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Supporting Online Material for

The Right and the Good: Distributive Justice and Neural Encoding of Equity and Efficiency

Ming Hsu, Cédric Anen, Steven R. Quartz*

*To whom correspondence should be addressed. E-mail: steve@hss.caltech.edu

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This PDF file includes:

- Materials and Methods
- SOM Text
- Figs. S1 to S7
- Tables S1 to S14
- References

Other Supporting Online Material for this manuscript includes the following: (available at www.sciencemag.org/cgi/content/full/1153651/DC1)

- Movies S1 and S2

Correction (29 May 2008): The original SOM text incorrectly said that "each child gets $5." The correct text now states that "each set of 3 children was endowed by the experimenters with $5, the monetary equivalent of 24 meals per child."

Supplementary Online Material

Supplementary Methods

Subjects. Twenty-six healthy volunteers (17 female, 9 male) were recruited through Craigslist (www.craigslist.org), a popular online bulletin system. Demographics of the subjects are as follows: mean age: 39.2 +/- 5.7 years, range 29-55; marital status: 15 single, 9 married, 2 divorced (4 subjects were parents); education: 18 college, 7 MS, 1 Ph.D.

Informed consent was obtained using a consent form approved by the Internal Review Board at Caltech. Subjects were required to have college education and to be 28-55 years old. The age requirement was imposed to ensure subjects were not considered elderly, and that their moral character had been fully developed; the latter is speculated to be still developing possibly in the mid-20s (*S1*).

Experimental Setup. Prior to the experiment, subjects read through a brochure with a description of the organization and a short biography of each of the 60 orphans. Figure S1 contains a sample entry of one of the biographies. Permission to use the images of the children was obtained from the organization prior to the experiment. Images within each trial were matched for similar age, lighting conditions, skin tone, and facial expressions. Location of the children, default group of children to take from, and a number of other variables were counterbalanced across trials.

Subjects were then given instructions about the experiment and on how to make their decisions. In particular, subjects were told that each group of 3 children was endowed by the experimenters with the $5, denominated in 24 meals per child, and that each child would appear only once in the experiment. The purpose of denominating in meals is to give subjects an idea of the purchasing power of their contributions, as it differs markedly between Uganda and the United States—the cost of one month of food per child is approximately $5. This ensured that subjects did not utilize distribution strategies that averaged across trials. Images were standardized in size and presented on gray background. Next, they were given instructions about the experiment and on how to make their decisions. A total of 18 such trials were presented over the course of the experiment. The amounts taken and the distribution of the amounts varied each trial (Table S1). Subjects also made decisions over positive donations (Give trials) over the course of the experiment. We present the results for Take trials only in this paper. Following the experiment, subjects completed a questionnaire containing demographic information and two pairs of moral dilemma scenarios.

At the beginning of each trial, subjects see an animation in which a projectile is moving across the screen towards two groups of children (Movie S1, S2). The number of meals that each child could potentially lose is denoted next to the picture of the child. A directional lever in the middle of the screen indicates which group of children will lose the meals. During the display phase (Display, 7.5 seconds) the projectile moves from the right of the screen towards the lever. After it crosses a dotted line, the subjects have 3.5 seconds to decide whether they want to switch the lever (Switch), hereby preventing the default group of children to lose any meals. After the projectile reaches the lever (Lever), the subject can no longer switch it, and the projectile continues to move towards the chosen group of children. After 6.5 seconds it hits the box surrounding the children (Hit), which remains highlighted for 3.5 seconds. After a blank screen of random duration (uniformly distributed on 1–3 seconds), a 2 second feedback screen informs the subject how many meals each child had taken away (Feedback). Trials are separated by a blank screen of random duration (uniformly distributed on 5–7 seconds).

Throughout the instructions it was emphasized to the subjects that their choices had real outcomes and monies would be donated to the orphanage according to their choices. Subjects donated on average $87, for a total of $2,279, which was donated to the charity.

Inequity Aversion Model. To characterize subjects' choice behavior, we considered a model in which individuals trade-off between equity and efficiency linearly. Efficiency is measured by the total number of meals in the allocation. We denote M_c as the sum of meals in the chosen allocation, M_u that of the unchosen allocation, and marginal efficiency as $\Delta M = M_c - M_u$. To measure equity we used the Gini coefficient, which in addition to being the most widely used income inequity index, also has the appealing property of being scale and translation invariant.

The Gini coefficient varies between 0 and 1, where 0 is perfect equity, and 1 is perfect inequity. It is defined as the area between the Lorenz curve of the distribution and the uniform distribution, where the Lorenz curve is the proportion of the distribution assumed by the bottom $x\%$ of the values. For example, for a dataset that includes the income of all households, every point on the Lorenz curve can be described as "the bottom $x\%$ of all households have $y\%$ of all income". The gini coefficient across households is determined by calculating the surface of the area between the uniform distribution and the Lorenz curve (Figure S2). For discrete and unordered data the gini coefficient is calculated as the normalized mean difference between every possible pair of outcomes in the distribution

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|x_i - x_j\right|}{2n\sum_{i=1}^{n}x_i}$$

where *n* is the number of realizations.

We denote G_c as the Gini coefficient for the chosen allocation, G_u for the unchosen allocation, and marginal inequity as the difference $\Delta G = G_c - G_u$.

We assume the utility function for subject *i* to be $u_i(\mathbf{x}) = \sum_{x \in \mathbf{x}} x - \alpha_i \bullet \text{gini}(\mathbf{x})$, where $\mathbf{x}$ is a vector of allocations for the children, and the parameter α captures the weighting placed upon inequity. Individuals with higher α are considered more inequity averse. The additive nature of the function allowed us to create orthogonal regressors for efficiency and inequity, and to explore the possibility of separate neural encoding of efficiency and inequity.

We denote the utility of the chosen allocation U_c, the utility of the unchosen allocation U_u, and the marginal utility of subjects' choices as

$$\Delta U = \underbrace{(M_c - \alpha G_c)}_{U_c} - \underbrace{(M_u - \alpha G_u)}_{U_u} = \Delta M - \alpha \Delta G\,.$$

The intuition for the inequity aversion model is as follows. Faced with an allocation of x_1 = (-23, -0, -0), and x_2 = (-0, -21, -5), the subject can choose between taking away 23 meals from child 1, or taking away a total of 26 meals away from children 2 and 3. Although x_2 takes away more in total, it is a more equitable allocation. A purely equity minded subject would therefore choose x_2, whereas one who is purely efficiency minded would choose x_1. For those who value both equity *and* efficiency, one can increase the appeal of x_2 by making it even more equitable, e.g., x_2' = (-0, -13, -13), where x_2 is a mean-preserving spread of x_2'. Amongst our subjects, 38% chose x_2, versus 46% for x_2' when having to choose between x_1 and x_2 (or x_2').

The utility function makes the strong assumption that efficiency is valued linearly. Good cases can be made for either diminishing or increasing marginal utility of meals. The former is commonly assumed in the economics literature. The latter may be justified if subjects believe they were maximizing the probability of survival, where the probability is a convex function of the number of meals, e.g., if the subjects believed there was some minimum number of meals needed for each child. Diminishing marginal utility is also central to equity arguments in utilitarian theories of justice. In the classic pie sharing example, two individuals with identical concave utility (e.g., $u(x) = \log(x)$), the utilitarian solution maximizing the sum of individual utilities would give equal shares of the pie to both individuals.

Although we cannot reject the hypothesis that the utility function may be nonlinear in some way, we note that given the range of allocations in our experiment (0 – 24), the linearity assumption is a good approximation of standard utility functions used in applied economics (e.g., log, power, exponential). The more strenuous test in the current experiment is whether there are regions that respond differentially to inequity *and* efficiency. Future experiments with larger ranges of the outcomes are needed to assess these important questions.

It is also possible that subjects used aspects of age, gender, or other variables in their decisions (e.g., 1 subject stated in post-experiment questionnaire of favoring younger children). Because all trials were matched carefully over a number of variables, including age, these effects are likely to be minimal.

Inequity Aversion Model Estimation. The probability that the subject chooses an allocation is given by the logit or softmax formula,

$$P(\mathbf{x}_1, \mathbf{x}_2; \alpha, \lambda) = \left\{1 + \exp\left(-\lambda\left(u(\mathbf{x}_1;\alpha) - u(\mathbf{x}_2;\alpha)\right)\right)\right\}^{-1}.$$

The parameter λ is the sensitivity of choice probability to the utility difference (the degree of inflection), or the amount of "randomness" in the subject's choices (λ = 0 means choices are random; as λ increases the function is more steeply inflected at zero). For individual fits sensitivity parameter λ was constrained to unity (the standard logit case) because of a lack of data to accurately estimate λ individually. Because the range of subjects inequity aversion attitudes, the inequity aversion parameter for some subjects was on the boundary of the estimable parameter space [0, 23]. To take into account this estimation problem, we used rank correlation in all correlational analyses with individual inequity aversion estimates, notably in our second-level fMRI analyses.

Denote the choice of the subject in trial *i* by y_i, where y_i =1 if subject chooses the allocation $\mathbf{x}_1$, and 0 otherwise. We fit the data using maximum likelihood, with the log likelihood function

$$\sum_{i=1}^{N} y_i \log\left(P(\mathbf{x}_1, \mathbf{x}_2; \alpha, \lambda)\right) + (1 - y_i)\log\left(1 - P(\mathbf{x}_1, \mathbf{x}_2; \alpha, \lambda)\right).$$

The Nelder-Mead simplex algorithm (*S2*), implemented in Mathematica v5.2, was used to find the maximum. Ten random starting positions were used and the iteration with the highest likelihood value was chosen.

fMRI Data Acquisition and Analysis. Brain images were acquired on a 3T Siemens Trio. High-resolution T1-weighted scans (1mm x 1mm x 1mm) were acquired using a MPRage sequence. Functional images were acquired using echo-planar T2* images with BOLD (blood oxygenation-level-dependent) contrast, and angled 30 degrees with respect to the AC-PC line to minimize susceptibility artifacts in the OFC. MR imaging settings were as follows: repetition time (TR) = 2000ms; echo time (TE) = 40ms; slice thickness = 3mm yielding in a 64x64x32 matrix (3mm x 3mm x 3mm); flip angle = 90 degs; FOV read = 220mm; FOV phase = 100mm, series order: interleaved.

Imaging data was preprocessed using *SPM2*, and included, in order, slice time correction, motion correction, coregistration, normalization to the MNI template and smoothing of the functional data with an 8mm kernel (*S3*).

Random effects analyses were done in *SPM2* (*S3*) by specifying a separate general linear model for each subject and pooled at the second level. Two subject's fMRI data were excluded due to motion artifacts. First all images were high-pass filtered in the temporal domain (filter width 128s) and autocorrelation of the hemodynamic responses was modeled as an *AR*(1) process. In the GLM model all visual stimuli and motor responses were entered as separate regressors that were constructed by convolving a hemodynamic response function (hrf) with a comb of Dirac functions at the onset of each visual stimulus or motor response. Parametric modulations were added to the main regressors as interaction terms.

Supplementary Results

Behavioral Results

The group inequity aversion parameter was $\alpha = 6.95 \pm 1.08$. Females were found more inequity averse ($\alpha_{female} = 10.26$, $\alpha_{male} = 4.69$, $p < 0.06$ two-tailed, Table S2). The sample was unbalanced between gender (9 males). Therefore, although the coefficient of females is almost double that of males, the difference not significant at the $p < 0.05$ level. No age effect was found, nor was there a significant group time trend in inequity aversion attitude.

fMRI Results

Anatomical Location of ΔU region. The activation we observe falls in a midline structure that overlaps both the caudate head and the septal-subgenual region, also called Brodman 25 or ventral cingulated. Of the 42 total voxels in the activation, 24 fall in the caudate and caudate head, and 13 in the septal-subgenual/Brodman 25 region. Given their close proximity, and the fact that both have been implicated in tracking social reward, a definitive classification is unlikely in the current study and the limitation of the spatial resolution afforded by fMRI. Future studies are necessary to clarify this important point.

Anterior vs. Posterior Insula. A potentially important difference between the studies is that the insula activation found here is further posterior than those reported on the Ultimatum Game. We speculate that this may reflect functional differences between anterior/posterior insula. In particular, hyperactivation of the posterior insula was found to be associated with social anxiety but not specific phobia or post-traumatic disorder (*S4*). Such negative social affective processing in posterior insula suggests it plays an important regulative role in sociality, and supports our view that posterior insula may provides an anticipatory negative affective signal in the context of a potential social norm violation.

Cognitive Regions. Although we emphasize reward-related regions, cognitive processes are clearly involved, and have been implicated in a wide variety of tasks, including those involved in moral conflict monitoring (*S5*) and related executive processes (*S5, 6*). Our focus on interactions with behavioral variables implicitly control for cognitive and emotional differences between the choices. Involvement of higher cognitive regions was apparent when we contrasted different stages of decision-making (e.g., *Display* vs. *Hit*). These results show large and robust activations of conflict control regions such as anterior cingulate, executive control regions such as Brodmann areas 8 and

10, and areas involved in integration of emotion and cognition such as the orbitofrontal cortex (Figure S5).

Importantly, however, these regions do not exhibit significant correlation with measures of equity and efficiency. Rather, we speculate that their role is likely to be in the domain of higher order reasoning and integration of emotions and reward processes, as exemplified by the finding that orbitofrontal lesion patients are strikingly utilitarian in their moral judgments (*S7*). The interaction among these structures will be crucial to a better understanding of the complexities of distributive justice and moral decision-making. These are important problems that are only beginning to be approached with a combination of data and ideas from a wide range of disciplines.

Supplementary Discussion

Relationship between Inequity and Risk. Central in the connection between measurement of inequity and decision-making under risk is the idea of welfare. This is uncontroversial in the latter, and is traditionally meant to denote individual welfare, or utility. As pointed out in Dalton (*S8*), however, judgments of social welfare underlies the conception of any inequity measure. Furthermore, if we assume that the social welfare function is additively separable and symmetric in income, we would arrive at the following

$$W = \int_0^{\bar{y}} U(y) f(y) dy.$$

This form is immediately familiar in its resemblance to the standard expected utility representation. In fact many of the concepts in decision-making under risk, e.g., second-order stochastic dominance, mean-preserving spread, have formally identical counterparts in measurements of inequity, e.g., Lorenz dominance, principle of transfer, respectively (*S9*). The assumptions of additive separability and symmetry, interestingly, can in addition be derived axiomatically via an appeal to decision-making under risk (*S10*).

Relationship to Ultimatum Game. Our finding is that insula activity is negatively correlated with the *choice* of equitable allocation, and not with inequity per se. This is also the case with Sanfey et al (*S11*). They found that unfair offers elicited greater insula activity. These unfair offers, however, are also likely to be rejected. The crucial point is that rejection yields the equitable allocation of (0, 0).

Higher level of insula activity is therefore correlated with rejecting the proposed offer (Figure S7), and thus with *choosing* the fairer allocation—note that offers of (5, 5) were never rejected in Sanfey et al. This underlies the apparent paradox that although inequity itself is positively correlated with insula activity, it is negatively correlated with choosing of the inequitable offer. For a comparison of activity of the insula and behavioral interpretations, see Table S4.

An intuitive way to phrase this is that the negative emotions encoded in the insula are "biasing" the behavior towards the fairer allocation. That statement includes claims of causality that obviously cannot be substantiated with fMRI. Future studies with different experimental methodology, e.g., lesion patients, are needed to address this question.

Our finding is also consistent with the connection between measurement of inequity and decision-making under risk that exists in economic theory. In studies of risk, risk *perception* is found to be increasing in insula activity (*S12*), whereas insula activity precedes *riskless* choices (*S13*), in much the same way as insula activity precedes equitable choices in the current study.

Future Extensions

Our work shows the importance of interdisciplinary work that combines different perspectives from neuroscience, economics, and philosophy, and points to a number of possible extensions. We note three in particular. First, and perhaps most obvious, is the issue of cultural differences. Although fairness norms are common to most societies, substantial cross-cultural differences exist as measured through surveys (*S14, 15*) and tasks such as the Ultimatum Game (*S16*). For example, Europeans have been shown on surveys to be more concerned about income inequity than Americans on average, but intriguingly, the rich in America are more concerned about inequity than their European counterparts (*S15*). However, the larger question of cultural differences in fairness norms and how they impact neural function remains a major and largely unexplored issue.

Another important and long-standing question lies in the role of extra-utility information in forming and shaping people's distributive decisions. A famous example due originally to Sen (*S17*) points out that a strict utilitarian would not take into account the source of the utils produced. Therefore, whether redistribution comes about through taxation or torture should be irrelevant to the utilitarian, which runs counter to conventional intuitions about distributive justice. Indeed, there is evidence that humans take into account perceived moral character in the Trust game (*S18*), but such tasks, as discussed earlier, can involve strategic considerations as well as other-regarding preferences. A definitive study establishing the effects of extra-utility information in distributive justice therefore remains to be done.

Finally, we note the importance of poverty—a concept related to but distinct from that of inequity. Poverty, even more so than social and economic inequity, is a pressing and desperate issue for many countries, and one that a number of organizations with substantial resources are dedicated to combating (e.g., World Bank). On the other hand, even basic issues and definitions, perhaps none so more than "who is poor?" have remained unsettled and subject to politically contentious debate (*S9*). Our investigation of inequity provides some hope for shedding light on this difficult and important question. In particular, the current literature distinguishes between *absolute* poverty (e.g., having enough sustenance) and *relative* poverty, a concept defined by norms and standards of a particular community (*S9*). Future work can begin by investigating the neural basis of how individuals perceive and encode different aspects of poverty, the relative contribution of emotion and cognition in these different aspects, and, potentially, recommend strategies based on such findings for combating poverty and its consequences.

Supplementary Tables

Child 1	Child 2a	Child 2b
-23	-13	-13
-23	-21	-5
-23	-12	-12
-23	-21	-3
-23	-12	-11
-23	-20	-3
-19	-11	-11
-19	-17	-5
-19	-10	-10
-19	-17	-3
-19	-10	-9
-19	-16	-3
-15	-9	-9
-15	-13	-5
-15	-8	-8
-15	-13	-3
-15	-8	-7
-15	-12	-3

Table S1: Allocation of meals. The first column denotes the number of meals taken from child 1, and columns 2 and 3 denote the number of meals taken from the group of 2 children. Each line represents a different moral dilemma. Order of trials in experiment are counterbalanced and do not follow order of entries in table.

	Female	Male
Mean	10.26	4.69
Variance	97.47	19.90
Observations	17	9
df	24	
t Stat	1.974	
P(T<=t) two-tail	0.060	

Table S2: Gender differences in inequity aversion attitude assuming unequal variance.

	ΔU	M_C		ΔG	
	Caudate	L Putamen	R Putamen	L Insula	R Insula
ρ	-0.419	-0.13	-0.07	-0.356	-0.410
p-value	0.021	0.28	0.37	0.044	0.023

Table S3: Spearman rank correlation coefficients and *p*-values (two-tailed) between brain regions and subject-wise inequity aversion parameter.

	High Insula Activity	*Low Insula Activity*
Sanfey et al.	Reject offer -> (0, 0)	Accept more unfair offer
Kuhnen & Knutson	Riskless choice	Risky choice
Present study	Equitable allocation	Inequitable allocation

Table S4: Comparison of activations in studies on Ultimatum game, decision-making under risk, and the present study.

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
36	4.68	0	-27	-78	-9	L	Brodman 18/Fusiform Gyrus
	4.27	0	-33	-60	-12	L	
	4.21	0	-30	-72	-15	L	

Table S5: Regions significantly correlated with ΔU during *Display* event ($p < 0.001$, cluster size $k > 10$).

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
20	3.23	0.002	12	21	3	R	Caudate Head/Anterior Cingualte
	3.14	0.002	18	27	9	R	
11	3.21	0.002	-54	36	9	L	Inferior Frontal Gyrus

Table S6: Regions significantly correlated with ΔU during *Switch* event ($p < 0.005$, $k > 10$).

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
19	5.06	0	21	-3	-6	R	Thalamus
16	4.89	0	-39	30	12	L	Inferior Frontal Gyrus
10	4.48	0	21	-21	6	R	Globus Pallidus
19	4.38	0	-9	-12	6	L	Thalamus

Table S7: Regions significantly correlated with ΔU during *Feedback* event ($p < 0.001$, $k > 10$).

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
38	6.24	0	-9	-9	45	L	Brodman 24/Cingulate Gyrus
	4.15	0	-6	-15	54	L	
40	5.55	0	15	-15	36	R	Cingulate Gyrus
	5.07	0	12	-24	30	R	
36	5.48	0	30	-21	45	R	Brodman 4
	4.46	0	36	-18	54	R	
37	5.41	0	9	-21	54	R	Medial Frontal Gyrus
19	5.29	0	-12	-27	30	L	Cingulate Gyrus
28	5.18	0	51	-9	45	R	Precentral Gyrus
148	5.16	0	6	-66	15	R	Posterior Cingulate/Precuneus
	4.81	0	9	-42	-9	R	
	4.77	0	0	-57	9	M	
21	5.15	0	-39	-9	30	L	Precentral Gyrus
	3.8	0.001	-51	-9	39	L	
20	5.14	0	-30	-24	18	L	Insula
26	5.11	0	45	-45	6	R	Middle Temporal Gyrus

	4.69	0	45	-54	12	R	
19	4.85	0	30	18	3	R	Cingulate Gyrus
16	4.77	0	-33	27	-6	L	Brodman 13/Insula
12	4.72	0	-54	9	-15	L	Inferior Frontal Gyrus
15	4.64	0	54	-42	24	R	Inferior Parietal Lobule
10	4.58	0	-33	-39	15	L	Superior Temporal Gyrus
10	4.58	0	30	-24	12	R	Brodman 13/Insula
14	4.41	0	-27	-78	12	L	Middle Occipital Gyrus
	3.74	0.001	-33	-87	15	L	

Table S8: Regions significantly correlated with M_C during *Switch* event ($p < 0.001$, $k > 10$).

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
14	3.93	0.001	18	-42	-36	R	Cerebellum

Table S9: Regions significantly correlated with M_C during *Hit* event ($p < 0.005$, $k > 10$).

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
17	4.44	0	15	18	57	R	Superior Frontal Gyrus
37	4.08	0	-18	54	6	L	Medial Frontal Gyrus
42	3.98	0	9	24	30	R	Cingulate
	2.9	0.004	9	12	24	R	
15	3.36	0.001	15	48	15	R	Medial Frontal Gyrus
	3.26	0.002	21	45	9	R	

Table S10: Regions significantly correlated with M_C during *Feedback* event ($p < 0.005$, $k > 10$).

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
74	6.01	0	27	51	24	R	Brodman 10
31	5.4	0	-42	-42	-24	L	Brodman 37/Inferior Temporal Gyrus
20	4.79	0	12	57	15	R	Medial Frontal Gyrus
89	4.76	0	39	-27	21	R	Brodman 13/Insula
	4.03	0	45	-21	24	R	
80	4.45	0	-15	-54	9	L	Posterior Cingulate
	4.21	0	-9	-51	15	L	
64	4.28	0	-51	-66	21	L	Brodman 39
	3.66	0.001	-39	-60	12	L	
52	4.25	0	33	0	9	R	Insula
	3.51	0.001	42	-6	12	R	
99	3.89	0.001	60	-57	12	R	Superior Temporal Gyrus
24	3.59	0.001	-27	-3	12	L	Insula
28	3.54	0.001	9	-63	15	R	Precuneus

Table S11: Regions significantly correlated with ΔG during *Display* event ($p < 0.002$, $k > 10$).

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
26	4.26	0	60	-21	21	R	Postcentral Gyrus
12	4.16	0	-36	-3	12	L	Insula
31	4.08	0	42	0	-3	R	Insula/Brodman 13
	3.72	0.001	39	3	9	R	
11	3.74	0.001	0	-27	57	M	Medial Frontal Gyrus

Table S12: Regions significantly correlated with ΔG during *Switch* event ($p < 0.002$, $k > 10$).

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
5	3.95	0	21	15	45	R	Brodman 8
8	3.64	0.001	-48	-36	-18	L	Brodman 37/Fusiform Gyrus
7	3.4	0.001	-24	15	18	L	Claustrum

Table S13: Regions significantly correlated with ΔG during *Hit* event ($p < 0.005$, $k \geq 5$).

k	*T*	*p*	*X*	*Y*	*Z*	*L/R*	*Region*
17	4.89	0	-45	-6	12	L	Insula
29	4.77	0	-18	-75	21	L	Brodman 31/Precuneus
37	4.76	0	12	-57	0	R	Posterior Cingulate/Cuneus
	4.51	0	9	-63	6	R	
18	4.74	0	45	-9	12	R	Insula/Brodman 13
15	4.7	0	54	6	27	R	Inferior Frontal Gyrus
13	4.7	0	-51	3	33	L	Inferior Frontal Gyrus
11	3.69	0.001	-21	33	15	L	Medial Frontal Gyrus

Table S14: Regions significantly correlated with ΔG during *Feedback* event ($p < 0.001$, $k > 10$).

Supplementary Figures

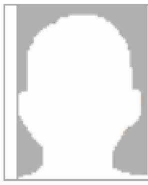	Bernard xxx	10	Bernard is from southern Uganda. He would like to learn to ride a bicycle and wants a job in medicine when he grows up.

Figure S1: Example of a child's biography (picture and full name available upon request).

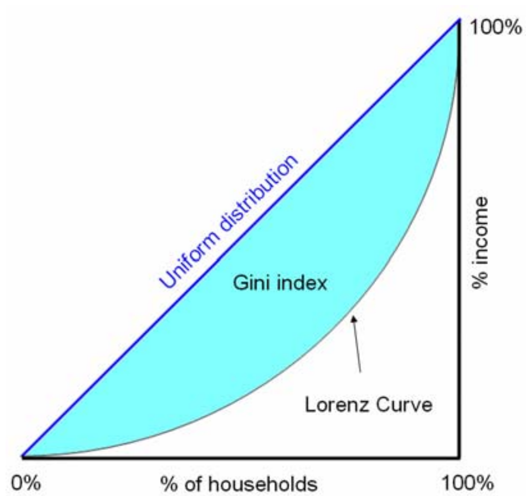

Figure S2: Graphical representation of the gini coefficient.

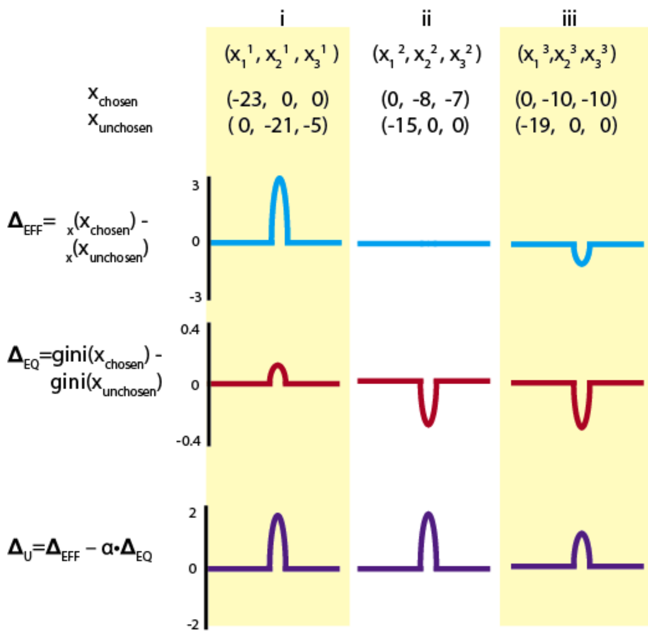

Figure S3: Inequity aversion model where utility as a weighted sum of efficiency and equity, calculated using the group inequity aversion parameter $\alpha = 6.9$. Schematic shows three choices taken from the set used in the study. Subject chooses allocation with (i) greater efficiency and greater inequity, such that $\Delta_{EFF} = 3$, $\Delta_{EQ} = 0.128$, $\Delta_U = 2.10$; (ii) identical efficiency and lower inequity, $\Delta_{EFF} = 0$, $\Delta_{EQ} = -0.311$, $\Delta_U = 2.18$; and (iii) lower efficiency but lower inequity, $\Delta_{EFF} = -1$, $\Delta_{EQ} = -0.333$, $\Delta_U = 1.33$.

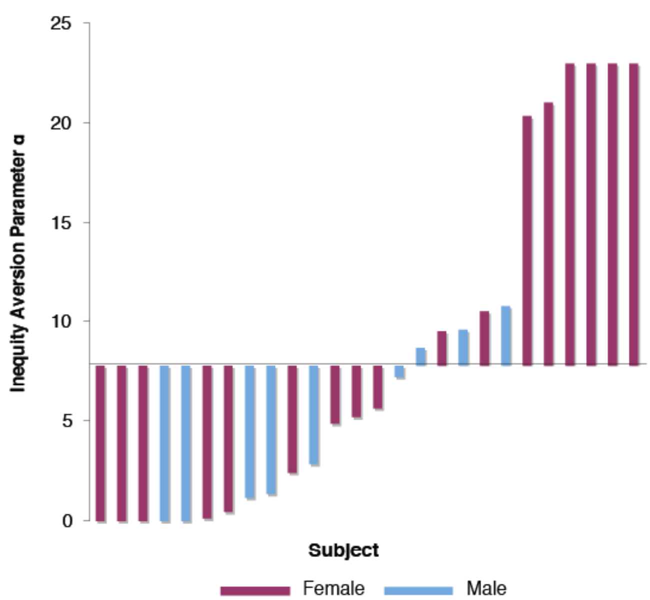

Figure S4: Distribution of inequity aversion parameter α in sample by the study. The abscissa crosses at group estimate of $\alpha = 6.9$.

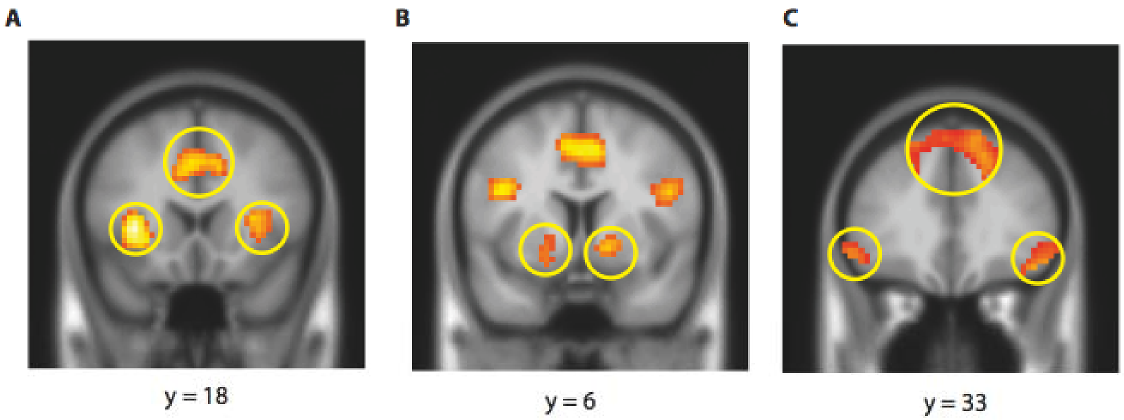

Figure S5: Regions that are differentially activated when the scenario is first displayed (*Display*) versus when the projectile touches the box around the children (*Hit*). (**A**) *Display* > *Hit*: Bilateral anterior insula and cingulate gyrus. (**B**) *Display* > *Hit*: Bilateral putamen/globus pallidus. (**C**) *Hit* > *Display*: bilateral OFC and Brodman 6, 8, 9, 10. All activations are at p < 0.001 and k > 10.

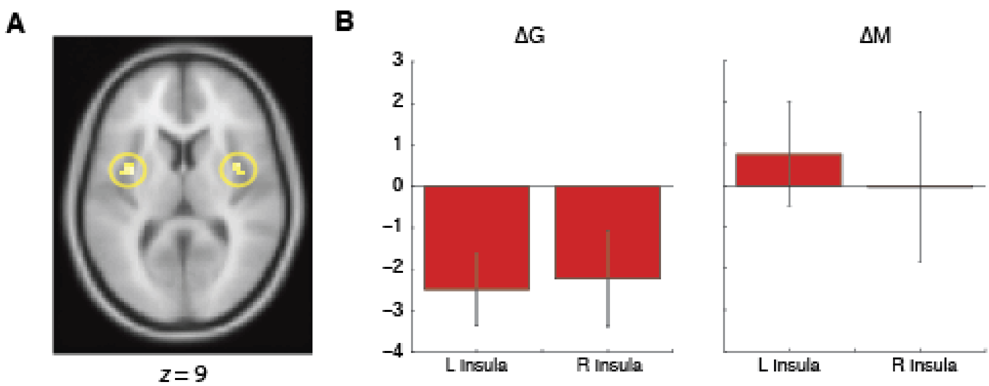

Figure S6: Insula activity during *Switch*. (**A**) Bilateral insula activity during *Switch* ($p < 0.005$, $k > 10$). (**B**) Dissociation between ΔG and ΔM in insula. Insula activity is significantly negative correlated with ΔG (left panel) but not ΔM (right panel).

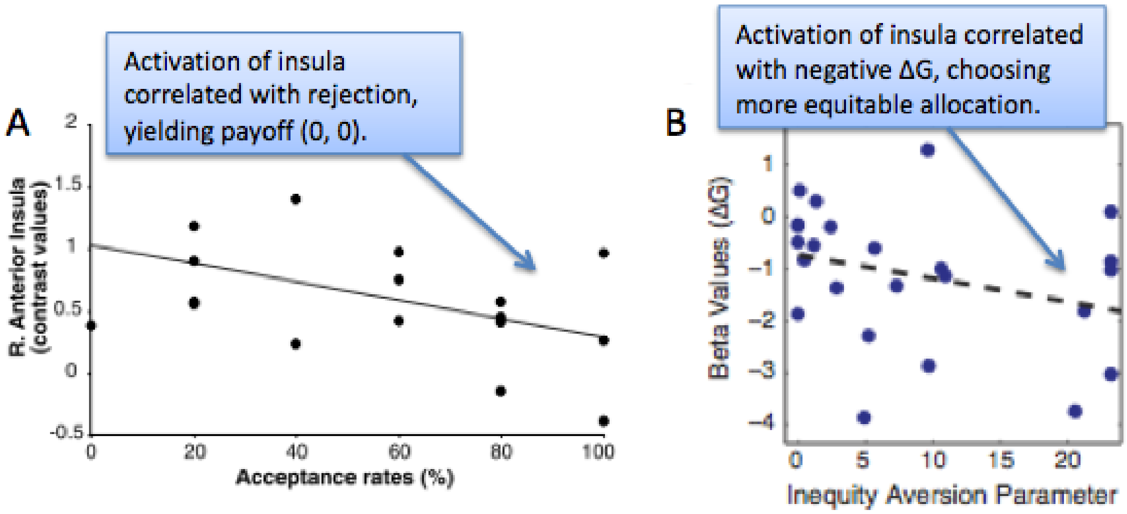

Figure S7: (A) Negative correlation between insula activity and acceptance of unfair offer in Ultimatum Game, (B) Negative correlation between insula activity and choosing of unfair offer in current study.

Supplementary Movies

Movie S1: Switch Trial. Illustration of a trial where the subject switches the lever. Animation speed is increased for illustration purposes. See Fig. 1 for actual duration of events and screens.

Movie S2: No Switch Trial. Illustration of a trial where the subject does not switch the lever. Animation speed is increased for illustration purposes. See Fig. 1 for actual duration of events and screens.

Supplementary References

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