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
- randomly oriented

Inside magnetic field
- oriented with or against B0
- M = net magnetization

- when placed in a magnetic field (B0; 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)

RF Excitation

Excite Radio Frequency (RF) field
- transmission coil: apply magnetic field along B1 (perpendicular to B0) for ~3 ms
- oscillating field at Larmor frequency
- frequencies in range of radio transmissions
- B1 is small ~1/10,000 T
- tips M to transverse plane – spirals down
- analogies: guitar string (Noll), swing (Cox)
- final angle between B0 and B1 is the flip angle

Source: Robert Cox's web slides
Susceptibility and BOLD fMRI

- Magnetic susceptibility ($\chi$) refers to magnetic response of a material when placed in $B_0$.
- Red blood cells exhibit a change in $\chi$ 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 $\mu$m diameter.
  - $<15\%$ blood volume of cortical tissue.
- Venules
  - $Y=60\%$ at rest.
  - $Y=90\%$ during activation.
  - 25-50 $\mu$m diameter.
  - 40$\%$ blood volume of cortical tissue.
- Red blood cell
  - 6 $\mu$m wide and 1-2 $\mu$m thick.
  - Delivers $O_2$ in form of oxyhaemoglobin.
- Capillaries
  - $Y=80\%$ at rest.
  - $Y=90\%$ during activation.
  - 8 $\mu$m diameter.
  - 40$\%$ blood volume of cortical tissue.
  - Primary site of $O_2$ exchange with tissue.
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

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 building relationships, receiving, growing, and distributing food for distribution through a network of social service agencies and programs, and through public awareness, education, and community outreach.

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 provides solutions to hunger and the 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 of 5 stars from Charity Navigator, a nonprofit organization that works to help charitable gives make better decisions through its star rating system, which is based on transparency, accountability, and financial health.

VOLUNTARY:

Change to your account: - $30
- Accept
- Reject

Change to Food for Lane County account: + $30
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

- 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 wrt 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:

\[ y_i = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_{36} x_{i36} + \epsilon_i \]

- \( y_i \) = BOLD Signal
- \( x_i \) = Convolved Indicator for Condition \( i \)
- \( \epsilon_i \) = 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

Money to Subject (Mandatory)

Money to Charity (Mandatory)
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

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.

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
• 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.”

### Table S3

<table>
<thead>
<tr>
<th>ROI</th>
<th>$x_1$ (mm)</th>
<th>$x_2$ (mm)</th>
<th>$x_3$ (mm)</th>
<th>Anatomical (mm$^3$)</th>
<th>Functional (mm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caudate (L)</td>
<td>-8</td>
<td>4</td>
<td>4</td>
<td>1768</td>
<td>1720</td>
</tr>
<tr>
<td>Caudate (R)</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>1768</td>
<td>1344</td>
</tr>
<tr>
<td>Insula (L)</td>
<td>-34</td>
<td>18</td>
<td>-12</td>
<td>4168</td>
<td>3560</td>
</tr>
<tr>
<td>Insula (R)</td>
<td>34</td>
<td>18</td>
<td>-12</td>
<td>4168</td>
<td>2966</td>
</tr>
<tr>
<td>NAcc (L)</td>
<td>-10</td>
<td>10</td>
<td>-6</td>
<td>984</td>
<td>728</td>
</tr>
<tr>
<td>NAcc (R)</td>
<td>10</td>
<td>10</td>
<td>-6</td>
<td>984</td>
<td>560</td>
</tr>
</tbody>
</table>

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.
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?

\[ Y_i^\text{ROI} = \beta_0 + \beta_1 \text{Subject}_i + \beta_2 \text{Charity}_i + \epsilon_i \]

- Mandatory conditions only
- OLS with random effects by individual

Neural responses to mandatory payoff changes

<table>
<thead>
<tr>
<th>Table S4</th>
<th>Activations in Six ROIs During Mandatory Conditions as a Function of Transfer Amounts to Subject and Charity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictor</td>
<td>Candulate (L)</td>
</tr>
<tr>
<td>$ to Subject</td>
<td>0.0008*</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
</tr>
<tr>
<td>$ to Charity</td>
<td>0.0013***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
</tr>
</tbody>
</table>

Adjusted $R^2$: 0.0058, 0.0075, 0.0049, 0.0072, 0.0000, 0.0000

- 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>
<thead>
<tr>
<th>Table S5</th>
<th>Activation in Six ROIs as a Function of Mandatory-Voluntary Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictor</td>
<td>Candulate (L)</td>
</tr>
<tr>
<td>Voluntary</td>
<td>0.0592**</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
</tr>
</tbody>
</table>

Adjusted $R^2$: 0.0052, 0.0030, 0.0000, 0.0000, 0.0010, 0.0000

Note: n=1183. Contrast not shown. Absolute value of z-score in parentheses. Standard errors clustered by 18 subjects. "***" denotes significance at the 1% level, "**" at the 5% level, "*" at the 10% level. See Section 4.4 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

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Caudate (L)</th>
<th>Caudate (R)</th>
<th>NAcc (L)</th>
<th>NAcc (R)</th>
<th>Insula (L)</th>
<th>Insula (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voluntary</td>
<td>0.00875**</td>
<td>0.00489**</td>
<td>0.00060</td>
<td>0.00772**</td>
<td>0.00080</td>
<td>0.00275</td>
</tr>
<tr>
<td>$ to Subject</td>
<td>0.00679</td>
<td>0.00110*</td>
<td>0.00200**</td>
<td>0.00211**</td>
<td>0.00039</td>
<td>0.00059</td>
</tr>
<tr>
<td>$ to Charity</td>
<td>0.00136*</td>
<td>0.00137*</td>
<td>0.00120*</td>
<td>0.00207**</td>
<td>0.00026</td>
<td>0.00052</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.0029</td>
<td>0.0041</td>
<td>0.0021</td>
<td>0.0040</td>
<td>0.0004</td>
<td>0.0010</td>
</tr>
</tbody>
</table>

Notes: n=208. Contrast not shown. Absolute value of t-statistic in parentheses. Standard errors clustered by 13 subjects. ** denotes significance at the .01 level, * at the .05 level, # at the .10 level. See Section 4.4 for discussion.

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.”

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

egoistic: $ to subject $ to charity altruistic: $ to subject $ to charity

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>
<thead>
<tr>
<th>Subject $</th>
<th>Charity $</th>
</tr>
</thead>
<tbody>
<tr>
<td>-45</td>
<td>-45</td>
</tr>
<tr>
<td>-30</td>
<td>-30</td>
</tr>
<tr>
<td>-15</td>
<td>-15</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: Choices as a Fraction of Total Responses From Part-Gala to Charity and From Part-Gala to Subject for Each RRB

<table>
<thead>
<tr>
<th>Predictor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ to Subject</td>
<td>3.20**</td>
<td>3.00***</td>
<td>3.00***</td>
<td>3.00***</td>
<td>3.00***</td>
</tr>
<tr>
<td>$ to Charity</td>
<td>3.00***</td>
<td>3.00***</td>
<td>3.00***</td>
<td>3.00***</td>
<td>3.00***</td>
</tr>
<tr>
<td>Customer A</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
</tr>
<tr>
<td>Customer B</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
</tr>
<tr>
<td>Customer C</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
</tr>
<tr>
<td>None (E)</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
</tr>
<tr>
<td>None (F)</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
</tr>
<tr>
<td>None (G)</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
</tr>
<tr>
<td>None (H)</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
<td>0.10**</td>
</tr>
</tbody>
</table>

*Denotes a significant at the .05 level; **Denotes a significant at the .01 level.

(See text for footnotes to these tables. If a table is not footnoted, it means that no footnotes were necessary.)
MRS measured from brain activation predicts giving

Egoists: higher activation from own gains
Altruists: higher activation from charity gains

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

$R^2 = 27\%, \ p=0.02$
"Altruists" give nearly twice as often as egoists
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?