to find. A natural example is $\gamma(x) = x^+$: the subject only cares about the case in which he is first, and the utility is proportional to the size of the gap between him and the other.

2 Statistical Analysis

The analysis was conducted with Stata, Stata Corp, College Station, TX, Release 9/SE. The significance of the difference between behavioral variables, response time and subjective evaluations is estimated with the Wilcoxon non parametric test ([8]); the hypothesis tested is that the distribution of two random variables for matched pairs is the same.

2.1 Subjective ratings and SCR response

Table 1: Subjective Ratings and SCR response for different emotions. (N = 42). The magnitude of the SCR response is computed for the moment in which the outcomes of the two lotteries are displayed.

Emotion	Ratings	SCR response
Gloating	33.04	0.1055
Relief	25.62	0.0886
Shared Relief	19.91	0.0589
Shared Regret	-18.49	0.0375
Regret	-25.27	0.0559
Envy	-29.19	0.0799

2.2 Non parametric test on the ratings

Table 2: Wilcoxon-Mann-Whitney signed rank test on the ratings for negative emotions. The null hypothesis is that the two ratings are the same. (N = 42).

	stronger than	z	p
Envy	Regret	2.754	0.0059
Regret	Shared Regret	4.120	0.00001
Envy	Shared Regret	4.276	0.00001

Table 3: Wilcoxon-Mann-Whitney signed rank test on the ratings for positive emotions. The null hypothesis is that the two ratings are the same. (N = 42).

	stronger than	z	p
Gloating	Relief	4.032	0.0001
Relief	Shared Relief	4.620	0.00001
Gloating	Shared Relief	4.670	0.00001

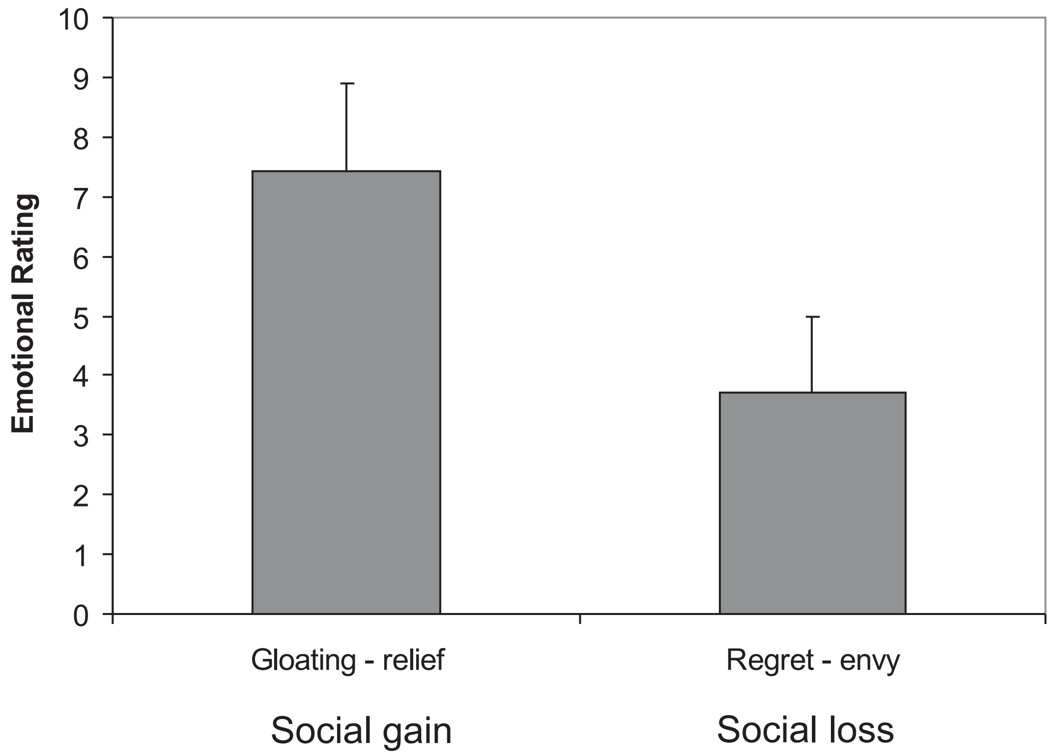


Figure S1: Difference between evaluations in social and private domains: on the left for gains (Gloating minus Relief), on the right for losses (Regret minus Envy).

2.3 Choice

The model used to estimate the parameters of the choice of players is the *logit*:

$$Pr(c = 1|x) = \frac{exp(\alpha + \beta(dev) + \gamma(stdev)}{1 + exp(\alpha + \beta(dev) + \gamma(stdev)}$$

where if ev_i is the expected value of lottery $i, i = 1, 2$, then $dev \equiv ev_1 - ev_2$. Similarly, if $stdev_i$ is the standard deviation of the value of lottery $i, i = 1, 2$, then $stdev \equiv stdev_1 - stdev_2$.

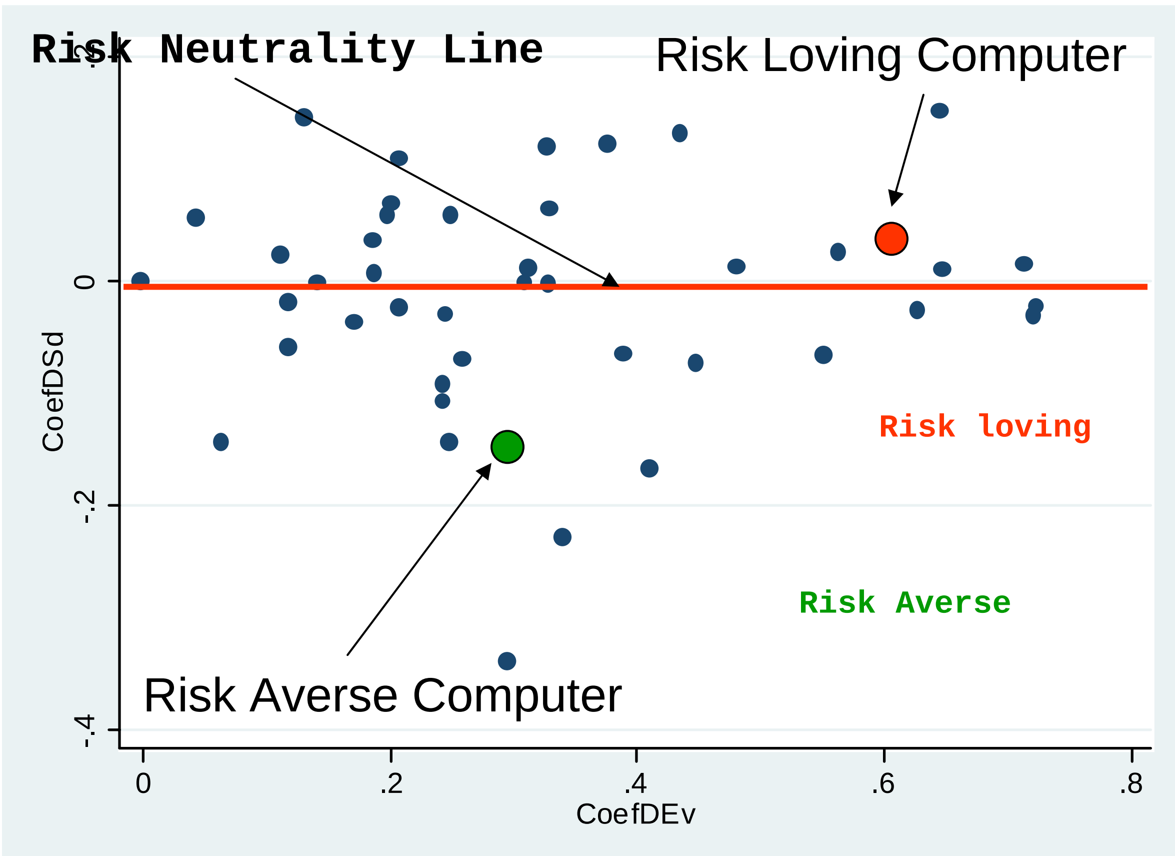


Figure S2: Coefficients of the expected value and standard deviation in the logit regression. Each dot corresponds to the pair of the coefficients for each subject. The green and red dot represent the same estimated coefficients for the computer choices.

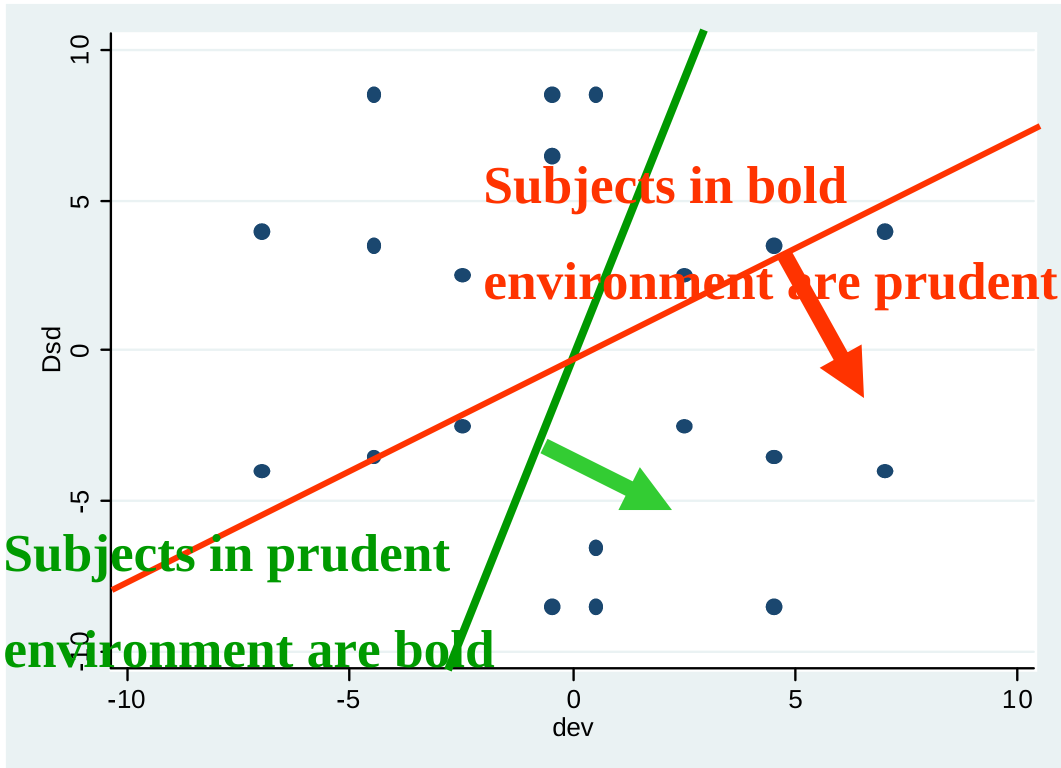


Figure 4S: Choice behavior of subjects in the bold and prudent environment.

2.4 Panel data analysis of choice

The panel data analysis ([2], [9]) takes each subject as the unit and the round as time. The model estimated is the random effects model, and the parameters are estimated by maximum likelihood.

Table 4: Panel data logit analysis of choice. The variable *dev* is the difference in expected value between the two lotteries; *dsd* is the difference in the standard deviation; *devloss* and *dsdloss* are equal to *dev* and *dsd* for choices where the expected value of both lotteries was negative (loss domain). In all trial the sign of the expected value of the two lotteries was the same.

choice	overall b/se	early b/se	late b/se
dev	0.285***	0.319***	0.252***
	(0.017)	(0.027)	(0.023)
dsd	–0.032***	0.010	–0.062***
	(0.010)	(0.015)	(0.014)
devloss	–0.019	–0.050	0.010
	(0.025)	(0.037)	(0.034)
dsdloss	0.046***	0.005	0.077***
	(0.015)	(0.022)	(0.021)
constant	–0.121***	–0.161***	–0.098*
	(0.039)	(0.060)	(0.057)
N	3360	1638	1680

2.5 Occurrence of emotions

Table 5: Average over subjects of the number of occurrences of each event in the bold environment in the prudent environment

Variable	Observations	Mean	Std. Err.	[95% Conf. Interval]
Gloating	21	10.76	.42	[9.87, 11.64]
Envy	21	8.23	.50	[7.18, 9.29]
Regret	21	13.33	.47	[12.34, 14.32]
Relief	21	24.66	.47	[23.67, 25.65]
Shared Regret	21	4.23	.42	[3.35, 5.12]
Shared Relief	21	14.76	.50	[13.70, 15.81]

Table 6: Average over subjects of the number of occurrences of each event in the bold environment

Variable	Observations	Mean	Std. Err.	[95% Conf. Interval]
Gloating	21	5.66	.33	[4.97, 6.36]
Envy	21	7.28	.75	[5.70, 8.86]
Regret	21	13.28	.68	[11.85,14.71]
Relief	21	24.71	.68	[23.28, 26.14]
Shared Regret	21	6.52	.33	[5.82, 7.22]
Shared Relief	21	18.52	.76	[16.93, 20.11]

2.6 Values of emotions

Table 7: Average over subjects of the total Value for each event in the prudent environment. The Value at Envy is defined as the difference between the payment to the other subject and the payment to the subject in the event Envy; the value at the other events is defined similarly.

Variable	Observations	Mean	Std. Err.	[95% Conf. Interval]
Value at Gloating	21	241.90	11.71	[217.46, 266.34]
Value at Envy	21	174.04	13.10	[146.72, 201.37]
Value at Regret	21	296.42	15.28	[264.53, 328.31]
Value at Relief	21	533.57	15.28	[501.68, 565.46]

Table 8: Average over subjects of the total Value for each event in the bold environment. See the caption of Table 7 for details.

Variable	Observations	Mean	Std. Err.	[95% Conf. Interval]
Value at Gloating	21	108.09	6.16	[95.23, 120.95]
Value at Envy	21	183.33	17.20	[147.44, 219.22]
Value at Regret	21	300.71	16.60	[266.08, 335.34]
Value at Relief	21	529.28	16.60	[494.65, 563.91]

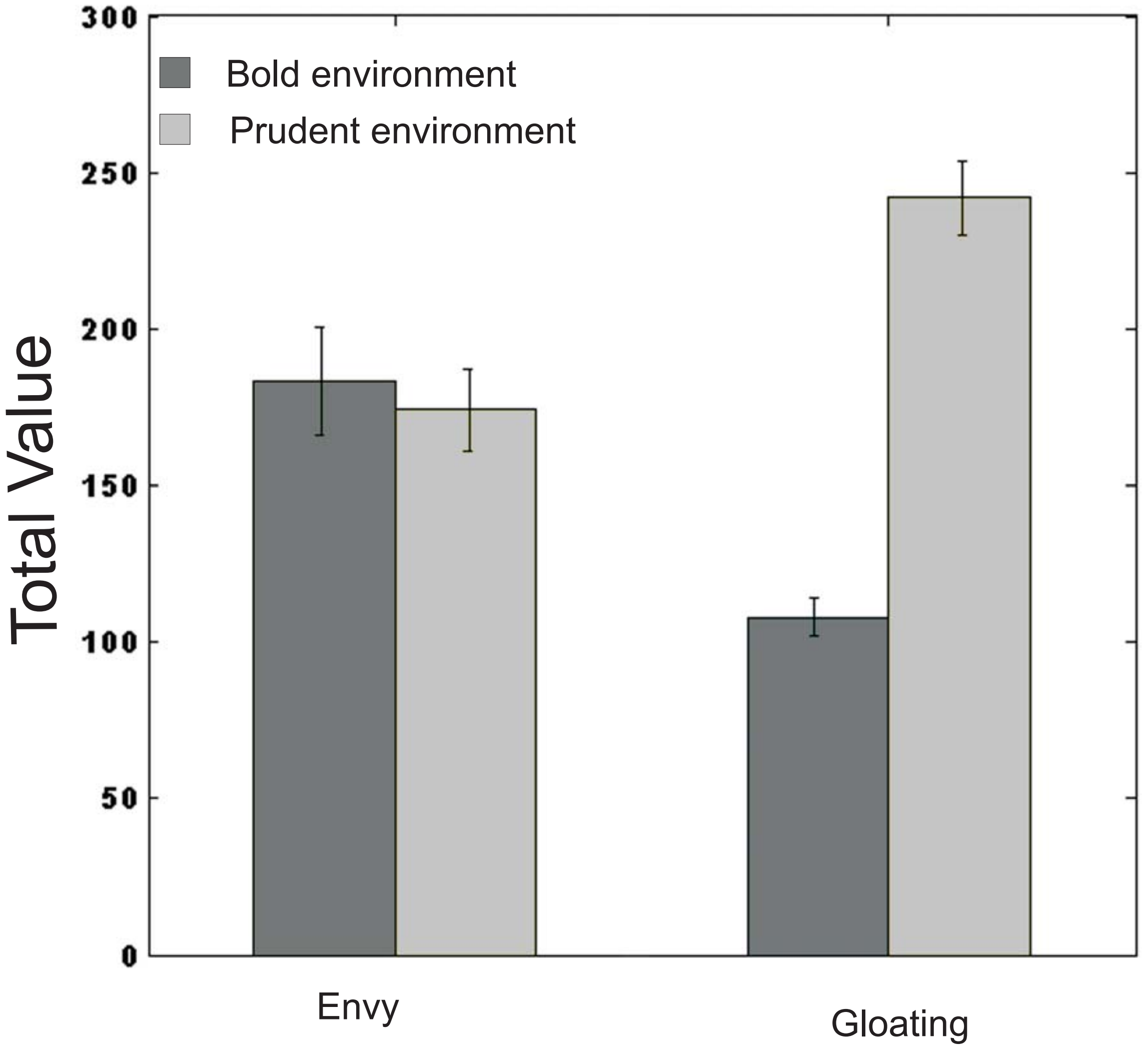


Figure S4: Average over subjects of the total Value at Envy and Gloating in the bold and prudent environments.

References

[1] Anscombe, F. and Aumann, R. J., (1963): “A Definition of Subjective Probability,” *Annals of Mathematical Statistics*, 34, 199-205.

[2] Baltagi, B. H., (2001), *Econometric Analysis of Panel Data*, New York, Wiley.

[3] Boucsein, W., (1992), *Electrodermal Activity*, Plenum Series in Behavioral Psychology and Medicine, Plenum

[4] Daniel Kahneman and Amos Tversy, (1979), “Prospect Theory: An Analysis of Decision under Risk”, *Econometrica*, 47, 2, 263-292.

[5] Dawson, M. E., Schell, A. M., and Filion, D. L., (2000), *The electrodermal system*, in Cacioppo, J. T., Tassinary, L. G., and Berntson, G (Eds.). *Handbook of Psychophysiology*, 2nd ed., Cambridge University Press, Cambridge, UK

[6] Maccheroni, F., Marinacci, M., and Rustichini, A., (2006), “Ambiguity Aversion, Robustness, and the Variational Representation of Preferences”, *Econometrica*, November, 1-62.

[7] Maccheroni, F., Marinacci, M., and Rustichini, A., (2006), “Social Decision Theory”. Mimeo.

[8] Wilcoxon, F., (1945), ”Individual comparison by the ranking method”, *Biometrics I*, 80-83.

[9] Wooldridge, J. M., (2002), *Econometric Analysis of Cross Section and Panel Data*, Cambridge MA, MIT Press.