Neural Responses to Taxation and Voluntary Giving Reveal Motives for Charitable Donations

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Science (2007)

Why do we care?

Because we want public goods

US:	1.5% giving, 35% taxation
Europe:	0.3% giving, 50% taxation

Motives for giving are unclear:

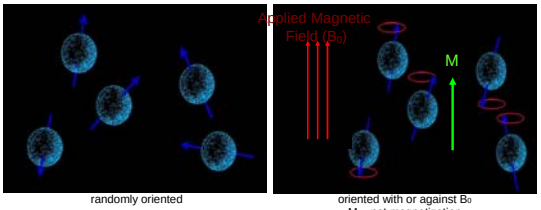
- Pure altruism $U = U(x, G)$
  - (Samuelson). Give to increase the level of the good. Predicts crowding out, zero giving, and just doesn't explain the facts.
- Warm glow $U = U(x, g)$
  - (Andreoni). Works, but strikes some as ad hoc.
- Impure: $U = U(x, G, g)$

Outline of Talk

- Participants, Methods, Protocol
- Behavioral results
- Contrast pictures
- ROI Regression results
- Conclusion

Protons aligning within a magnetic field

In “field free” space | Inside magnetic field



randomly oriented | oriented with or against B_0
M = net magnetization

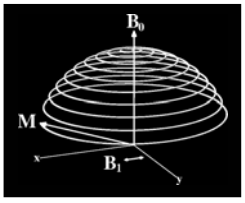
- when placed in a magnetic field (B_0; e.g., our MRI machines) protons will either align *with* the magnetic field or *orthogonal* to it (process of reaching magnetic equilibrium)
- there is a small difference (10:1 million) in the number of protons in the low and high energy states – with more in the low state leading to a net magnetization (M)

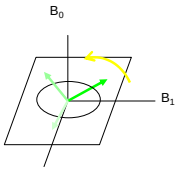
Source: Mark Cohen's web slides *Source: Robert Cox's web slides* *Source: Jody Culham's web slides*

RF Excitation

Excite Radio Frequency (RF) field

- transmission coil: apply magnetic field along B1 (perpendicular to B_0) for ~3 ms
- oscillating field at Larmor frequency
- frequencies in range of radio transmissions
- B_1 is small: ~1/10,000 T
- tips M to transverse plane – spirals down
- analogies: guitar string (Noll), swing (Cox)
- final angle between B_0 and B_1 is the flip angle



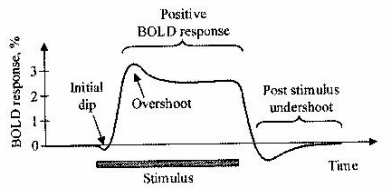


Source: Robert Cox's web slides

Susceptibility and BOLD fMRI

- Magnetic susceptibility (χ) refers to magnetic response of a material when placed in B_0.
- Red blood cells exhibit a change in χ during 'activation'
- Basically, oxyhaemoglobin in the RBC (HbO_2) becomes deoxyhaemoglobin (Hb):
  - Becomes paramagnetic.
  - Susceptibility difference between venous vasculature and surroundings (susceptibility induced field shifts).

Hemodynamic Response Function



% signal change
= (point – baseline)/baseline
usually 0.5-3%

initial dip
-more focal
-somewhat elusive so far

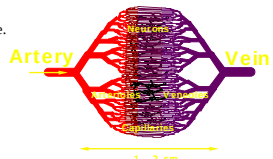
time to rise
signal begins to rise soon after stimulus begins

time to peak
signal peaks 4-6 sec after stimulus begins

post stimulus undershoot
signal suppressed after stimulation ends

Vascular Network

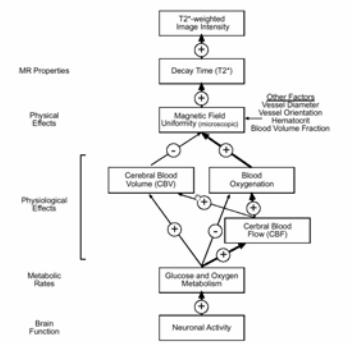
- Arterioles
  - Y=95% at rest.
  - Y=100% during activation.
  - 25 μm diameter.
  - <15% blood volume of *cortical* tissue.
- Venules
  - Y=60% at rest.
  - Y=90% during activation.
  - 25-50 μm diameter.
  - 40% blood volume of *cortical* tissue.
- Red blood cell
  - 6 μm wide and 1-2 μm thick.
  - Delivers O_2 in form of oxyhemoglobin.
- Capillaries
  - Y=80% at rest.
  - Y=90% during activation.
  - 8 μm diameter.
  - 40% blood volume of *cortical* tissue.
  - Primary site of O_2 exchange with tissue.



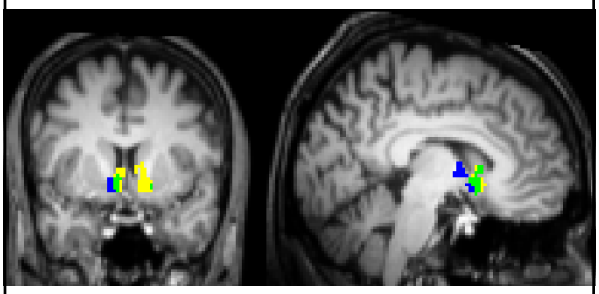
Transit Time = 2-3 s

Source: Chris Thomas' Slides

BOLD signal



Source: Doug Noll's primer



Participants and Methods

- Sample
  - 19 female students
- Scanning
  - Indirect measure of the BOLD response to neuron firing
  - Siemens Allegra 3T scanner
  - Head coil, mirror, immobilized subjects with button boxes
  - Voxels: 3.125 x 3.125 x 4mm
  - TR = 2 seconds
  - About 50k voxels in brain, 2.5m neurons per voxel
  - Differences of <0.5% in signal
  - Many t-tests, FSL does corrections

Protocol

- Start with $100
- Transfers of money from the subject to *Food for Lane County*
- Procedures to ensure confidentiality and credibility:
  - USB keys
  - checks to charity
  - subjects paid privately

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FOOD for Lane County's mission

The mission of FOOD for Lane County is to eliminate hunger by creating access to food. We accomplish this by soliciting, collecting, rescuing, growing, preparing and packaging food for distribution through a network of social service agencies and programs; and through public awareness, education and community advocacy.

FOOD for Lane County is the regional food bank serving all of Lane County, Oregon. As the second largest food bank in the state, FOOD for Lane County finds creative solutions to hunger and its root causes. We believe a responsive food bank includes programs that help people help themselves. Food banking also requires the participation of the whole community.

FFLC receives highest charity rating

FOOD for Lane County has received the highest charity rating (4 stars) from Charity Navigator, a nonprofit organization that works to help charitable givers make intelligent giving decisions. Charity Navigator provides information on more than 3,000 charities and evaluates the financial health of each.

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VOLUNTARY:

Change to your account: - $30

Change to Food for Lane County account: + $30

Accept

Reject

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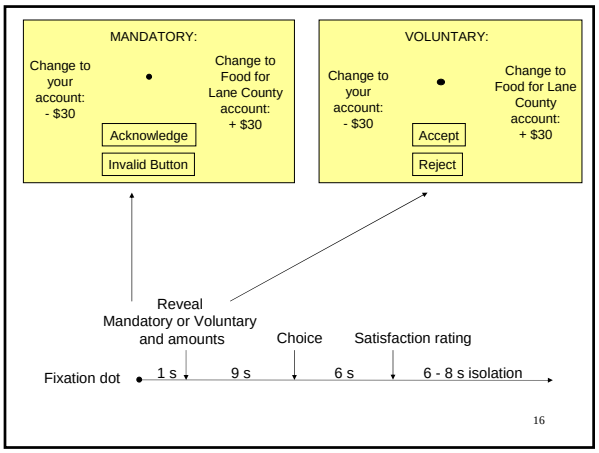


More Protocol:

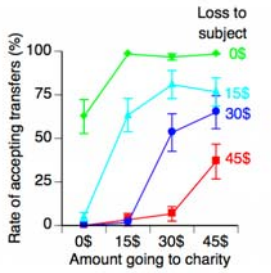
- Told to think about their decision when the cue appears
- Asked to rate satisfaction on a 1-4 scale, to increase attention
- One mandatory, one voluntary treatment chosen to count for payment
- Order of conditions is random
- Most transfers involve a tradeoff, but some only benefit subject, some only benefit charity
- Start with coffee!

Design Matrix for Transfers

Subject $ / Charity $	45 / 0	30 / 0	15 / 0
- 45 / 0	- 45 / 15	- 45 / 30	- 45 / 45
- 30 / 0	- 30 / 15	- 30 / 30	- 30 / 45
- 15 / 0	- 15 / 15	- 15 / 30	- 15 / 45
0 / 0	0 / 15	0 / 30	0 / 45

- Subjects start with $100
- Note prices, incomes, pure treatments
- 19 mandatory and 19 voluntary
- 3 runs, 13 minutes each

Behavioral results for Voluntary:



- Price and income variations make sense
- For the -$30/+$30 transfer, 9 subjects accepted all 3 transfers, 7 rejected all 3, and 3 subjects changed their responses
- Changes in payoffs for (subject, charity) average

(-$14, $19) in the mandatory,
(-$1, $12) in the voluntary

FMRI Methods

- BOLD responses
  - within subjects, across conditions
  - across subjects
- FSL 3.2 for extraction, correction, translation, analysis
- Two standard approaches to analyze the data: *Contrasts*, then *Region of Interest Analysis*
- Contrasts are t-tests
  - assume a gamma function for the hemodynamic response,
  - assume the stimulus began with M/V and amounts and lasted 9 seconds.
- ROI
  - extract functional data from the regions, average it wrst baseline, and regress

Contrasts

Contrasts are just visual representations of t-tests, done voxel by voxel.

Think of an A B design. Hypothesis is that the BOLD response is higher in A than in B. Repeat A and B many times, measure BOLD each time.

Take the time series of activation, deconvolve it using the assumed HDR function, run a regression with activation on the LHS, and a dummy variable for the A treatments.

Dummy coef. is essentially the extra amplitude of the HDR in A, relative to B, in that voxel.

~80,000 voxels, lots of tests. Adj. significance to correct for the large numbers of comparisons, with clustering to account for spatial correlation.

Contrast Specification:

$$y_t = \beta_0 + \beta_1 x_{1t} + \cdots + \beta_{38} x_{38t} + \varepsilon_t$$

y_t – BOLD Signal

x_{it} – Convolved Indicator for Condition i

ε_t – AR(1) Gaussian disturbance (pre-whitening)

Use Cochrane-Orcutt

Get betas for every voxel, compare the betas from the treatments to get the contrasts

Second & Third Level Analyses

Build up hierarchically

- 2nd level: within subjects (across 3 runs)
- 3rd level: across subjects

Contrasts of PEs from 3rd level

- Images were thresholded using clusters determined by Z>2.3 and a (corrected) cluster significance threshold of p = 0.05

Contrasts of what?

$ to subject in mandatory

Activation responses to increases in $ to subject, independent of charity's payoff

$ to charity in mandatory

Activation responses to increases in $ to charity, independent of subject's payoff

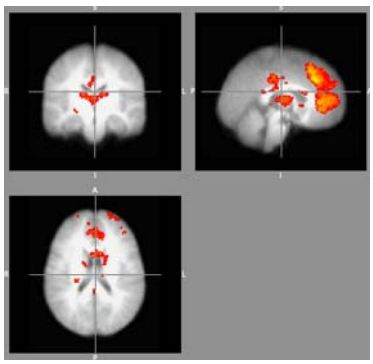
Voluntary / Mandatory

Differential activation when you have to think about your choice.

Choice Difficulty, on and off diagonal.

Some decisions are harder

Voluntary / Mandatory Contrast



Reward Areas:

- •Ventral Striatum, Insulae

Decision Processing Areas:

- •Lateral & Medial Pre-Frontal Cortex
- •Orbital Frontal Cortex, Anterior Cingulate Cortex

Need to disentangle choice and reward

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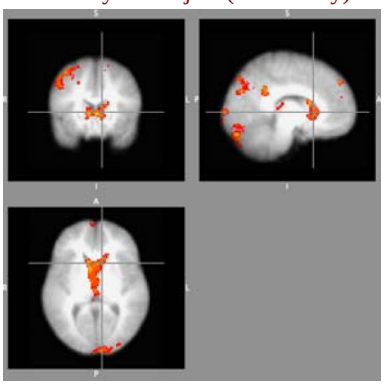
Money to Subject (Mandatory)



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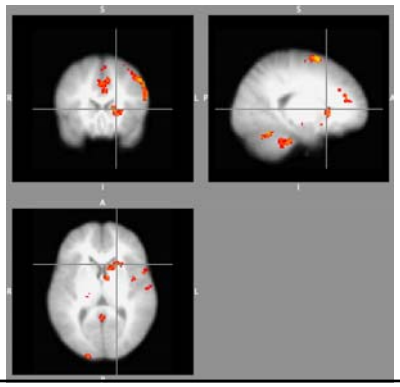
Money to Charity (Mandatory)



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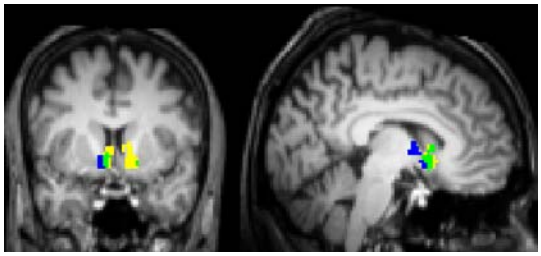
Ventral Striatum only (-8, 8, -8)

Yellow: $ to Self
Blue: $ to Charity
Green: Overlap

Mandatory, forced taxation for a public good activates same areas as private rewards

Come back to this with ROI regressions



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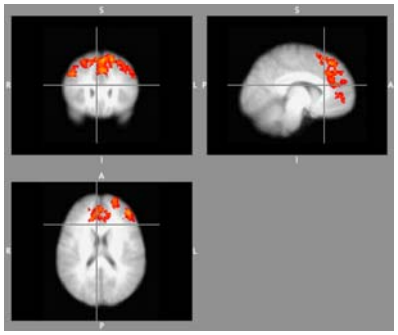
Decision Difficulty



Comparison of activation in V, as choices get "harder"

No reward center activation differences.

Lateral Pre-Frontal Cortex, Medial Pre-Frontal Cortex, Anterior Cingulate Cortex.

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Region of Interest Analysis

Complicated design:

- Look at decisions, activation magnitude
- Take activation data from regions of interest and attempt to explain it as function of treatment parameters, using regressions

We use "functional ROIs":

- Intersect contrasts with anatomical masks
- Neither the contrasts nor the masks are individual specific, conservative, results are robust

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NAcc (10, 10, -8)

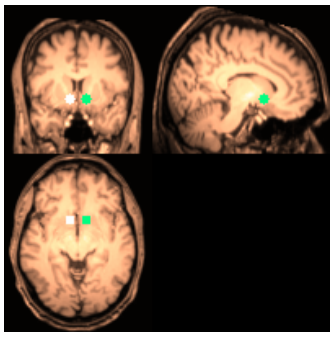

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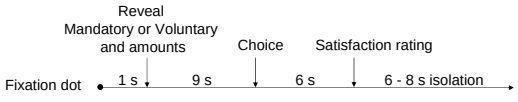
Table S3
Regions of Interest
Location and Volume in MNI-152 Space

ROI	x_1 (mm)	x_2 (mm)	x_3 (mm)	Anatomical (mm^3)	Functional (mm^3)
Caudate (L)	-8	4	4	1768	1720
Caudate (R)	8	4	4	1768	1344
Insula (L)	-34	18	-12	4168	3560
Insula (R)	34	18	-12	4168	2096
NAcc (L)	-10	10	-6	984	728
NAcc (R)	10	10	-6	984	560

Notes: Coordinates in MNI-152 space. The coordinates listed (x_1, x_2, x_3) are the distance of the ROI centroid from the origin, in millimeters (mm). See Section 4.1 for definitions of anatomical and functional ROIs

- Masks are the portions of anatomical regions that respond to variables of interest.
- Take the functional data for all those voxels within each mask, and average over those voxels.
- Computed the time-courses for each treatment as the percentage deviation of that signal from the average of the first 3 seconds before the stimulus. (2s TR, linear interpolation.)
- We then average these percentage differences up, over the time period from 2 seconds to 13 seconds after the stimulus.
- Call that "activation in the ROI."



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ROI Analysis

- Q1:In reward centers, can time averaged activation be explained by the the $ amounts of mandatory transfers from the subject and to the charity?

$$\bar{y}_i^{ROI} = \beta_0 + \beta_1 Subject_i + \beta_2 Charity_i + \varepsilon_i$$

- Mandatory conditions only
- OLS with random effects by individual

Neural responses to mandatory payoff changes

Table S4
Activations in Six ROIs During Mandatory Conditions as a Function of Transfer Amounts to Subject and Charity

Predictor	Caudate (L)	Caudate (R)	NAcc (L)	NAcc (R)	Insula (L)	Insula (R)
$ to Subject	0.00094*	0.00147**	0.00118**	0.00141**	-0.00001	0.00039
	(1.68)	(2.41)	(2.10)	(2.13)	(0.02)	(0.92)
$ to Charity	0.00243***	0.00267***	0.00191**	0.00288***	0.00033	0.00084
	(3.04)	(3.07)	(2.37)	(3.03)	(0.43)	(1.38)
Adjusted R^2	0.0058	0.0075	0.0040	0.0072	0.0000	0.0000

Notes: n=1064. Constant not shown. Absolute value of z-stats in parenthesis. Standard errors clustered by 19 subjects. ***denotes significance at the 1% level, **at the 5% level, *at the 10% level. See Section 4.2 for discussion.

- Significant activation effects for $ to subject and $ to charity
- Coefficient values are higher for $ charity than $ to self
- Matches contrast result, supports “pure altruism” and common neural currency ideas.

Compare M & V

- Contrast shows much more pre-frontal activation in the voluntary conditions
- Is there a “free to choose” effect - more reward area activation from the ability to make a decision?

Table S5
Activation in Six ROIs as a Function of Mandatory-Voluntary Contrast

Predictor	Caudate (L)	Caudate (R)	NAcc (L)	NAcc (R)	Insula (L)	Insula (R)
Voluntary	0.05992**	0.07019***	0.03566	0.08178**	0.04017*	0.03308*
	(2.43)	(2.87)	(1.14)	(2.57)	(1.86)	(1.78)
Adjusted R^2	0.0020	0.0030	0.0000	0.0025	0.0010	0.0010

Notes: n=2128. Constant not shown. Absolute value of z-stats in parenthesis. Standard errors clustered by 19 subjects. ***denotes significance at the 1% level, **at the 5% level, *at the 10% level. See Section 4.3 for discussion.

- remove a constraint, re-optimize, higher utility
- people often reject, leads to payoff differences.
- Here, subjects get $13 more in voluntary, charity gets $7 less

Table S6
Activation in Six ROIs as a Function of Mandatory-Voluntary Contrast and Design Factors Incorporating Actual Payoffs

Predictor	Caudate (L)	Caudate (R)	NAcc (L)	NAcc (R)	Insula (L)	Insula (R)
Voluntary	0.05875**	0.06489**	0.02049	0.06777**	0.03680	0.02876
	(2.27)	(2.53)	(0.62)	(2.03)	(1.62)	(1.48)
$ to Subject	0.00079	0.00110*	0.00201**	0.00211**	0.00039	0.00059
	(1.22)	(1.73)	(2.46)	(2.54)	(0.68)	(1.22)
$ to Charity	0.00136*	0.00137*	0.00170*	0.00205**	0.00026	0.00052
	(1.72)	(1.75)	(1.69)	(2.01)	(0.37)	(0.88)
Adjusted R^2	0.0029	0.0041	0.0021	0.0049	0.0004	0.0010

Notes: n=2128. Constant not shown. Absolute value of z-stats in parenthesis. Standard errors clustered by 19 subjects. ***denotes significance at the 1% level, **at the 5% level, *at the 10% level. See Section 4.4 for discussion.

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Voluntary Boost

Higher reward center activation from voluntary giving
- Free to Choose: remove a constraint, people are better off.
- Additionally, this persists even when we control for the amounts of the payoffs

- Neural support for the warm glow theory
  - Consistent with Moll et al. 2006, PNAS.
  - We already showed pure altruism. Reward center activation increased when the charity got money in the Mandatory
  - Now we show that, controlling for payoffs, there's an additional benefit from those amounts having come from voluntary giving rather than "taxation."

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Prediction results:

Two reasons to give money away:
- You just don't like money that much
- You get a big reward from seeing the charity get money

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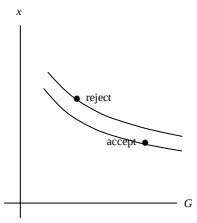
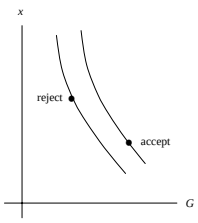
Marginal Rate of Substitution: Reward from $ to charity, relative to $ to self

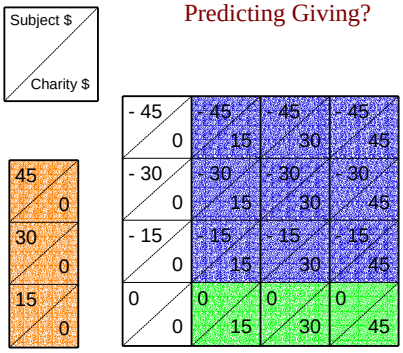
egoistic :



altruistic:



Predicting Giving?

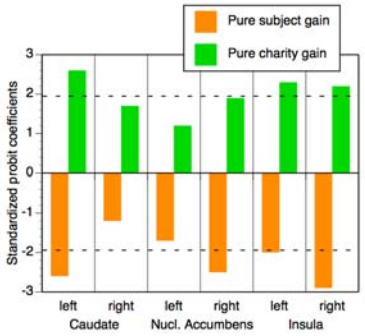


- Use activation from the Mandatory treatments where *only* the subject or the charity gets money.
- Calculate an MRS.
- Then predict decisions in the Voluntary treatments.

Table S7
Choices as a Function of Neural Responses From Pure Gains to Charity and From Pure Gains to Subject for Each ROI

Predictor	(1)	(2)	(3)	(4)	(5)	(6)
$ to Subject	0.134*** (10.72)	0.135*** (10.76)	0.135*** (10.76)	0.133*** (11.05)	0.135*** (10.69)	0.133*** (10.94)
$ to Charity	0.094*** (9.24)	0.094*** (9.23)	0.094*** (9.26)	0.093*** (9.42)	0.094*** (9.24)	0.093*** (9.36)
Caudate-S (L)	-6.103*** (2.58)					
Caudate-C (L)	5.213*** (2.59)					
Caudate-S (R)		-3.803 (1.22)				
Caudate-C (R)		3.098* (1.69)				
NAcc-S (L)			-7.284* (1.72)			
NAcc-C (L)			3.233 (1.17)			
NAcc-S (R)				-8.412** (2.49)		
NAcc-C (R)				3.650* (1.80)		
Insula-S (L)					-4.545** (2.01)	
Insula-C (L)					3.880** (2.32)	
Insula-S (R)						-6.675*** (2.86)
Insula-C (R)						5.147** (2.17)
Log-L	-144.1	-145.6	-145.7	-144.7	-143.0	-144.2

Notes: n=504. Constant not shown. Absolute value of *z*-stats in parenthesis.
***denotes significance at the 1% level, **at the 5% level, *at the 10% level.
-S denotes activation from mandatory conditions where only the subject receives money.
-C denotes activation from mandatory conditions where only the charity receives money.
See Section 4.5 for discussion.



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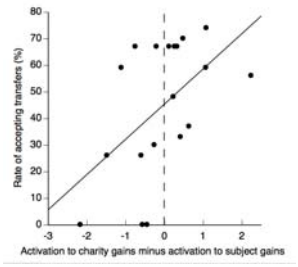
MRS measured from brain activation predicts giving

Egoists: higher activation from own gains

Altruists: higher activation from charity gains



R^2 = 27%, p=0.02

"Altruists" give nearly twice as often as egoists

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Prediction results:

Two reasons to give money away:

- You just don't like money that much
- You get a big reward from seeing the charity get money

- People who show higher reward center activation when they get money are less likely to give. High MU from money
- People who show higher activation when the charity gets money are more likely to give. High altruism.
- These effects, measured in the mandatory treatments, predict about 30% of variation in giving in the voluntary treatments, across subjects
- Note that these are "out of treatment" predictions

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Conclusions

- Getting money, pure altruism from seeing the charity get money, and warm glow all activate similar reward areas in the VTS and the insulae.
- People “prefer” to pay for a public good with voluntary giving, rather than mandatory taxation - and this is only in part because if it’s voluntary, they don’t have to give.
- MRS, or MUc relative to MUs, measured as % increases in BOLD response in reward areas, predicts who will give. This supports pure altruism.
- Extra activation in the V treatments, controlling for payoffs, supports warm glow motive.

Implications and Questions

Supports the “impure” motive for giving

- Need to ask what influences warm glow

Should we rely more on taxes or more on giving?

Does voting for a tax provide a warm glow?

Supports the idea that a choice is a good
- Is this effect restricted to giving?
- Can you drive it away?

Could we use this method to value public goods?

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