Supplementary Material

for

A reward prediction error for charitable donations reveals outcome orientation of donators

Kuss K.; Falk A.; Trautner P.; Elger C.E. ; Weber B.; Fliessbach K.

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Methodological Details

Subjects

From originally 36 participants, data of one male subject was excluded from the analysis because of a high number of implausible decisions (e.g. the subject frequently chose alternatives yielding a lower own and charity payoff) during the first part of the experiment. Additionally data from two subjects were excluded due to head movement. The remaining 33 subjects (17 women; 25.6 (*mean*) ± 3 (*SD*) years of age), were native German speakers and all, except one, were right handed. Subjects had no history of psychiatric or neurological disorders. Data from another female subject was missing for the second part of the experiment due to abortion of the task by the subject (the subject failed to memorize the assignment of the response buttons). Informed written consent was obtained from all subjects; the study was approved by the Ethics committee of the University of Bonn.

Technical details

Scanning was performed on a 3 Tesla Trio Scanner (Siemens, Erlangen, Germany) using an 8-channel head coil. Functional data were acquired using EPI-sequences with a repetition time (TR) of 2.5s, an echo time (TE) of 30ms and a Flip angle of 90 degrees. Each volume comprised 37 slices acquired in an axial orientation covering all of the brain, including the midbrain, but sparing parts of the cerebellum. The presentation of the task and recording of behavioral responses were performed with Presentation® software version 14.9 (Neurobehavioral Systems, Albana, Canada). Subjects saw the experiment via Video goggles (Nordic NeuroLab, Bergen, Norway) and gave their responses by response grips (Nordic NeuroLab, Bergen, Norway) using the index fingers of both hands.

Experimental procedure

Before scanning, all subjects received detailed written and verbal instruction and completed practice trials on a laptop, in order to ensure correct understanding of the experimental procedure. They were informed that they would receive a participation fee of

30€ plus an additional payoff depending on their decisions in the experiment (*actual payoff*). They were also informed that, in addition to their own payoff, a payoff for a charity organization would be determined. These randomly chosen payoffs were directly presented via video goggles at the end of the experiment. We did not use deception and actually disbursed the *actual payoff* to the subject and the individually chosen charitable organization. After the study was completed, all subjects were informed about the quantity of donations for each organization resulting from all subjects.

Before entering the scanner, subjects chose a charitable organization, which they were most willing to donate money to out of a list of six. The list of charitable organizations covered a wide range of interests and topics: humanitarian aid, including children, development and emergency aid, as well as environment and animal protection. Supplementary Table S1 lists the six organizations as well as the frequency they were chosen by the subjects and the amount of donated money added over all the subjects.

Importantly, subjects were guaranteed anonymity of their decisions during the decision phase of the experiment. We ensured this by:

- Covering the decisive parts of the control monitor that could be seen by the scanning staff with cardboard. By doing this, the decisions of the subjects could not be observed during the experiment.
- Automatically and randomly determining the *actual payoffs* by the presentation software. Only the chosen alternative and not the respective alternative was shown. Therefore neither the subject nor the experimenter were able to reconstruct which decision situation the randomly chosen outcome was based on.
- Analysis of fMRI and behavioral data was conducted with anonymized datasets so that during the analysis, no association between a dataset and a specific subject could be deduced.

Subjects were explicitly informed about these measures in the written instructions and were shown the cardboard mask on the control monitor before entering the scanner.

Scanning was divided in two sessions, separated by a 10-minute break outside the scanner. The first part lasted on average 47.1 minutes and the second part lasted on average 14 minutes. After the fMRI experiment, subjects filled out a self-report questionnaire regarding their charitable activities in real-life (for a translation of the questions, see appendix 1).

Supplementary Table S1. List of charity organizations

Charity Organization	Times chosen by subjects	Transferred money
Doctors Without Borders	13	510€
World Wide Fund For Nature (WWF)	8	355€
Greenpeace	7	215€
Amnesty International	3	130€
Deutsche Welthungerhilfe (German World Hunger Aid)	3	40€
UNICEF	2	45€

Payoff structure and decision types

We implemented 5 categories of subject´s and charity´s payoff (5€, 10€, 20€, 40€, 80€) resulting in 25 possible combinations of the two payoffs into an alternative (A/B, represented in the rows and columns of Figure S1 respectively). Those 25 alternatives can be assembled into 625 combinations of the two alternatives represented in the cells of Supplementary Figure S1 (decisions-situations: A1/B1, A2/B2). Twenty-five of those are of no interest, since the two alternatives are identical (black cells of Supplementary Figure S1). Three-hundred unique decision-situations can be classified into one of the following four decision situation types (the remaining 300 decision-situations are identical, except for the order of alternative 1 and 2, and are referred to as mirrored situations; grey cells in Supplementary Figure S1):

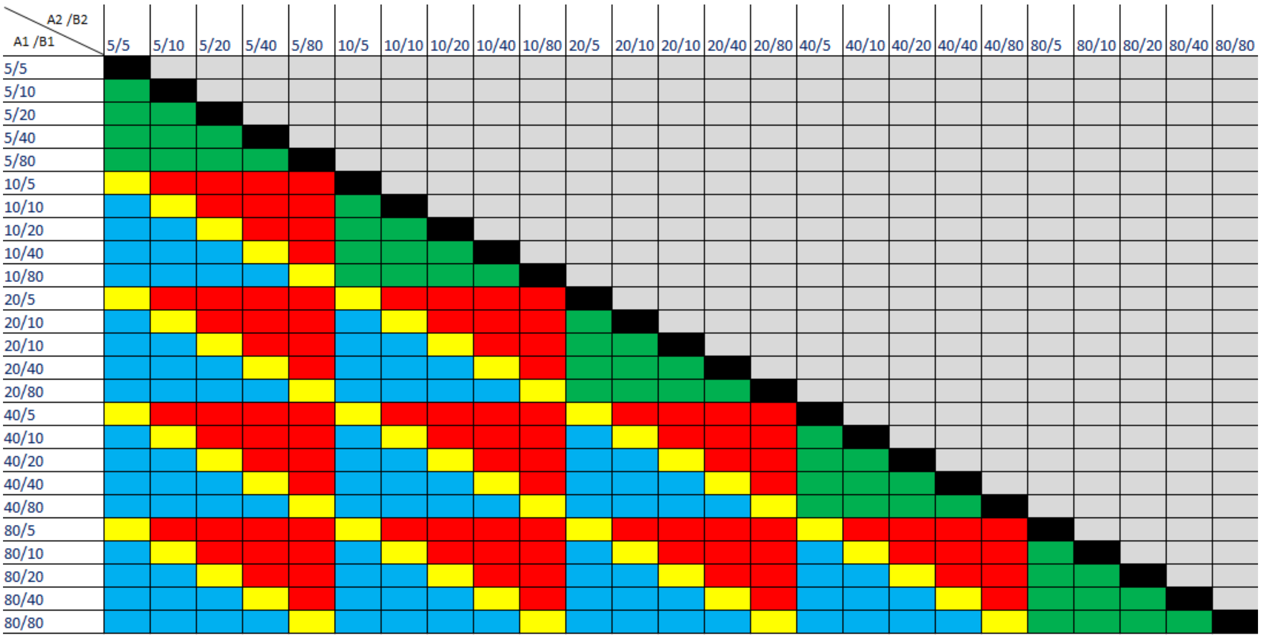
1. Pure-self-interest-decisions-situations (PSI): decisions aimed at monetary gain for the subject, since the subject´s payoff varied whereas the charity`s payoff was held constant. There were 50 unique decision situations of this type (yellow cells in Supplementary Figure S1).

2. Non-costly-donation-decision-situations (NCD): decisions did not affect the subject´s payoff as it was held constant. The charity`s payoff varied. There were 50 unique decision situations of this type (green cells in Supplementary Figure S1).

3. Efficiency-decision-situations (E): both payoffs varied in the same direction, resulting in an alternative with a higher subject´s payoff and a higher charity´s payoff and another alternative with lower payoffs for both. There were 100 unique decision situations of this type (blue cells in Supplementary Figure S1).

4. Costly-donation-decision situations (CD): both payoffs varied in opposing directions, resulting in one alternative with a higher subject´s payoff and lower charity´s payoff, and in another alternative with a higher charity´s and a lower subject´s payoff. There were 100 unique decision situations of this type (red cells in Supplementary Figure S1).

During the first part of the experiment, subjects were confronted with 180 trials randomly drawn out of the 600 decision-situations of interest: in each case, 30 out of the PSI- and the NCD-type, as well as 60 in each case out of the CD- and the E-type were chosen. This distribution represents a weighted sample out of the possible decision situations according to the base rate of the four decision situation types. Half of the 180 decision-situations presented were drawn from the mirrored situations for each decision situation type (15 mirrored situations from the PR- and NCD-type, 30 from the CD- and E-type).



Supplementary Figure S1. Payoff Structure and the classification into 4 decisions situation types

Notes: A: subject´s payoff, B: charity's payoff; A1/B1: alternative 1; A2/B2: alternative 2; 50 yellow cells: Pure-self-interest; 50 green cells: Non-costly-donation; 100 blue cells: efficiency; 100 red cells: Costly-donation; 300 grey cells: mirrored situations (corresponding decisions situations except for the order of alternative 1 and 2)

Details of analysis

Data analysis

Image processing and statistical analyses were performed using SPM8 (Wellcome Department of Imaging Neuroscience, London, UK), MarsBaR (Matthew et al., 2002) and IBM® SPSS® Statistics Version 19 (IBM, Armonk, USA). The figure of the coronal brain section (Figure 3a) as well as Supplementary Figures S2, S7-S11 were generated with MRIcron (http://www.cabiatl.com/mricro/).

Preprocessing

For motion correction, the functional images were realigned to the first image of each time series and again realigned to the mean image after the first realignment. Translational movement never exceeded 2.5 mm and rotational movement never exceeded 2.5° (with respect to the first acquired image) in any subject. Images were then slice-timed using a sync interpolation, normalized to the canonical EPI template used in SPM8 and smoothed with a 6-mm Gaussian kernel. After normalization, images were re-sampled to a voxel size of 3x3x3mm.

Supplementary Table S2. The first level general linear model

Onset regressors	Additional modulators
Part 1 of the experiment	
Event 1 (appearance of alternative 1)	
- 1 onset regressor (R1)	- Parametric regressor representing subject´s payoff (R2) - Parametric regressor representing charity´s payoff (R3)
Event 2[a] (appearance of alternative 2)	
- 1 onset regressor for PSI+ (R4)	
- 1 onset regressor for NCD+ (R5)	
- 1 onset regressor for E+ (R6)	
- 1 onset regressor for CD+ (R7)	
- 1 onset regressor for CD- (R8)	
Event 3 (confirmation / privation of a choice)	
- 1 onset regressor (R9)	- Parametric regressor representing the RPE of the subject´s payoff (R10) - Parametric regressor representing the RPE of the charity´s payoff (R11)
1 nuisance regressor of no interest (R12)[b]	
6 movements parameters	
Part 2 of the experiment	
Event 4 (appearance of a chosen alternative)	
- 1 onset regressor (R1)	- Parametric regressor representing subject´s payoff (R2) - Parametric regressor representing charity´s payoff (R3)
Event 5 (confirmation / privation of a choice)	
- 1 onset regressor (R4)	- Parametric regressor representing the RPE of the subject´s payoff (R5) - Parametric regressor representing the RPE of the charity´s payoff (R6)
6 movement parameters	

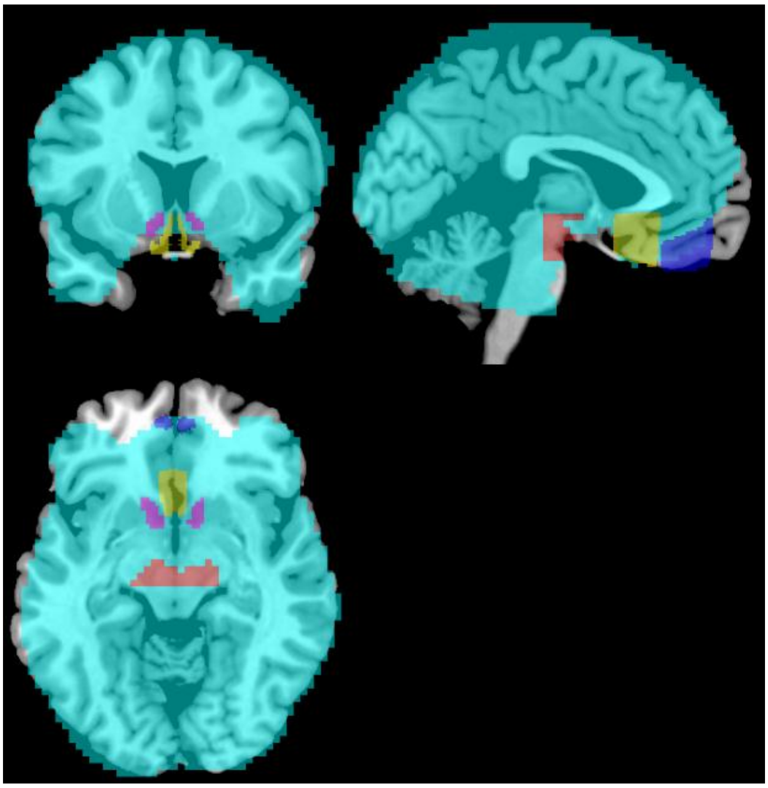
Notes. PSI+: trials where subjects chose the self-interest alternative, NCD+: trials where subjects choose the donation alternative, E+: trials where subjects chose the efficient alternative, CD+: trials where subjects chose the donation alternative, CD-: trials where subjects chose the self-interest alternative ; [a] : To account for reaction time (RT) differences between the conditions, RT were entered as durations of the events into the model (Grinband, Wager, Lindquist, Ferrera, & Hirsch, 2008); [b]: includes trials without decisions and trials of PSI-, NCD- and E- decisions (“implausible decisions”)

Second-level analysis

Effects of RPE regressors: For first and second RPE-induction, we conducted one-sample T-tests for the RPE-contrast for the subject`s payoff and for the charity`s payoff. This was done for the whole group of subjects and for the subgroups of donators and non-donators separately. For the joint analysis of first and second RPE-induction (average RPE effects across time-points), we created mean contrast images for the respective contrast images and subjected them to one-sample T-tests. To test for group differences between the group of donators and non-donators, two-sample T-tests were additionally applied.

Effects of different decision situation types: For analyzing decision-related activity (event 2), we performed a within-subject ANOVA with R4-R8, allowing for comparisons between the four decision types. Additionally one-sample T-tests for each decision type were conducted.

We extracted parameter estimates from the Nucleus accumbens (based on the Harvard-Oxford cortical and subcortical atlases, 50% probability) and averaged across all voxels. Additionallly we applied small volume corrections for the subgenual area, the MOFC and the ventral midbrain (based on the Harvard-Oxford cortical and subcortical atlases, 50% probability). Further a whole brain conjunction analysis to test for joint effects of the subject's payoff RPE and the charity's payoff RPE regressor in the donator group was applied.



Supplementary Figure S2. Mask image of the 2nd level analysis (in light blue) and the regions of interest according to the Harvard Oxford cortical and subcortical structural atlases, 50% probability: mOFC in dark blue (127 voxels), NAc in violet (42 voxels), subgenual area in yellow (190 voxels), ventral midbrainin red (290 voxels). MNI-coordinates: X= -3, Y= 11 , Z= -9

Reward prediction error model

The term reward prediction error (RPE) originates from studies of reinforcement learning. Here, a mismatch between an actual outcome and an expected outcome is thought to be the critical moment that drives adaptive learning (Schultz, 1998). More generally, RPEs arise when rewards occur in an unforeseeable manner. In this sense, the term RPE also applies to lottery gambles or guessing tasks with fixed a priori reward probabilities and without learning (Knutson, Westdorp, Kaiser, & Hommer, 2000; Yacubian et al., 2006) but also in choice experiments, when it is not clear whether a choice is actually realized or not as it is the case in our experiment.

In general the prediction error term can be defined as

$$RPE = R - EV$$

Where R is the reward magnitude of the actual outcome and EV is the expected value in a given situation. EV is given by gain probability times reward magnitude (Yacubian, et al., 2006).

In our study, in order to separate the effects of personal monetary payoffs and payoffs to the charity organization, we calculated reward magnitude and the resulting RPE separately for both payoffs. We focused on the time point, at which the chosen alternative is either confirmed or discarded for the *actual payoff* and the induced RPE through this manipulation. The gain probability in our experiment was fixed because exactly 50 percent of trials were either confirmed or discarded at each RPE induction, which subjects were informed of through the instructions. Therefore, we assumed that the gain probability would constantly be 0.5 during the experiment. The reward magnitude (RM_n, see formula 1) of a given choice in our experiment is not simply reflected by the respective absolute payoffs (x) of a chosen alternative (as it would be the case in any one-shot game). In our experiment, the reward magnitude must be computed with respect to a reference point, which is acquired during the experiment through facing the range of possible payoffs. This is because subjects associate a low reward magnitude to the confirmation of a relative small payoff, since whenever a small payoff is confirmed, the chance of receiving a high payoff as the *actual payoff* decreases. Therefore, subjects should attribute a negative reward magnitude to payoffs which are lower than their reference point.

The following formulas were used to compute the RPEs. Note, we computed the RPE and all necessary parameters (x, RP, EV) separately for the subject´s and charity´s payoff:

$$RM_n = x_n - RP_n; \qquad (1)$$

RM_n=Reward magnitude in a given trial n; x_n= absolute payoff of a chosen alternative in trial n; RP_n = Reference point

$$RP_n = Median(x_1, \dots, x_{n-1}) \qquad (1.1)$$

$$RP_n = Mean(x_1, \dots, x_{n-1}) \qquad (1.2)$$

$$RP_n = Median(x_j\colon 1 \leq j \leq i-1) \qquad (1.3)$$

$$RP_n = Mean(x_j\colon 1 \leq j \leq i-1) \qquad (1.4)$$

j=trials confirmed by the computers

$EV_n = RM_n * 0.5$ (2)

$RPE_n = R_n - EV_n$ (3)

$R_n = RM_n$, in case of confirmation of the chosen alternative (3.1)

$R_n = 0$, in case of deprivation of the chosen alternative (3.2)

The outcome of a given trial (R_n, see formula 3) is given by RM_n in the case of a confirmation (see formula 3.1). In the case of a deprivation, the outcome is 0 (see formula 3.2). The RPE results from comparing the outcome of a given trial with the expected value (see formula 3).

There are several possibilities to approximate the reference point of the subjects. Obviously, it should be based on the distribution of possible payoffs encountered during the experiment. Subjects could base their reference point on the distribution of all previously chosen payoffs (formula 1.1 and 1.2) or only on payoffs that were confirmed by the computer (formula 1.3 and 1.4). Additionally, they could form the reference point based, for example, on the median (formula 1.1 and 1.3) or the mean of this distribution (formula 1.2 and 1.4). We tested these different possibilities and chose the model that best fit the data for the BOLD response to the *subject`s own payoff*. In this case, the reference point was the median of payoffs from all previously chosen trials (formula 1.1). Note, our regressor of interest is the charity's payoff RPE regressor. We orthogonalized our regressor of interest with respect to the subject´s payoff RPE regressor. By choosing the model with the best fit for the subject´s payoff RPE regressor the results for the charity´s payoff RPE regressor are not biased. Rather, by optimizing variance explanation by the first regressor (the subject´s payoff RPE regressor), parameter estimation for the second regressor (the charity's payoff RPE regressor) become more robust. As a robustness check, we also tested the other possible models and confirmed the results for the second RPE induction in any model (event 5, all results are significant on a *p*-level of 0.05). For the first RPE induction (event 3) the effects for the charity's payoff RPE regressor are not significant for options 1.2 and 1.4, but indicate a trend for option 1.3 (Supplementary Table S6 in the Additional results).

As outlined above, applying the model that provides the strongest effects for the subject's payoff RPE regressors provides a fair choice given that the charity´s payoff RPE regressor was orthogonalized to it.

Additional results

Demographic variables

Supplementary Table S3. Demographic variables for donators and non-donators

Demographic variable	**Donators (n=16)** Mean (±*SD*)	**Non-Donators (n=17)** Mean (±*SD*)	***t* (df)**	***p***
Age	24.78 (±2.22)	26.36 (±3.45)	-1.55 (31)	.131
Monthly income (€)	1512.86 (±681.07)	2606.67 (±2415.64)	-1.63 (27)	.114
Gender	10 female	7 female	#	

Notes: Ps are two-tailed, # chi-quadrat test reveals no significant association between the variables gender and subgroup (donator / non-donator): chi-quadrat = 1.5, exact *p* according to Fisher = .303 (two-tailed)

The majority of our sample was students and additionally marginally employed (9 subjects in each group). 2 donators and 3 non-donators were fully employed, 3 donators and 4 non-donators were part-time employed, 2 donators and 1 non-donator were unemployed. In sum, the groups showed a similar structure of occupation. A regression-analysis on the donation rate in the costly-donation situations (CD+) with age, gender and monthly income as explanatory variables showed no significant influences (all $p > 0.170$).

Correlation of experimental donation rate and real-life prosocial activities

As a measure of subjects' real-life prosocial activities, we summed up the number of positive answers on the binary questions addressing real life charitable giving and engagement in charitable organizations (5 questions with binary answers, see appendix 1). This results in a sum score ranging between 0 and 5. A score of 0 indicates that a person is not engaged in the described activities at all, whereas a score of 5 indicates high engagement. This sum score correlated positively with the donation rate in the CD-condition in the experiment (Spearman's rho = 0.4314, $p = 0.012$, two-tailed) and differed significantly between the subgroups of donators and non-donators ($t(31) = 2.29$, $p = 0.029$, two-tailed). Due to the distribution of the donation behavior in the CD-condition (no normal distribution according to the Kolmogorov-Smirnov-test, $p< 0.001$), the correlation reported is the non-parametric Spearman-coefficient.

Reaction time differences

Supplementary Table S4 shows the mean reaction-times (in ms ±SD) of choosing an alternative in the four decision situations for the subgroup of donators and non-donators (reaction times for donations decision (CD+) in the costly donation situations are only reported for the donators).

Supplementary Table S4. Mean reaction times (in ms) of choosing the indicated alternative in the four decision situation for the subgroup of donators and non-donators with group-differences (two-sample t-tests)

Decision situation	**Donators** Mean (±*SD*)	**Non-donators** Mean (±*SD*)	***t* (df)**	***p***
PSI+	1140.7 (±195.63)	938.05 (±195.24)	2.977 (31)	.006
NCD+	1222.78 (±174.47)	1238.92 (±233.88)	-0.224 (31)	.824
E+	1033.65 (±162.3)	926.75 (±203.25)	1.663 (31)	.106
CD+	1559.3 (±320.97)			
CD-	1381.77 (±334.43)	1039.01 (±283.72)	3.182 (31)	.003

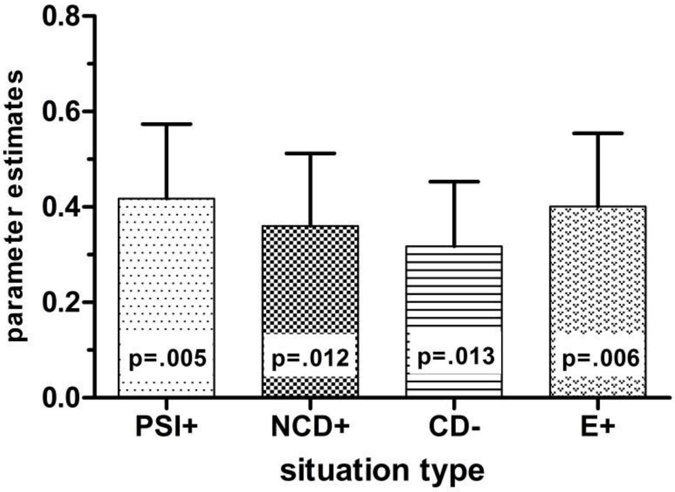
Notes: Ps are two-tailed, donators: n = 16, non-donators: n=17; PSI+: choosing the alternative with the higher subject's payoff in pure self-interest situations, NCD+: choosing the donation alternative in non-costly donation situations, E+: choosing the efficient-alternative in efficiency situations, CD+: choosing the alternative with the higher charity's payoff in costly donation situations, CD-: choosing the alternative with the higher subject's payoff in costly donation situations

The reaction-time differences between the decision situations in the whole sample were significant ($F(3, 93) = 44.848$, $p < 0.001$, ANOVA for repeated measures). Besides a significant main-effect of decision situations there was a significant interaction (decision situation X subgroup: $F(3, 93) = 16.686$, $p < 0.001$). Post hoc t-tests reveal faster reactions of the non-donators in pure self-interest situations (PSI+), and for self-interest decisions in costly donation situations (CD-, see Supplementary Table S4).

The following comparisons between decision situations within the donators (n = 16) remain significant on a p-level of 5% after bonferroni-correction for multiple comparisons: costly donations decisions (CD+) were significant slower than non-costly donation decisions (CD+ vs. NCD+; $t(15) = -5,89$, $p < .001$), decisions in PSI situations (CD+ vs. PSI+: $t(15) = -6.11$, $p < .001$) and efficiency decisions (CD+ vs. E+; $t(15) = 9.19$, $p < .001$). Decisions not to donate (CD-) took the donators significantly longer than self-interested decisions in the PSI situations (CD- vs. PSI+, $t(15) = -5.87$, $p < .001$).

For the non-donators, the following comparisons remain significant on a p-level of 5% after bonferroni-correction for multiple comparisons: decisions to donate in NCD situations were slowest and differed significantly from efficiency-decision (NCD+ vs. E+: $t(16) = 9.43$, $p < 0.001$), PSI-decisions (NCD+ vs. PSI+, $t(16) = -8.43$; $p < 0.001$) and self-interested decisions not to donate in CD situations (NCD+ vs. CD-: $t(16) = 3.96$; $p = 0.001$). Decisions not to donate (CD-) were slower than self-interested decisions in the PSI situations (CD- vs. PSI+: ($t(16) = -3.39$, $p = .004$).

Decision-related Activity

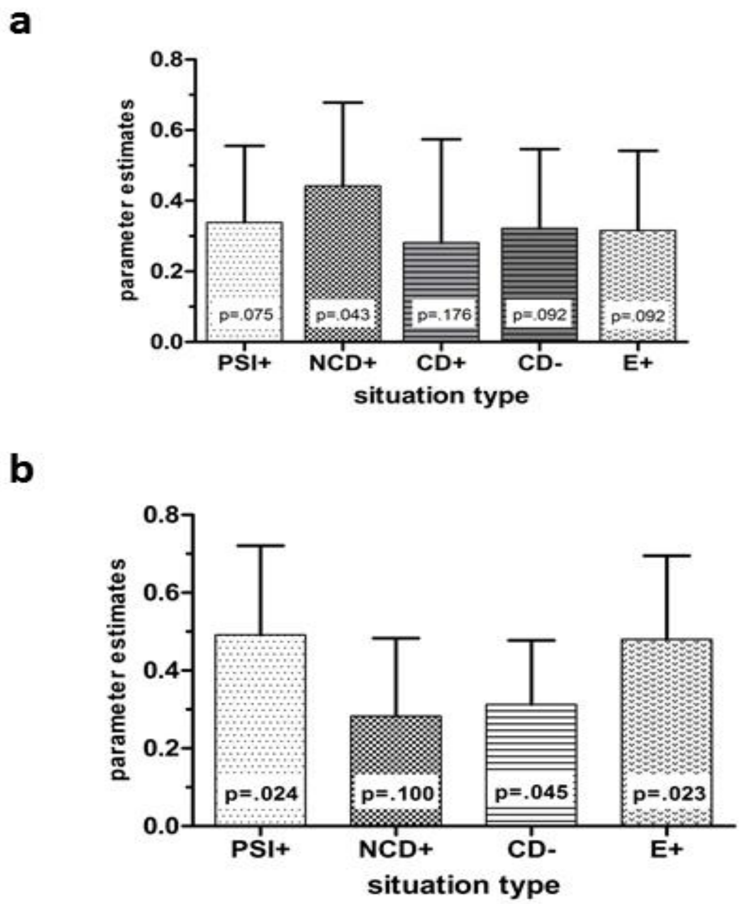


Supplementary Figure S3. Averaged parameter estimates (±SEM) for event 2 from the bilateral NAc for four decision types (*N*=33): PSI+: choosing the alternative with the higher subject's payoff in PSI-situations, NCD+: choosing the donation-alternative in NCD-situations, CD-: choosing the alternative with the higher subject's payoff in CD-situations, E+: choosing the efficient-alternative in E-situations; *P* (one-tailed) for one sample T-Tests against zero

One-sample T-tests against zero indicated significant activation during the four decision-types within the ROI (NAc) in the whole group (*N*=33), see Supplementary Figure S3. A within-subject ANOVA for those parameter estimates indicated no significant differences between the decision types (main effect of decision type: $F(3, 93) = 0.369$, $p = 0.775$; decision type x subgroup: $F(3, 93) = 1.162$, $p = 0.329$). There were no significant differences between donators and non-donators in the activation during the four decision-types (two-sample T-tests, all $p > 0.602$). In the subgroup of donators (*n*=16), additional parameter estimates for CD+ (donation decisions in costly donation situations) can be derived. Supplementary Figure S4 shows the parameter estimates separate for the donators (Figure S4a) and for the non-donators (Figure S4b): one-sample T-tests against zero replicated the results for the whole group, at least indicating a trend (all $p < 0.1$, except for CD+ within the donators).

To test for differential, donation-specific activation, we tested donation decisions in a within subject ANOVA: the comparison of non-costly donation decision (NCD+) over all other decision types (NCD+ > PSI+, NCD+ > CD-, NCD+ > E+) did not survive small volume correction in the NAc in the whole sample (N=33). In the subgroup of donators the comparison of donation decisions in costly donation situations (CD+) over all other decision types (CD+ >

PSI+, CD+ > NCD+, CD+ > CD-, CD+ > E+) did not survive small volume correction in the NAc either. These results show significant activation within the NAc during active decision making (for all decision types), but no differential effects for donation decisions and no differences in activation between the donators and non-donators.



Supplementary Figure S4. Averaged parameter estimates (±*SEM*) for event 2 from the bilateral NAc. **a:** for the subgroup of donators (n = 16) parameter estimates for five decision types. **b:** for the subgroup of non-donators (n = 17) parameter estimates for four decision types: PSI+: choosing the alternative with the higher subject´s payoff in PSI-situations, NCD+: choosing the donation-alternative in NCD-situations, CD+: choosing the alternative with the higher charity´s payoff in CD-situations, CD-: choosing the alternative with the higher subject´s payoff in CD-situations, E+: choosing the efficient-alternative in E-situations; *P* (one-tailed) for one sample T-Tests against zero

We included the mOFC, ventral midbrain and subgenual area in our analyses of donation-specific activation and contrasted donation decisions over all other decision situations. In the whole sample the comparison of non-costly donation decision over all other decision situation types (NCD+ > PSI+, NCD+ > CD-, NCD+ > E+) did not survive small volume correction in the mOFC, ventral midbrain and subgenual area. In the subgroup of donators the comparison of donation decisions in costly donation situations (CD+) over all other decision types (CD+ > PSI+, CD+ > NCD+, CD+ > CD-, CD+ > E+) did not survive small volume correction in those three ROIs either.

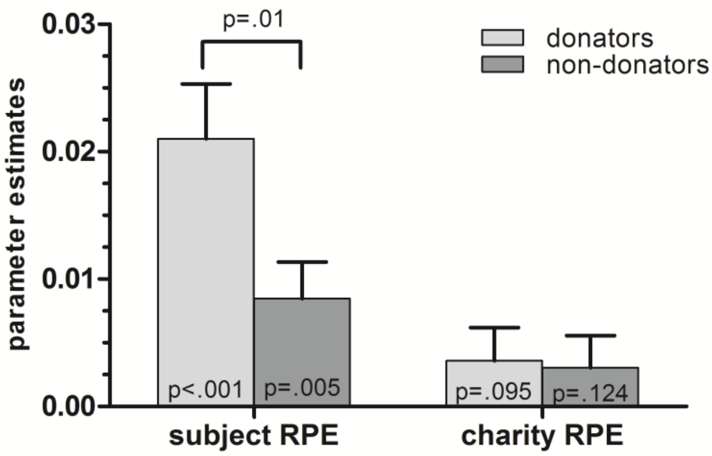
Detailed RPE results

Supplementary Table S5. Statistics for the effects of the RPE regressors separately for the first and second RPE-induction and both sides of the NAc. Reported data is extracted from the NAc according to the Harvard-Oxford cortical and subcortical structural atlases.

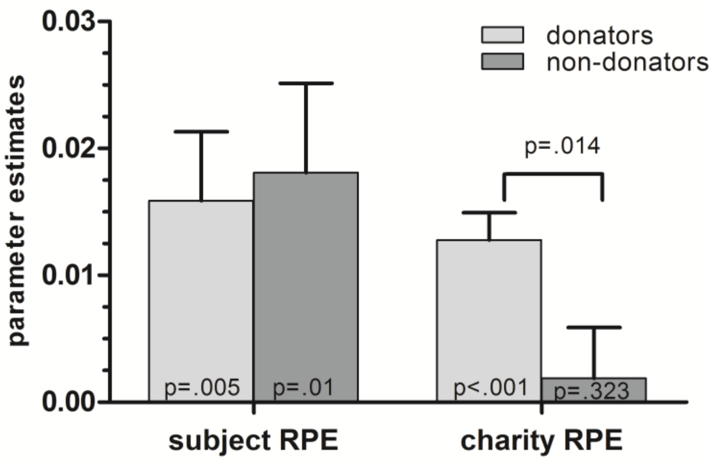
	donators (*n*=16)		non-donators (*n*=17)	
1st RPE-induction				
A left NAc	$t(15) = 4.65$	$p < 0.001$	$t(16) = 3.21$	$p = 0.002$
A right NAc	$t(15) = 4.69$	$p < 0.001$	$t(16) = 2.38$	$p = 0.015$
A bilateral NAc	$t(15) = 4.89$	$p < 0.001$	$t(16) = 2.94$	$p = 0.005$
B left NAc	$t(15) = 0.92$	$p = 0.186$	$t(16) = 1.47$	$p = 0.08$
B right NAc	$t(15) = 1.76$	$p = 0.049$	$t(16) = 0.81$	$p = 0.213$
B bilateral NAc	$t(15) = 1.38^{\#}$	$p = 0.094$	$t(16) = 1.2$	$p = 0.124$
2nd RPE-induction	**donators (*n*=15)**		**non-donators (*n*=17)**	
A left NAc	$t(14) = 2.37$	$p = 0.017$	$t(16) = 2.36$	$p = 0.015$
A right Nac	$t(14) = 3.58$	$p = 0.001$	$t(16) = 2.98$	$p = 0.004$
A bilateral NAc	$t(14) = 2.93$	$p = 0.005$	$t(16) = 2.57$	$p = 0.01$
B left NAc	$t(14) = 4.96$	$p < 0.001$	$t(16) = 0.41$	$p = 0.343$
B right NAc	$t(14) = 5.17$	$p < 0.001$	$t(16) = 0.28$	$p = 0.39$
B bilateral NAc	$t(14) = 5.97^{\#}$	$p < 0.001$	$t(16) = 0.47$	$p = 0.323$
A overall (average for event 3 and 5), bilateral	$t(14) = 5.87$	$p < 0.001$	$t(16) = 3.46$	$p = 0.001$
B overall (average for event 3 and 5), bilateral	$t(14) = 4.64$	$p < 0.001$	$t(16) = 1.19$	$p = 0.125$

Notes: A= Subject´s payoff RPE; B= charity´s payoff RPE; *P* (one-tailed) for one sample T-Tests against zero;

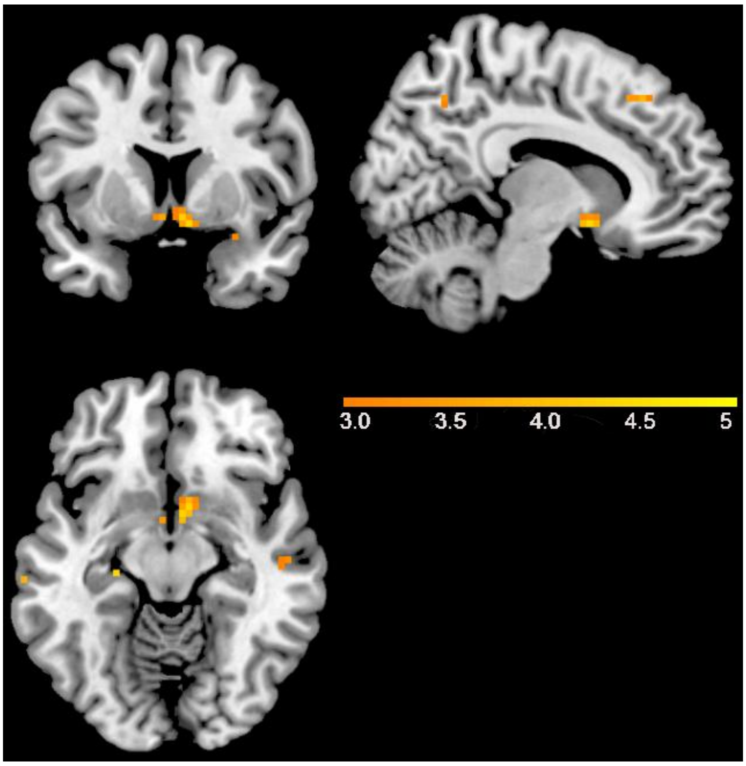
[#]T-test for repeated measurements revealed a significant difference between 1st and 2nd RPE-induction charity's payoff RPE within the donators: $t(14) = -2.71$, $p = 0.017$, two-tailed



Supplementary Figure S5. Bar plot showing mean parameter estimates (±*SEM*) for the regressors of subject's payoff RPE and charity's payoff RPE extracted from the bilateral NAc for the first RPE induction (event 3). Group-differences between donators and non-donators (subject RPE: $t(31) = 2.46$, $p = 0.01$). P_s (one-tailed) for one-sample T-tests against zero for each regressor and for two-sample T-tests are shown; donators: *n*=16, non-donators: *n*=17



Supplementary Figure S6. Bar plot showing mean parameter estimates (±*SEM*) for the regressors of subject's payoff RPE and charity's payoff RPE extracted from the bilateral NAc for the second RPE induction (event 5). Group-differences between donators and non-donators (charity RPE: $t(31) = 2.31$, $p = 0.014$). P_s (one-tailed) for one-sample T-tests against zero for each regressor are shown; donators: *n*=15, non-donators: *n*=17



Supplementary Figure S7. Voxels with a significant modulation of the BOLD signal by the charity's payoff RPE (thresholded at $t > 2.94$ corresponding $p < 0.005$, uncorrected) for the subgroup of donators (n=16) for the first RPE induction. MNI-coordinates: X=9, Y=8, Z=-11. For the RPE calculation, all trials of costly donation situations were excluded. A ROI analysis for the bilateral NAc reveals significant effects for the charity's payoff RPE: $t = 2.75$, $p = 0.007$, one-tailed. The charity's payoff RPE does not differ between first and second RPE induction within the bilateral NAc for the donators ($t(14) = -1.28$, $p = 0.219$, two-tailed)

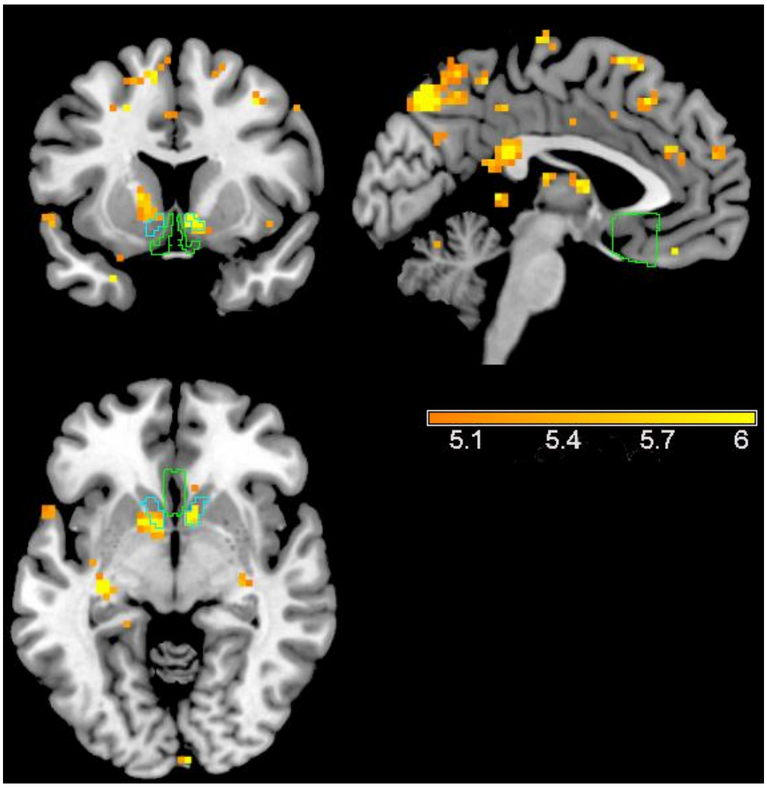
Robustness check with different classification of donators and non-donators

To address the relatively low donation rate in our sample, we excluded five subjects from the donator group with a donation rate of 8% (corresponding to 5 costly donations) from the analysis, leaving 10 subjects in the donator-group. Even in this small group of subjects we replicate our main finding: besides a significant modulation of the BOLD response in the bilateral NAc by the subject's payoff RPE in both groups (donator: $t(9) = 4.99$, $p < 0.001$; non-donator: $t(16) = 3.46$, $p = 0.001$, one-tailed), there is also a significant modulation by the charity's payoff RPE only in the donators ($t(9) = 3.95$, $p = 0.001$; non-donator: t(16) = 1.19, $p = 0.125$, one-tailed).

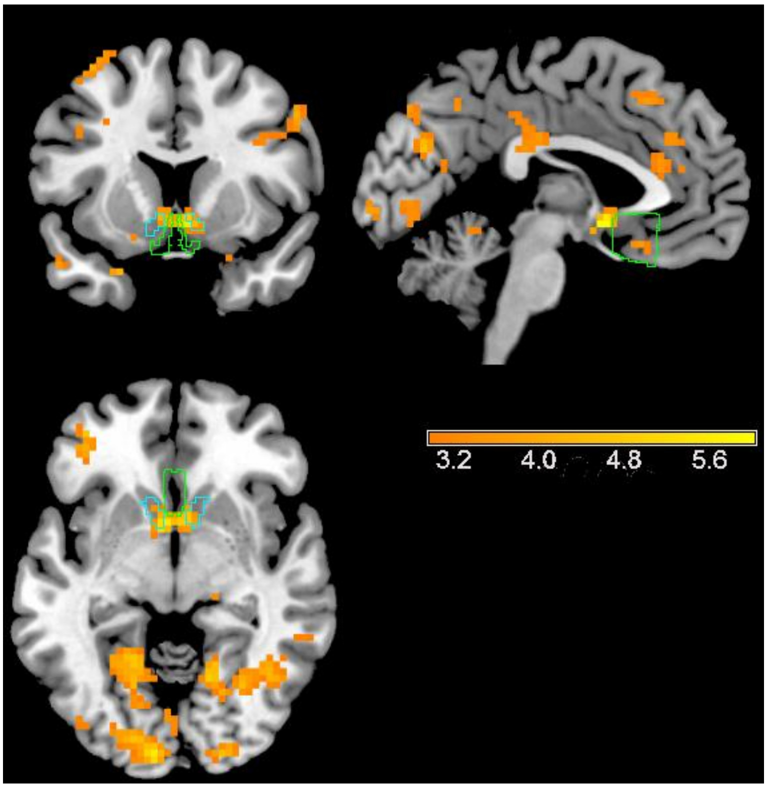
Supplementary Table S6. Statistics for the effects of the RPE regressors for the first and second RPE-induction based on three different *reference point* calculations. Reported data is extracted from the bilateral NAc.

Reference point based on mean of all chosen payoffs (Formula 1.2. in Details of Analysis)				
1st RPE-induction	**donators (n=16)**		**non-donators (n=17)**	
A bilateral NAc	$t(15) = 4.44$	$p < 0.001$	$t(16) = 2.41$	$p = 0.014$
B bilateral NAc	$t(15) = 0.68$	$p = 0.253$	$t(16) = 0.87$	$p = 0.198$
2nd RPE-induction	**donators (n=15)**		**non-donators (n=17)**	
A bilateral NAc	$t(14) = 2.84$	$p = 0.006$	$t(16) = 1.7$	$p = 0.054$
B bilateral NAc	$t(14) = 3.09$	$p = 0.004$	$t(16) = -0.41$	$p = 0.342$
Reference point based on median of confirmed payoffs (Formula 1.3. in Details of Analysis)				
1st RPE-induction	**donators (n=16)**		**non-donators (n=17)**	
A bilateral NAc	$t(15) = 4.69$	$p < 0.001$	$t(16) = 3.12$	$p = 0.004$
B bilateral NAc	$t(15) = 1.29$	$p = 0.108$	$t(16) = 1.67$	$p = 0.058$
2nd RPE-induction	**donators (n=15)**		**non-donators (n=17)**	
A bilateral NAc	$t(14) = 2.92$	$p = 0.006$	$t(16) = 2.57$	$p = 0.01$
B bilateral NAc	$t(14) = 5.45$	$p < 0.001$	$t(16) = 0.47$	$p = 0.323$
Reference point based on mean of confirmed payoffs (Formula 1.4. in Details of Analysis)				
1st RPE-induction	**donators (n=16)**		**non-donators (n=17)**	
A bilateral NAc	$t(15) = 4.15$	$p < 0.001$	$t(16) = 2.49$	$p = 0.012$
B bilateral NAc	$t(15) = 0.31$	$p = 0.381$	$t(16) = 1.02$	$p = 0.161$
2nd RPE-induction	**donators (n=15)**		**non-donators (n=17)**	
A bilateral NAc	$t(14) = 2.65$	$p = 0.009$	$t(16) = 1.73$	$p = 0.051$
B bilateral NAc	$t(14) = 2.91$	$p = 0.005$	$t(16) = -0.59$	$p = 0.282$

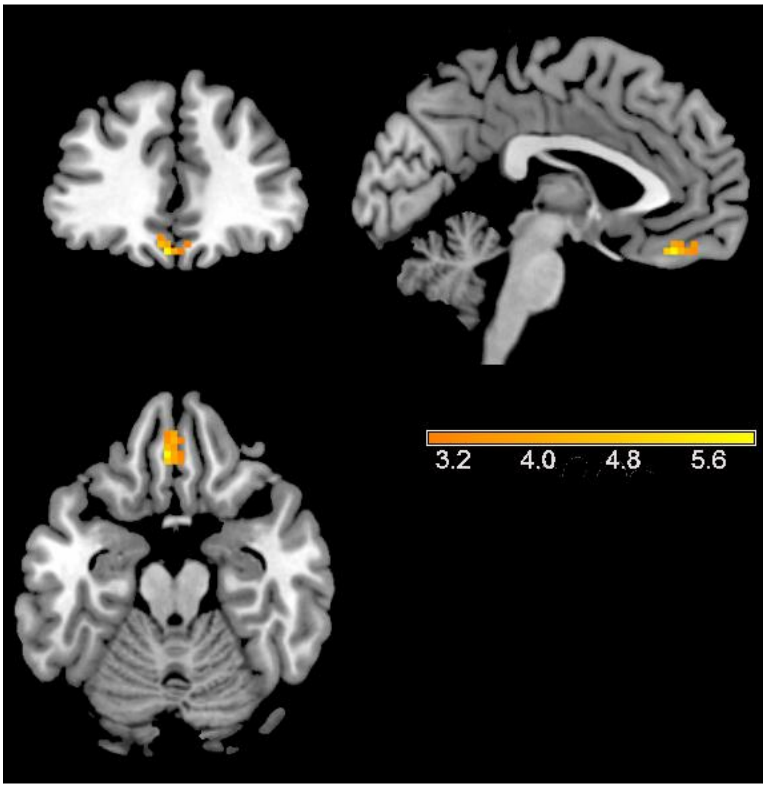
Notes: A = Subject´s payoff RPE; B = charity´s payoff RPE; *P* (one-tailed) for one sample T-Tests against zero



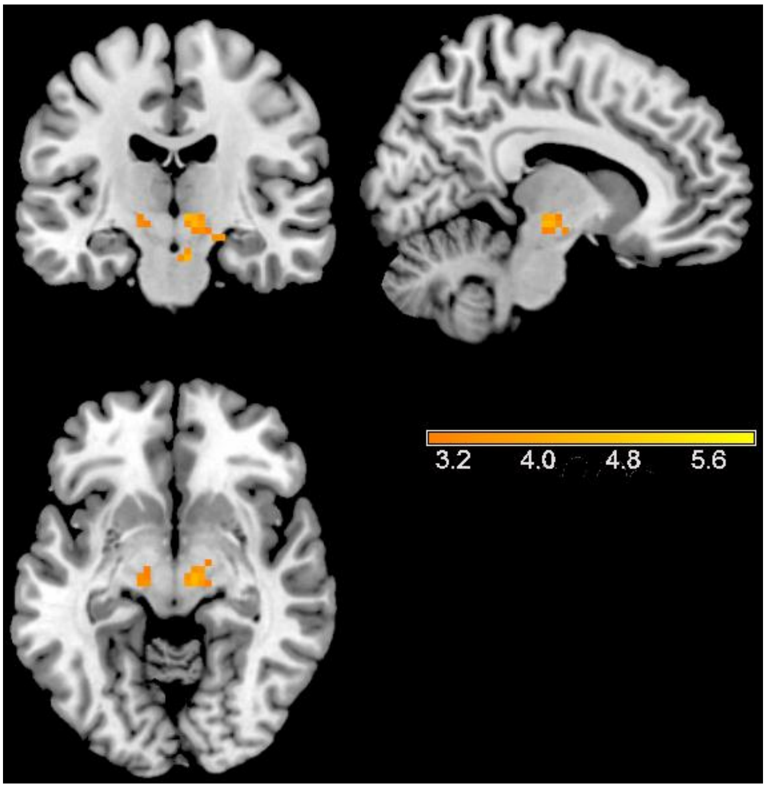
Supplementary Figure S8. Voxels with a significant modulation of the BOLD signal by the subject's payoff RPE (thresholded at $t > 4.98$ corresponding to $p < 0.0001$, uncorrected) for the subgroup of donators (n=15) averaged over both RPE-induction time-points. The NAc is framed in blue, the subgenual area is framed in green. MNI-coordinates: X=-3, Y=11, Z=-6. MNI-coordinates for peak voxel in the subgenual area ROI: X=6, Y=23, Z=-11, t = 5.22, $p_{fwe(small\text{-}volumecorrected)} < 0.05$. MNI-coordinates for peak voxel in the NAc ROI: X=9, Y=11, Z=-8, t = 8.79, $p_{fwe(small\text{-}volumecorrected)} < 0.05$.



Supplementary Figure S9. Voxels with a significant modulation of the BOLD signal by the charity's payoff RPE (thresholded at $t > 2.97$ corresponding to $p < 0.005$, uncorrected) for the subgroup of donators (n=15) averaged over both RPE-induction time-points. The NAc is framed in blue, the subgenual area is framed in green. MNI-coordinates: X=-3, Y=11, Z=-6. The peak voxel (MNI-coordinates: X=-3, Y=8, Z=-8, t = 6.45, $p_{uncorrected,\ whole\ brain}<0.001$) lies outside both ROIs toward the septal region. MNI-coordinates for peak voxel in the subgenual area ROI: X=3, Y=11, Z=-8, t = 4.95, $p_{fwe(small\text{-}volumecorrected)} < 0.05$. MNI-coordinates for peak voxel in the NAc ROI: X=6, Y=8, Z=-8, t = 5.56, $p_{fwe(small\text{-}volumecorrected)} < 0.05$.



Supplementary Figure S10. Voxels with a significant modulation of the BOLD signal by the subject's payoff RPE in the mOFC (thresholded at *t* > 2.97 corresponding to p < 0.005, uncorrected) for the subgroup of donators (n=15) averaged over both RPE-induction time-points. The image was masked with the medial orbito-frontal cortex, according to the Harvard-Oxford cortical and subcortical structural atlases, MNI-coordinates: X=-3, Y=38, Z=-20



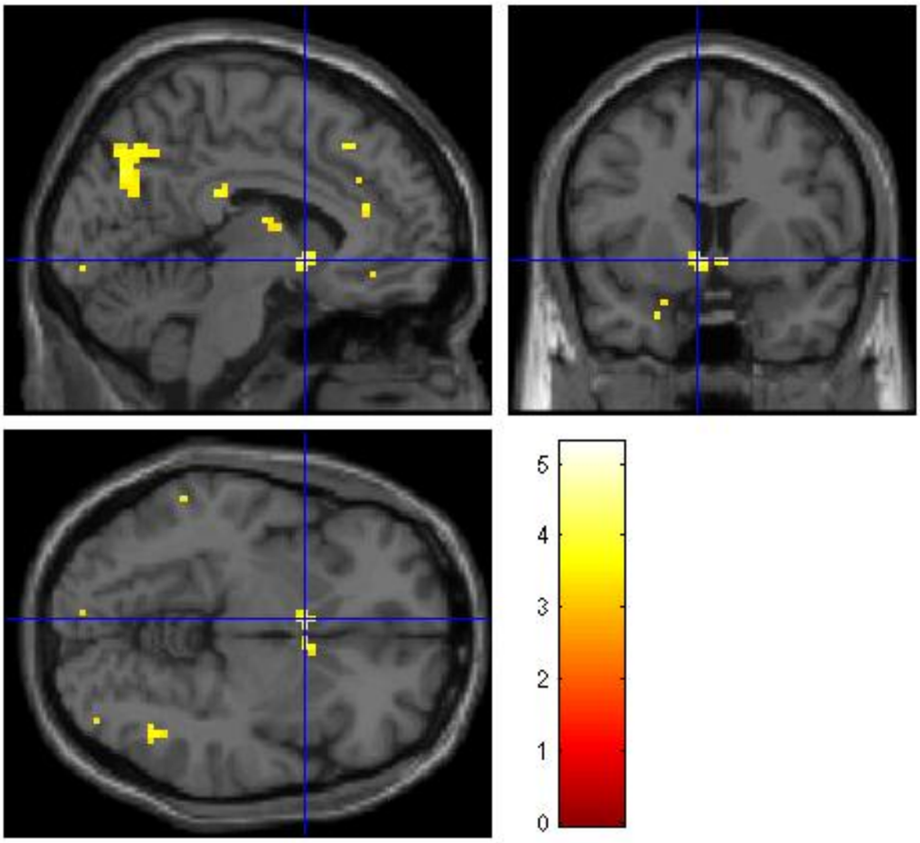
Supplementary Figure S11. Voxels with a significant modulation of the BOLD signal by the subject's payoff RPE in the ventral midbrain (thresholded at $t > 2.97$ corresponding to $p < 0.005$, uncorrected) for the subgroup of donators (n=15) averaged over both RPE-induction time-points. The image was masked with the ventral midbrain, according to the Harvard-Oxford cortical and subcortical structural atlases, MNI-coordinates: X=9, Y=-16, Z=-8

Whole brain conjunction analysis

Supplementary Table S7. Whole brain activation for the conjunction of the regressors of subject's and charity´s payoff RPE for the subgroup of donators (Minimum statistic against conjunction null at P < 0.001, uncorrected for each individual contrast. Only cluster with >10 voxels are reported.

Brain region (peak activation)	MNI-coordinates			*n*	*Z*
	X	Y	Z		
R. Precentral gyrus	45	-22	64	179	4.78
L. Cerebellum	-24	-49	-26	98	4.18
R. posterior cingulate cortex	3	-34	22	68	4.16
L. nucleus caudatus	-6	8	-5	12	4.15
R. temporal inferior gyrus	63	-43	-11	18	3.93
L. insula	30	-22	13	16	3.87
R. Precuneus	3	-61	46	102	3.76
L. frontal sup. medial gyrus	-3	38	28	41	3.59
L. Lingual cortex	-12	-91	-8	13	3.47

Notes: n=number of voxels; brain regions are labeled according to the automated anatomic labeling toolbox for SPM8



Supplementary Figure S12. Whole brain activation for the conjunction of the regressors of charity´s payoff RPE and subject´s payoff RPE for the subgroup of donators (p = 0.001, uncorrected). MNI: -6 8 -5. Results of a small-volume correction indicate significant effects of the charity´s RPE regressor within the NAc (left NAc: $t(14) = 5.27$, $p_{FWE} = 0.001$, right NAc: $t(14) = 5.56$, $p_{FWE} = 0.001$)

Appendix: Self-report on charitable activities in real-life

1. Are you a member of a charitable organization (yes / no)?
    a. If so, which organization?
2. Have you ever donated money to a charity (yes / no)?
3. Did you donate money within the last 12 months (yes / no)?
    a. If so, to which organization?
    b. If so, how much money?
4. Do you donate on a regular basis (yes / no)?
    a. If so, to which organization?
    b. If so, how much money?
5. Did you do a donation in kind (e.g. clothes, food, drugs) within the last 12 months (yes / no)?
    a. If so, to which organization?

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