Equity theory and fair inequality: A neuroeconomic study

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The present paper reports results from, to our knowledge, the first study designed to examine the neuronal responses to income inequality in situations in which individuals have made different contributions in terms of work effort. We conducted an experiment that included a prescanning phase in which the participants earned money by working, and a neuronal scanning phase in which we examined how the brain responded when the participants evaluated different distributions of their earnings. We provide causal evidence for the relative contribution of work effort being crucial for understanding the hemodynamic response in the brain to inequality. We found a significant hemodynamic response in the striatum to deviations from the distribution of income that was proportional to work effort, but found no effect of deviations from the equal distribution of income. We also observed a striking correlation between the hemodynamic response in the striatum and the self-reported evaluation of the income distributions. Our results provide, to our knowledge, the first set of neuronal evidence for equity theory and suggest that people distinguish between fair and unfair inequalities.

fairness | inequality | striatum | equity theory

The study of inequality, its sources and consequences, has been a core issue in all of the social sciences and in the philosophical literature on distributive justice. Important normative theories have argued that income inequalities are inherently unfair (1), whereas other theories, in particular libertarianism and liberal egalitarian theories of justice (2–5), argue that income inequalities can be fair if they reflect morally relevant differences. This theoretical debate is mirrored in the political debate on tax, welfare, and health policies, where a key question is whether some inequalities should be accepted as fair. In particular, a core issue in the design of tax and welfare policies is how to handle income inequalities caused by differences in work effort, productivity, or risk-taking. Similar issues arise in the discussion of how to handle inequalities in health due to lifestyle choices. Moreover, in the private sector, heated debates about the fairness of workplace inequalities in earnings are common (6).

Preferences for income distribution have been extensively studied in both controlled economic experiments and surveys, and the nature of such preferences has become one of the major questions in behavioral research in social psychology and economics. Important papers in behavioral economics have studied how people respond to different income distributions and have documented, using economic experiments, that people dislike unequal outcomes and are willing to make a tradeoff between their own income and equality (7–9). An extensive and influential literature on equity theory in social psychology has studied how perceptions of fairness in social situations depend on the relationship between input and output. The main result reported in this literature is that people find it fair that the income (output) of a person is in proportion to the work effort (input), and that they dislike deviations from a proportional distribution (10–12). In line with equity theory, more recent papers in behavioral economics, studying distributive behavior in situations in which people have earned the money being distributed, have found that the majority of people accept income inequalities as fair if the inequalities correspond to differences in contributions (13–17). Thus, there is evidence suggesting that people are averse both to deviations from an equal income distribution and to deviations from an income distribution in proportion to work effort.

An important neuroeconomic study by Tricomi et al. (18) provided suggestive neuronal evidence of inequality aversion. There is, however, no direct neural evidence of how the brain evaluates an income distribution in situations in which people have made different contributions in terms of work effort. The present paper reports from, to our knowledge, the first neuroimaging study designed to examine how the brain responds to the distribution of income in such situations. As such, it is also, to our knowledge, the first study to examine the neuronal basis for equity theory. We focus on two main questions. First, we examine whether a person's contribution in terms of work effort affects the way in which the brain's reward system responds to different income distributions. Addressing this question also allows us to examine how the brain's reward system responds to deviations from a proportional income distribution, and to

Significance

People's preferences for income distribution fundamentally affect their behavior and contribute to shaping important social and political institutions. The study of such preferences has become a major topic in behavioral research in social psychology and economics. Despite the large literature studying preferences for income distribution, there is no direct neuronal evidence of how the brain responds to income distributions when people have made different contributions in terms of work effort. The present paper reports from, to our knowledge, the first neuroimaging study designed to examine how the brain responds to the distribution of income in such situations. As such, to our knowledge it is also the first study to examine the neuronal basis for equity theory.

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compare this response with the response to deviations from an equal income distribution and to an increase in own income. Second, we study how the hemodynamic response in the brain to distributions of earned income correlates with the self-reported evaluations of the same income distributions.

To address these questions, we designed an experiment with two phases: a prescanning phase, in which the participants earned money by working on a real-effort task, and a scanning phase, in which we used functional magnetic resonance imaging (fMRI) to examine how different regions of the brain responded when the participants evaluated different distributions of their earnings. The participants were 47 male students from the Norwegian School of Economics.

In the prescanning phase of the experiment, each participant was randomly assigned to work on repetitive office work, stuffing envelopes, and entering records into a database, for a specific length of time. Roughly half of the participants (23 subjects) were randomly assigned to work for 60 min, whereas the remaining participants were randomly assigned to work for either 30 or 90 min (12 subjects in each group). All participants were told that their earnings would be based on an hourly wage of 500 Norwegian kroner (NOK) (~US$85), but that a random process could interfere so that their final payment would not necessarily be the same as their earnings.

In the scanning phase, the participants were matched with another participant, each pair worked for 120 min in total, and the sum of their earnings was 1,000 NOK. We had three conditions that differed only with respect to how much the participant in the scanner had contributed in terms of work effort. In the 30:90 condition, the participant in the scanner had worked for 30 min and was matched with someone who had worked 90 min. Participants in the 60:60 condition had worked for 60 min and were matched with someone who had also worked for 60 min, and the participant in the 90:30 condition had worked 90 min and was matched with someone who had worked 30 min. For the participant in the scanner, the share of total work effort in the three conditions was thus either 25%, 50%, or 75% depending on the condition.

While inside the MR scanner, the participants rated a sequence of 51 possible distributions of the total earnings on a scale that ranged from very bad (−5) to very good (+5). How much each participant in the pair had contributed in terms of work effort and earnings was common knowledge. Interspersed with the rating trials were 30 control trials. In the control trials, no income distribution was shown and the task of the participants was only to tick off a specific number on the rating scale. The control trials allowed us to distinguish between the neuronal response that resulted from motor and visual stimulation when ticking off a number on the rating scale and the neuronal response that resulted from the subjective evaluation of an income distribution.

A key feature of the design was that participants who disliked deviations from a proportional income distribution would respond differently to an increase in own income depending on which condition they were in. For such participants, an increase in own income beyond 250 NOK would have two counteracting effects in the 30:90 condition: they would like getting more money for themselves, but they would dislike the increase in the deviation from a proportional income distribution. For a participant in the 90:30 condition, however, an increase in their own income would result in both more money for themselves and a reduction in the deviation from a proportional income distribution, as long as their own income was below 750 NOK. We would therefore predict that participants in the 90:30 condition valued an increase in own income more than did participants in the 30:90 condition for own income ranging between 250 and 750 NOK (Prediction 1). Similarly, we would predict that participants in the 60:60 condition valued an increase in own income more than did those in the 30:90 condition in the interval between 250 and 500 NOK (Prediction 2), and that they valued an increase in own income less than did those in the 90:30 condition in the interval between 500 and 750 NOK (Prediction 3).

Results

Fig. 1 shows the average subjective rating of the income distributions as a function of own income for the participants in the three conditions. The participants in the three conditions had earnings of 250, 500, and 750 NOK, respectively, as indicated in the figure. We observe that the way in which participants evaluate a given income distribution differs between the conditions. We also note that the subjective ratings flatten out and, strikingly, even tend to drop, when the participant received a share of total income that was much larger than their earnings. The subjective ratings also show that the participants evaluated income inequalities very differently in the three conditions. For example, the income inequality (250 NOK, 750 NOK) was given a neutral rating by the participants who had worked for 30 min (where the inequality corresponded to differences in earnings); in contrast, it was given a highly negative rating by the participants who had worked for 60 or 90 min (where the inequality did not correspond to differences in earnings).

In the study of the neuronal underpinnings of the behavioral results, we focus on the response in the striatum. The striatum is a key part of the emotional circuitry of the brain and plays an important role in motivating and regulating behavior (19). Furthermore, the striatum has been associated with social preferences and moral choices in many earlier studies (18, 20–28). In the striatum we identify the left and the right caudate nucleus as regions of interest because experimental trials produced significantly different blood-oxygen-level–dependent (BOLD) response compared with control trials in these two regions. Both regions are indicated in Fig. 2*A*. For the two striatal regions we find a significant negative correlation between the subjective ratings and the BOLD response ($p < 0.01$ for both regions), which means that decreased blood activation in these regions is associated with increased subjective valuation.

In Table 1, we test whether the BOLD response in the two striatal regions and the subjective rating are in line with our three predictions. Columns 1–3 report the results from regressions testing the prediction that participants who worked for 90 min have a stronger response to an increase in own income than do participants who worked 30 min (Prediction 1). We find that this indeed was the case: the marginal effect of own income on both the BOLD response and the subjective rating was smaller for those participants who worked for 30 min than it was for those who worked for 90 min in the relevant interval of own income. The difference between the two conditions is statistically significant for the subjective rating ($p = 0.016$) and for the left caudate nucleus ($p = 0.043$), but not for the right caudate nucleus ($p = 0.141$). The difference in the marginal effects of own income is illustrated in Fig. 2*B*. The results reported in columns 4–6 and columns 7–9 of Table 1 also provide support for our two additional predictions. In the relevant intervals of own income, we find that the response to an increase in own income for participants who worked for 60 min is stronger than for those who worked for 30 min, which is in line with Prediction 2 (subjective rating, $p = 0.017$; left caudate nucleus, $p = 0.075$; and right caudate nucleus, $p = 0.150$), and weaker than for those who had worked 90 min, which is in line with Prediction 3 (subjective rating, $p < 0.01$; left caudate nucleus, $p = 0.049$; and right caudate nucleus, $p = 0.251$). Our results thus provide strong causal evidence of the effect of relative work effort on both the BOLD response in the left striatum and the subjective evaluations. The differences between the three conditions furthermore provide suggestive evidence of the participants being concerned with deviations from a proportional income distribution.

In Table 2 we report the results from regressions in which we directly examine how the participants respond to deviations from

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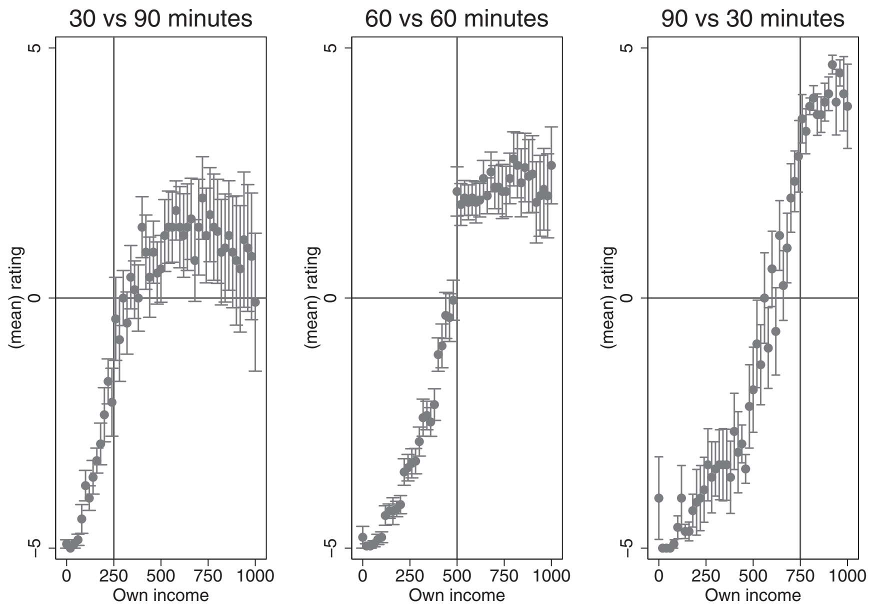

Fig. 1. Subjective ratings in the scanner. The graphs show the mean and SE of the subjective rating in the scanner for each of the 51 possible distributions of income. The subjective rating in the three graphs corresponds to the participants who worked for 30, 60, and 90 min, and was matched with participants who worked for 90, 60, and 30 min, respectively. The participants' earnings in each condition are indicated by a vertical line.

a proportional income distribution. We find that deviation from proportionality is significantly correlated with both the subjective rating ($p < 0.01$) and the BOLD response in the two striatal regions ($p < 0.01$ for the left caudate nucleus, and $p = 0.045$ for the right caudate nucleus). We interpret this result as providing, to our knowledge, the first set of evidence of a neuronal basis for the acceptance of income inequalities that correspond to differences in work effort. The regressions reported in Table 2 also estimate the effect of deviations from equality. We observe that deviations from equality, in contrast with deviations from proportionality, have no significant effect on the subjective rating or the BOLD response in the two striatal regions.

Using the estimates in Table 2, we compare the effect of a reduction in the deviation from proportionality with the effect of an increase in own income. Our estimates imply that a reduction in the deviation from proportionality of 10 percentage points results in the same BOLD response as an increase in own income of 73 NOK in the left caudate nucleus and the same BOLD response as an increase in own income of 45 NOK in the right caudate nucleus. For the subjective rating, we find that a reduction in the deviation from proportionality by 10 percentage points has the same effect as an increase in own income of 34 NOK.

In addition to the two regions in the striatum, we also identified several regions in the prefrontal cortex where experimental trials produced significantly different BOLD response from control trials. The analysis of the BOLD responses in these regions, which is reported in *SI Text*, did not show a clear pattern for how these regions respond to own income or to deviations from proportionality. However, it is interesting to observe that deviations from proportionality had a significant effect on the BOLD response in the left inferior frontal gyrus. This result suggests that cognitive processes in the prefrontal cortex are involved in the evaluation of fair and unfair inequalities (29).

Discussion

The present study has examined how participants respond to different distributions of a fixed sum of earned income between themselves and another participant. We had three experimental conditions that differed only with respect to the work effort of the participants. We found a strong effect of the conditions on the participant's BOLD response in the striatum to an increase in own income (and a corresponding decrease in the income to the other participant). We also found strong evidence of the participants being concerned with deviations from a proportional income distribution. In contrast, we did not find evidence of participants disliking deviations from an equal income distribution. We interpret this as showing that concerns for outcome equality are of relatively little importance in situations in which income has been earned through work effort. This result is particularly striking because our sample is from a Scandinavian country that is among the most egalitarian countries in the world.

The fact that we did not find any significant BOLD activation in the striatum in response to deviations from equality also sheds light on the neuronal evidence of inequality aversion that was reported in the paper by Tricomi et al. (18). In their experiment, there was no difference in the participants' contributions and, as a result, any deviation from an equal distribution would also be

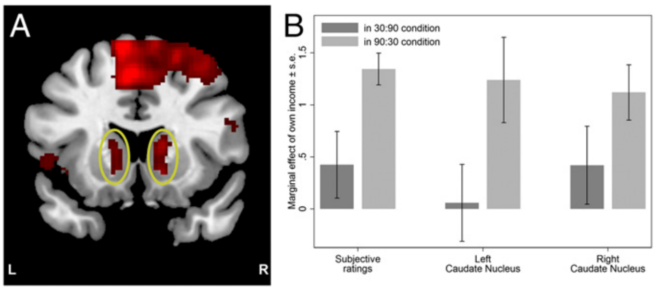

Fig. 2. Regions of interest. *A* indicates the two regions in the striatum, the left and right caudate nucleus, in which experimental trials produced significantly different BOLD responses from control trials. Other displayed areas are regions that were located outside the striatum in which we also found difference between experimental and control trials that were significant at an FWE-corrected threshold of $p(FWE) < 0.05$, and had at least 10 voxels per cluster. A complete list of these regions is reported and analyzed in *SI Text*. *B* reports the marginal effect of own income on the subjective rating and the BOLD response in the left and right caudate nucleus for participants in the 30:90 condition and the 90:30 condition in the interval between 250 and 750 NOK.

Table 1. Effects of the conditions

	Prediction 1			Prediction 2			Prediction 3		
		BOLD			BOLD			BOLD	
		Caudate nucleus			Caudate nucleus			Caudate nucleus	
Explanatory variable	Subjective ratings	Left	Right	Subjective ratings	Left	Right	Subjective ratings	Left	Right
Own income	1.343*** (0.153)	1.238*** (0.409)	1.119*** (0.265)	1.892*** (0.165)	1.160 (0.759)	1.302* (0.677)	1.751*** (0.348)	1.599** (0.760)	0.754 (0.948)
Own income × 30:90 condition	−0.919** (0.354)	−1.180** (0.551)	−0.700 (0.459)	−1.306** (0.520)	−2.115* (1.151)	−1.580 (1.073)			
Own income × 60:60 condition							−1.614*** (0.490)	−2.213** (1.086)	−1.368 (1.170)

SEs in parentheses. The table reports linear regressions with individual fixed effects of the subjective rating and the BOLD response in the left and right caudate nucleus on own income and the interaction between own income and conditions. All regressions only involve observations from the relevant conditions and the relevant intervals. The individual fixed effects capture the direct effect of each treatment. Prediction 1: the response to own income is lower in the 30:90 condition than in the 90:30 condition on $x_1 \in (250, 750)$. Prediction 2: the response to own income is lower in the 30:90 condition than in the 60:60 condition on $x_1 \in (250, 500]$. Prediction 3: the response to own income is lower in the 60:60 condition than in the 90:30 condition on $x_1 \in [500, 750)$. Marginal effects for subjective ratings are per 100 NOK; for BOLD responses, they are SDs per 1,000 NOK. *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$.

a deviation from a distribution in proportion to contributions. Thus, their finding is consistent with our results, because the neuronal response obtained using their design may well reflect a concern for a proportional distribution of income.

These results can be seen as adding to the literature on the role of social comparisons in the evaluation of income to self. Bault et al. (21) showed that the striatal response to an economic gain depends on whether the gain was smaller or larger than the gain of a counterpart. Our results can be interpreted as showing that such social comparisons also take into account the relative contribution of the counterpart. Our results are also complementary to the results reported by Vostroknutov et al. (30), who find that the response in the prefrontal cortex to an income inequality is sensitive to whether the inequality was a result of luck or skill.

Our paper has documented a striking similarity between the effect of our conditions on the subjective ratings and on the BOLD response in the striatum. The subjective ratings and the BOLD response also provided similar pictures of the tradeoff between own income and deviations from proportionality. We interpret this as showing that attitudes to income distribution have a neuronal basis in the brain's reward system.

Materials and Methods

Participants. Forty-seven neurologically and psychiatrically healthy male individuals took part in this study. Forty-eight students were recruited, but one did not show up. The mean age was 24.8 y (range, 20–33 y) and six participants were left-handed. Before fMRI measurement, participants gave written informed consent. The study was performed according to the Declaration of Helsinki.

When participants arrived for the experiment, they were given a detailed general information sheet regarding the manner in which the experiment would proceed. The sessions were held over three weekends in the spring of 2011 at Haukeland University Hospital, and participants were given a participation and transportation allowance (450 NOK in total), in addition to the payment from the experiment.

Apart from an initial check of signed consent forms, all identification of behavior and payment in the experiment was based on a random number that each participant drew from a bowl when they arrived for the experiment.

Behavioral Tasks. The experiment consisted of two phases: a prescanning phase, in which the participants earned income by working on a real-effort task, and a scanning phase, in which we used fMRI to examine how different regions of the brain responded when the participants evaluated different distributions of their earnings. In the prescanning phase of the experiment, each participant was randomly assigned to work either 30, 60, or 90 min performing repetitive office work, stuffing envelopes, and entering records into a database. They were told that their earnings would be based on an hourly wage of 500 NOK (~US$85), but that a random process could interfere so that their payment from the experiment would not necessarily be the same as their earnings.

In the scanning phase, the participants were matched with a participant who had worked either the same length of time, or with a participant who had worked a different length of time. The total working time for a pair was always 120 min, the total earnings of the pair was always 1,000 NOK, and the amount earned by each participant was common knowledge. Each participant was then asked to evaluate a sequence of possible distributions of the total earnings between the two of them on a scale from very bad (−5) to very good (+5). In total they made 51 such evaluations. Because the participants evaluated ex post facto distributions of the earned income, there were no incentive effects of the different distributions; therefore, efficiency considerations did not affect the evaluations. Interspersed with the rating trials were 30 control trials. In the control trials, no income distribution was shown and the task of the participants was only to tick off a specific number on the rating scale.

The number of seconds at each stage is indicated in the screenshots in *SI Text* for a sequence of one experimental trial and one control trial: 1 s for

Table 2. Effects of deviation from proportionality

		BOLD	
		Caudate nucleus	
Explanatory variable	Subjective ratings	Left	Right
Own income(in 100s NOK)	1.119*** (0.116)	0.645*** (0.212)	0.632*** (0.194)
Deviation from proportionality	−3.777*** (1.161)	−4.708*** (1.611)	−2.833** (1.373)
Deviation from equality	0.372 (0.970)	1.550 (1.698)	−0.468 (1.594)

SEs in parentheses. The table reports linear regressions of the subjective rating and the BOLD response in the left and right caudate nucleus on own income, deviation from proportionality, and deviation from equality. Deviation from proportionality and deviation from equality are measured relative to the maximum deviation possible. BOLD outcomes are measured in units of 1/10 SD. *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$.

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fixation, 2 s for showing the income distribution, 4 s for evaluating the income distribution on the rating scale (or ticking off a number in case of the control trials), and an interval between trials of varying length (randomly distributed between 1 and 7 s) to increase temporal resolution. This averaged 11 s per trial (range 8–14 s). Before entering the scanner, the screenshots were explained to the participants and they were trained on using the handgrip that controlled the interface. The hand that was used to hold the grip for the experimental interface was randomly allocated.

Image Acquisition. Data acquisition was performed on a 3T GE Signa Excite scanner. Thirty slices (3-mm thickness, 2.3 × 2.3 × 2.3-mm voxel size, 0.3-mm interslice gap) were obtained in an interleaved fashion parallel to the anterior commissure–posterior commissure line, using a single-shot gradient echo-planar imaging sequence (repetition time, 2,000 ms; echo time, 30 ms; bandwidth, 116 kHz; flip angle, 90°; 96 × 96-pixel matrix; field of view, 220 mm). Before functional scanning, a high-resolution anatomical brain image was recorded from each participant.

Image Preprocessing. All image processing and statistical analyses were performed using the statistical parametric mapping software SPM8. First, all images were realigned to the first image in the time series to correct for head movement, and movement-related image distortions were corrected by applying an unwarping procedure. Second, the images were normalized to the Montreal Neurological Institute (MNI) reference space. The transformation into the MNI space was estimated by warping an averaged image, which was created during the realignment procedure, into the MNI space. Subsequently this transformation was applied to each image of the time series. Normalized data were resliced to a cubic voxel size of 3 mm^3 and smoothed with a Gaussian kernel (8-mm FWHM).

Statistical Parametric Mapping. The statistical analysis was based on the general linear model framework, implemented in SPM8. First, a design matrix was specified, in which the onset and duration of the experimental and control trial were specified. In addition, for each condition, the trial-by-trial responses were included as an additional regressor. The model was fitted to the data by applying a high-pass filter with a cutoff frequency of 128 s. Thereafter, contrasts between the parameter estimates were defined. Group analyses were estimated by combining these individual contrasts in one-sample *t* tests. First, a one-sample *t* test was used for comparing the experimental with the control condition. This analysis was performed by applying a familywise-error (FWE)-corrected statistical threshold of $p(FWE) < 0.05$ and a threshold of at least 20 voxels per cluster.

Single-Trial Data. To study the neuronal responses to different types of inequality in the regions of interest, we estimated individual hemodynamic response functions using the method reported in ref. 31. For each participant and region of interest (ROI) separately, the empirical event-related hemodynamic responses (HRs) were deconvolved by forming the convolution matrix of all trial onsets with an assumed kernel length of 20 s, and multiplying the pseudoinverse of this matrix with the filtered and unit variance normalized ROI time course. Single-trial amplitudes were recovered by fitting a design matrix containing separate predictors for each trial onset, convolved with the estimated HR onto the ROI time course. The single-trial weights (scaling coefficients β) were estimated using multiple linear regression.

There was a significant negative correlation between the subjective ratings and the BOLD response in the two striatal regions ($p < 0.01$ for both regions). In the analysis, the sign of the single-trial data was normalized such that the marginal BOLD response to own income in the striatal regions coincided with that of the subjective ratings.

Analysis of Single-Trial Data. The single-trial data were analyzed using Stata, version 13.1, for each region separately.

The estimates of condition contrasts in subjective rating and BOLD response presented in Table 1 are based on the following regression:

$$y_{it} = \gamma_i + \beta_1 x_{it} + \beta_2 (T_i \times x_{it}) + \epsilon_{it}, \quad [1]$$

where *i* indexes individuals, T_i is a dummy for which condition the individual was in, and *t* indexes trials. All regressions are estimated on the ranges of own income (x_{it}) relevant to the hypothesis that is tested. BOLD responses are normalized to individual unit variance, and the γ_i s are fixed effects for individuals.

In Table 2 we report a linear regression of the subjective rating and the BOLD response in the left and right caudate nucleus on own income, deviation from proportionality, and deviation from equality. The regression is given by

$$y_{it} = \gamma_i + \beta_1 x_{it} + \beta_2 \frac{|x_{it} - m_i|}{\max|x_{it} - m_i|} + \beta_3 \frac{|x_{it} - 500|}{500} + \epsilon_{it}, \quad [2]$$

where m_i is the participant's earnings, $|x_{it} - m_i|$ is the deviation from a proportional income distribution, and $|x_{it} - 500|$ is the deviation from an equal income distribution.

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