The Neural Basis of Economic Decision-Making in The Ultimatum Game

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Behavioral Results

Fig. 1B
Neuro-imaging Data

Areas showing greater activation to unfair compared to fair offers
- Bilateral anterior insula
- Dorsolateral prefront cortex (DLPFC)
- Anterior cingulate cortex (ACC)
Event-related plot for unfair and fair offers in right anterior insula. The offer was revealed at $t = 0$ on the $x$ axis.
Event-related plot for unfair and fair offers in left anterior insula. The offer was revealed at $t = 0$ on the $x$ axis.
Event-related plot for unfair and fair offers in right anterior insula. The offer was revealed at $t = 0$ on the $x$ axis.
Bilateral Anterior Insula

• Associated with
  – Pain & distress
  – Hunger & thirst
  – Autonomic arousal
  – Negative emotional state
  – Anger & disgust (taste & odor)

• Emotional based disgust
Acceptance rates of unfair offers (8:2 and 9:1) plotted against right anterior insula activation for each participant.

Fig. 3. (A)
Dorsolateral prefrontal cortex (DLPFC)

- Observed higher activity for unfair offers
- Associated with
  - Cognitive processes
- Cognitive demand?
- Didn’t correlate with acceptance rate
Anterior Insula vs. DLPFC

Right anterior insula and right DLPFC activation for all unfair offer trials, categorized by subsequent acceptance or rejection.
Anterior cingulate cortex (ACC)

• Observed higher activity for unfair offers
• Associated with
  – Cognitive conflict
Conclusions

• Consistent with the idea that the areas of anterior insula and DLPFC represent the twin demands of the Ultimatum Game task, the emotional goal of resisting unfairness and the cognitive goal of accumulating money

• Supports the importance of emotional influences in human decision-making
Fig. 3. (A) Acceptance rates of unfair offers plotted against right anterior insula activation for each participant. (B) Right anterior insula and right DLPFC activation for all unfair offer trials, categorized by subsequent acceptance or rejection.
Neuroimaging Data

• Areas showing greater activation to unfair compared to fair offers
  – Bilateral anterior insula
  – Dorsolateral prefrontal cortex (DLPFC)
  – Anterior cingulate cortex (ACC)

• Magnitude of activation
  – Human unfair > PC and low control offers
  – Function of context
Neuroimaging Data

- Activation related to the presentation of an unfair offer
- Map of the $t$ statistic for the contrast [unfair human offer – fair human offer] showing activation of bilateral anterior insula and anterior cingulate cortex. Areas in orange showed greater activation following unfair as compared with fair offers ($P < 0.001$)

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Fig. 1. (A) Time line for a single round of the Ultimatum Game. Each round lasted 36 s. Each round began with a 12-s preparation interval. The participant then saw the photograph and name of their partner in that trial for 6 seconds. A picture of a computer was shown if it was a computer trial, or a roulette wheel if it was a control trial. Next, participants saw the offer proposed by the partner for a further 6 s, after which they indicated whether they accepted or rejected the offer by pressing one of two buttons on a button box. (B) Behavioral results from the Ultimatum Game. These are the offer acceptance rates averaged over all trials. Each of 19 participants saw five $5:$5 offers, one $7:$3 offer, two $8:$2 offers, and two $9:$1 offers from both human and computer partners (20 offers in total).
Fig. 2. Activation related to the presentation of an unfair offer. (A) Map of the $t$ statistic for the contrast [unfair human offer – fair human offer] showing activation of bilateral anterior insula and anterior cingulate cortex. Areas in orange showed greater activation following unfair as compared with fair offers ($P < 0.001$). (B) Map of the $t$ statistic for the contrast [unfair human offer – fair human offer] showing activation of right dorsolateral prefrontal cortex. (C) Event-related plot for unfair and fair offers in right anterior insula. The offer was revealed at $t = 0$ on the $x$ axis. (D) Event-related plot for unfair and fair offers in left anterior insula. (E) Event-related plot for different human unfair and fair offers in subset of left anterior insula.
She’s a Woman, Offer Her Less

• BW Online | May 7, 2001
Player A’s feelings about player B and actual payoff reduction imposed on B

Fig. 1. (A) Player A’s perceived unfairness if B kept all the money. During the 10-min interval between PET scans, player A indicated on a seven-point scale. (B) Player A’s desire to punish B if the latter kept all the money.
Actual payoff reduction imposed on B if the latter keeps all the money.
## Table 1. PET results.

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Region (BA)</th>
<th>Coordinates</th>
<th>Z value</th>
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<tbody>
<tr>
<td>(IC + IF) - (IS + NC)</td>
<td>Caudate nucleus</td>
<td>6, 22, 4</td>
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<td></td>
<td>Medial orbitofrontal cortex (BA 11)</td>
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Fig. 2. (A) Activation in the caudate nucleus in conditions in which subjects indicated a strong desire to punish and could effectively do so (IC and IF) relative to conditions in which there is no effective punishment or the desire to punish is absent (IS and NC). (B) Effect sizes at the peak of blood-flow increase in the caudate nucleus. Bars indicate caudate activity in each condition relative to the mean brain activation ± SD.
Positive correlation between caudate activation and the amount of money spent on punishment in the IC condition

Fig 3A
Correlation between caudate activation in the IF condition in those subjects that punished maximally and the amount of money spent on punishment by these subjects in the IC condition

Fig 3B
Fig. 4. The role of the prefrontal cortex in integrating the benefits and costs of punishing. Activation of the ventromedial prefrontal cortex and the medial orbitofrontal cortex in the condition where subjects have a strong desire to sanction but where sanctioning is costly for the punisher (IC) relative to the condition where there is also a strong desire to sanction but sanctioning is costless for the punisher (IF)
Sweet Revenge?

- Brian Knutson
- Revenge feels good! Most of us take satisfaction in punishing violators of social norms and may even incur costs to do so. In a Perspective, Knutson takes us on a joy ride through the brain to seek the areas involved in the exacting of revenge. Intriguingly, it is the striatum, a key subcortical brain structure involved in feeling satisfaction, that is activated in human volunteers subjected to PET imaging as they play a game designed to elicit acts of revenge.

"Go ahead, make my day." Dirty Harry succinctly informs a norm violator that he anticipates deriving satisfaction from inflicting altruistic punishment.
The Neural Basis of Altruistic Punishment

- Many people voluntarily incur costs to punish violations of social norms. Evolutionary models and empirical evidence indicate that such altruistic punishment has been a decisive force in the evolution of human cooperation. We used H2 15O positron emission tomography to examine the neural basis for altruistic punishment of defectors in an economic exchange. Subjects could punish defection either symbolically or effectively. Symbolic punishment did not reduce the defector's economic payoff, whereas effective punishment did reduce the payoff. We scanned the subjects' brains while they learned about the defector's abuse of trust and determined the punishment. Effective punishment, as compared with symbolic punishment, activated the dorsal striatum, which has been implicated in the processing of rewards that accrue as a result of goal-directed actions. Moreover, subjects with stronger activations in the dorsal striatum were willing to incur greater costs in order to punish. Our findings support the hypothesis that people derive satisfaction from punishing norm violations and that the activation in the dorsal striatum reflects the anticipated satisfaction from punishing defectors.
Scans Show Brain Hard-wired For Sweet Revenge

- Science, August 2004
- The Neural Basis of Altruistic Punishment
- Planning revenge really does feel sweet, according to a new study of brain scans. Researchers in Switzerland said the brain centers linked to enjoyment "lit up" in young men who punished those who cheated them.
- It's as if punishing cheaters is satisfying enough to motivate getting even, even if revenge is costly.

The reward centre in a man's brain, shown in gold, lights up if he can punish unfair behavior without fear of retribution.
A lot of fuss over one yuan  
(Shanghai Star)  
Updated: 2004-02-20 08:56

A 10-year-old primary schoolboy in Yangzhou, East China, came across one yuan lying on the ground when he was out shopping with his mother. He picked it up and gave it to a policeman at the street corner, who then, in front of the boy, threw the one yuan onto the ground. (Xinhua News Agency, www.people.com.cn, visited on February 10).