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Neural mechanism of proposer's decision-making in the ultimatum and dictator games☆

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Abstract

Previous studies have demonstrated that reactions to unfair offers in the ultimatum game are correlated with negative emotion. However, little is known about the difference in neural activity between a proposer's decision-making in the ultimatum game compared with the dictator game. The present functional magnetic resonance imaging study revealed that proposing fair offers in the dictator game elicited greater activation in the right supramarginal gyrus, right medial frontal gyrus and left anterior cingulate cortex compared with proposing fair offers in the ultimatum game in 23 Chinese undergraduate and graduate students from Beijing Normal University in China. However, greater activation was found in the right superior temporal gyrus and left cingulate gyrus for the reverse contrast. The results indicate that proposing fair offers in the dictator game is more strongly associated with cognitive control and conflicting information processing compared with proposing fair offers in the ultimatum game.

Key Words

neural regeneration; neuroimaging; functional magnetic resonance imaging; decision-making; fair behavior; neural mechanism; brain; brain activation; cognition; emotion; grants-supported paper; photographs-containing paper; neuroregeneration

Research Highlights

(1) The current functional magnetic resonance imaging findings reveal that the pattern of neural activity underlying fair behavior mainly driven by a tendency to fairness differs from that underlying fair behavior mainly driven by strategic motivations.
(2) The results indicate that proposing fair offers in the dictator game is more closely associated with cognitive control and conflicting information processing compared with proposing fair offers in the ultimatum game.

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INTRODUCTION

Standard economic models have traditionally assumed that individuals are motivated solely by material utility and are not directly influenced by emotional or social factors[1]. However, there is increasing behavioral and neural evidence that fairness and emotion play important roles in economic decision-making[2]. Much of this evidence comes from studies of the ultimatum game and the dictator game. In the ultimatum game, one player (the 'proposer') proposes a way of splitting a given sum of money with an anonymous player (the 'responder'). If the responder accepts the offer, the money is split as proposed, but if the responder rejects the offer, neither of the players receives anything. The dictator game is different to the ultimatum game, because the

responder must accept the proposer's offer.

A number of recent studies have used functional magnetic resonance imaging to examine the neural basis of fair behavior in economic games. Functional magnetic resonance imaging measures brain activity by detecting associated changes in blood flow, using the blood-oxygen-level-dependent contrast[3]. This technique has an advantage over other methods because it does not require surgery, injecting or ingesting substances, or exposure to radiation. In addition, functional magnetic resonance imaging has better spatial resolution than techniques like electroencephalography[3].

Previous studies of the ultimatum and dictator games have indicated that proposers do not maximize material utility by proposing extremely unfair offers, but rather tend to propose relatively fair offers[4]. Studies of the neural basis of responder's decision-making in the ultimatum game have revealed that being treated unfairly is associated with negative emotion, involving anterior insula activation, and with cognitive or emotional modulation, involving the dorsolateral prefrontal cortex and ventromedial prefrontal cortex[5-8]. However, no previous studies have compared the neural basis of proposer's decision-making in the ultimatum game and the dictator game. Conflicting findings have been reported regarding proposer's tendency to fairness in the ultimatum game. Some researchers have argued that fairness largely explains the proposer's tendency against reward maximization[9]. However, other researchers proposed that the tendency to divide the reward equally is not due to a tendency to fairness, but is entirely caused by the (justified) fear that unfair offers might be rejected[10].

In addition, it has been argued that the ultimatum game evokes strategic motivation, while the dictator game evokes concern for fairness[11]. Other researchers have attempted to combine the above explanations, proposing that both fairness and strategic motivations influence proposer's decision-making in the ultimatum game[12]. Comparing the neural basis of fair behavior in the ultimatum game with that in the dictator game may contribute to a better understanding of the role of fairness-related and strategic motivations.

RESULTS

Quantitative analysis of subjects

A total of 23 Chinese undergraduate and graduate students from Beijing Normal University in China volunteered to participate in the experiment. All subjects completed the experiments, and all data were included in the final analysis.

General data analysis

Subjects included eight males and 15 females, with an average age of 21.7 years. Behavioral data were collected while participants underwent functional magnetic resonance imaging scanning. Table 1 shows that participants tended to propose fair offers in the ultimatum game and unfair offers in the dictator game (χ^2 = 342.86, P < 0.001). The increase of unfairness from ¥7: ¥3 to ¥8: ¥2 shows that participants tended to propose less unfair offers and more fair offers in the ultimatum game (χ^2 = 36.79, P < 0.001).

Table 1 Distribution of subject's fair or unfair proposals in the ultimatum and dictator games

Game	Proposals by subjects [*n* (%)]				χ^2
	¥7: ¥3	¥5: ¥5	¥8: ¥2	¥5: ¥5	
Ultimatum	101(37)	175(63)	39(14)	237(86)	342.86[a]
Dictator	229(83)	47(17)	218(79)	58(21)	36.79[a]

"a" indicates P < 0.001. Number in the table refers to the number of proposals subjects made in ultimatum game or dictator game. Percentage refers to the number of fair offers or unfair offers/ number of fair offers and unfair offers.

Comparison of brain activation while proposing fair offers in the ultimatum game compared with the dictator game

To explore whether neural activation was significantly different between the dictator game and the ultimatum game, we examined functional magnetic resonance imaging results while participants proposed fair offers in each game. The results revealed that fair offers in the dictator game elicited greater activation in the right supramarginal gyrus, right medial frontal gyrus and left anterior cingulate cortex compared with proposing fair offers in the ultimatum game (paired t-test; P < 0.004). However, the reverse contrast revealed greater activation in the right superior temporal gyrus and left cingulate gyrus (paired t-test; P < 0.004; Table 2, Figures 1, 2).

DISCUSSION

Fair behavior is complex, and may have different psychological mechanisms. Some fair behaviors, like proposers' fair behavior in the ultimatum game, are thought to be mainly motivated by reward maximization[11-12], and proposers' fair behavior in the dictator game is thought to be mainly driven by a tendency to fairness[11].

Table 2 Brain areas exhibiting different activations between proposing fair offers in the ultimatum and dictator games

Area	Cluster size (voxel)	Z_{max}	Coordinate		
			X	*Y*	*Z*
Dictator game fair > ultimatum game fair					
Right supramarginal gyrus/BA 40	17	3.48[a]	57	–61	37
Right medial frontal gyrus/BA 10	23	3.31[a]	15	44	13
Left anterior cingulate cortex	27	3.25[a]	–9	32	–5
Ultimatum game fair > dictator game fair					
Right superior temporal gyrus/BA 38	12	3.88[a]	51	17	–20
Left cingulate gyrus	11	3.23[a]	–6	–37	31

Ultimatum game/dictator game fair refers to proposing fair offers in the ultimatum game/dictator game. The coordinates are from the Montreal Neurological Institute atlas. Significance was based on an uncorrected *P* value of 0.004 ($P < 0.004$), with a 10-voxel threshold. "a" indicates $P < 0.01$.

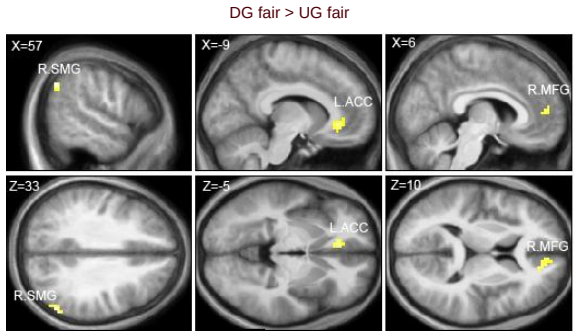


Figure 1 Brain areas exhibiting stronger activation while proposing fair offers in the dictator game (DG) compared with proposing fair offers in the ultimatum game (UG).

The activated brain areas include the right supramarginal gyrus (R.SMG)/BA 40, right medial frontal gyrus (R.MFG)/BA 10, and left anterior cingulate cortex (L.ACC).

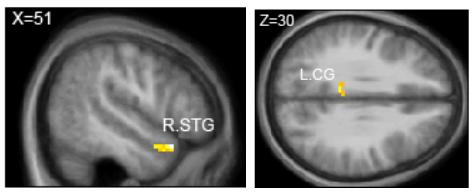


Figure 2 Brain areas exhibiting stronger activation while proposing fair offers in the ultimatum game (UG) compared with the dictator game (DG).

The activated brain areas included right superior temporal gyrus (R.STG), left cingulate gyrus (L.CG).

The behavioral findings in the present study revealed that participants mostly proposed fair offers in the ultimatum game (75%), while mainly proposing unfair offers in the dictator game (81%). These results lend further behavioral support to previous studies reporting that strategic motivations or the fear of rejection mainly accounts for the proposal of fair offers in the ultimatum game. To eliminate the effects of hand and finger movement in subjects' decision-making during functional magnetic resonance imaging scanning, we selected right handed subjects and balanced the presence of fair/unfair offers with equal frequency on the left and right sides of the screen. The conditions we used for comparison in functional magnetic resonance imaging analysis involved almost identical hand-movement patterns. As such, hand movement is unlikely to substantially affect functional magnetic resonance imaging analysis.

To further explore the difference in the pattern of neural activity exhibited by proposers during these two types of fairness-related behavior, we compared functional magnetic resonance imaging results during the proposal of fair offers in the dictator game with those in the ultimatum game. The functional magnetic resonance imaging findings revealed that fair offers in the dictator game elicited significantly greater activation in the right medial frontal gyrus, parietal lobe and left anterior cingulate cortex. However, the right superior temporal gyrus and left cingulate gyrus were significantly more activated in the reverse comparison (fair behavior in ultimatum game > fair behavior in dictator game). Interestingly, we found significantly greater activation of the prefrontal and parietal lobe while proposing fair offers in the dictator game compared with the ultimatum game. Previous studies reported that the right superior temporal gyrus played a role in processing threat-related information[13], and the anterior cingulate cortex was implicated in the detection of cognitive conflicts[14-15]. The prefrontal cortex is associated with executive control, behavioral loss aversion and response inhibition[16-19]. These findings indicate that fair offers in the dictator game may be associated with more cognitive control and conflicting information processing compared with fair offers in the ultimatum game. Moreover, proposing fair offers in the ultimatum game may be associated with more

threat-related information processing, as suggested by the greater activation in right superior temporal gyrus and left cingulate gyrus observed in the current study, and previous reports[13]. The current findings revealed that proposer's fair behavior in the ultimatum and dictator games was mainly associated with prefrontal and anterior cingulate cortex activation. This pattern of neural activity partially differs from that previously reported during responder's fair behavior in the ultimatum game, which mainly involved the ventromedial prefrontal cortex and insular cortex[4, 20-21]. These results may be partially due to the proposer's decision-making experience involving the balancing of more different alternatives than the responder's decision making in the current study. The current functional magnetic resonance imaging findings indicated that the neural substrate of fair behavior mainly driven by a tendency to fairness differs from that underlying fair behavior mainly driven by strategic motivations. The medial frontal cortex, supramarginal gyrus and anterior cingulate cortex appear to play an important role in fair behavior driven by a tendency to fairness.

SUBJECTS AND METHODS

Design

A self-controlled neuroimaging study.

Time and setting

Experiments were performed in the National Key Laboratory of Cognitive Neuroscience and Learning at Beijing Normal University, China in September 2009.

Subjects

A total of 23 healthy right-handed (Edinburgh Handedness Inventory[22]) Chinese undergraduate and graduate students from Beijing Normal University (8 males, 15 females; 18–27 years of age; 21.7 ± 2.1 years) volunteered to participate in this experiment.

Inclusion criteria

Right-handed subjects were included. None of the participants had a history of neurological disorders, surgery or serious physical illness. The participants provided written informed consent after a detailed description of the study.

Exclusion criteria

Left-handed subjects, subjects with neurological disorders, surgery or serious physical illness were excluded.

Methods

Functional brain image processing and functional magnetic resonance imaging acquisition during decision-making in the ultimatum and dictator games

Scanning was performed using a 3.0 T functional magnetic resonance imaging scanner at the National Key Laboratory of Cognitive Neuroscience and Learning at Beijing Normal University, China. Functional images were acquired using T2*-weighted echo-planar imaging sequence (repetition time = 2 seconds, echo time = 30 ms, flip angle = 90°, field of view = 200 mm × 200 mm, matrix = 64 × 64, number of slices for a whole brain = 30, slice thickness = 4 mm, gap = 0 mm, resolution = 3.1 × 3.1 × 4.0 mm^3). T1-weighted anatomy images were acquired using SPGR sequence (repetition time = 2 530 ms, echo time = 3.39 ms, flip angle = 7°, matrix = 256 × 256, number of slices for the whole brain = 128, slice thickness = 1.33 mm, resolution = 1.00 × 1.00 × 1.33 mm^3).

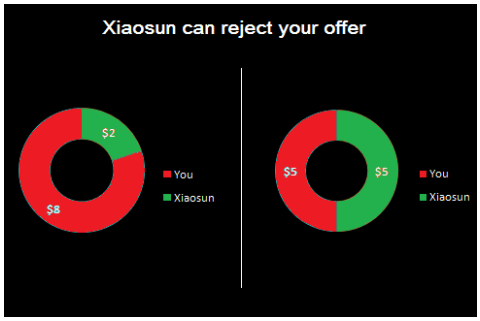
Trial procedure of functional magnetic resonance imaging stimulus design

The trial began with the presentation of a cross ('+') for 2, 4 or 6 seconds (selected randomly) on a screen inside the functional magnetic resonance imaging scanner. Two alternative proposals between unfair and fair offers (Figure 3) were presented for 6 seconds.

During this time, subjects were required to choose one of the two proposals by pressing the left or right button. There were two types of proposals in each trial: ultimatum game proposals and dictator game proposals. The type of proposal was indicated by the sentence at the top of the two alternative proposals. If the sentence at the top was phrased 'Xiaosun must accept your offer', it was a dictator game proposal. A blank jitter was then presented for 2, 4 or 6 seconds, selected randomly. At the end of each trial, the subject's 'partner' (actually a computer), responded by accepting or rejecting the offers, and feedback reporting their response was presented for 4 seconds. In ultimatum game trials, a rejection by the responder meant that both proposers and responders received ¥0, and accepting meant that the reward was allocated as proposed. In dictator game trials, the responder could only accept the proposer's offers with no opportunity to reject them.

Functional magnetic resonance imaging experimental procedure

The experiment was divided into three parts: an instruction phase, a scanning phase during which participants performed the task, and a post-scan debriefing phase.

<table>
<tr><td>2–6 seconds</td><td>6 seconds</td><td>2–6 seconds</td><td>4 seconds</td></tr>
<tr><td>+fixation</td><td> 

(Press button to choose offer; if the sentence on top of the slide changed to ‘Xiaosun can only accept your offer’, it is a dictator game proposal)</td><td>Blank</td><td>(Feedback)
Xiaosun rejects
You get $0
Xiaosun get $0</td></tr>
</table>

Figure 3 Timeline for a single trial of the ultimatum game or dictator game.
Red in the pie graph indicates the money you allocated to yourself and green means money you offered to other people.

In the instruction phase, the participants were familiarized with the ultimatum and dictator game tasks, and performed a number of practice trials on a laptop computer. Participants were told that in the ultimatum game/dictator game, they would play one game each with several different players. They were told that their offers with each player would not be revealed to the other players and, therefore, would not affect subsequent players’ responses.

In the scanning phase, to better compare unfair offers with fair offers, participants were asked to make a forced choice between the unfair proposal and the fair proposal (¥5: ¥5) (Table 3).

Table 3 Proposals in ultimatum game and dictator game

Unfair proposals	Fair proposals	The extent of unfairness
¥7:¥3	¥5:¥5	Moderately unfair
¥8:¥2	¥5:¥5	Highly unfair

Participants completed 48 trials (24 ultimatum game trials, 24 dictator game trials) in two runs. Each run lasted approximately 8 minutes. Trials were presented in a pseudo-random order. The timeline for a single trial of the ultimatum game or dictator game is presented in Figure 1. In ultimatum game trials, if the participant chose the unfair proposal (¥8: ¥2) they received “reject” responses at a ratio of 7/12 (randomly selected). In the ultimatum game, the ratios of response rejection were 4/12, and 0 for proposals of ¥7: ¥3 and ¥5: ¥5, respectively. The ratio for rejecting and accepting responses was based on that used in a previous study[23].

To minimize the potential effects of habit-related bias, the probability of fair and unfair proposals appearing on the left and right sides of the screen was counterbalanced. In the post-scan debriefing phase, participants were debriefed and given RMB¥50 (approximately USD$7) for participation.

Functional magnetic resonance imaging data processing

The imaging data were preprocessed and analyzed using SPM5 (Wellcome Department of Cognitive Neurology, London, United Kingdom). Image preprocessing included: slice scan time correction, head motion correction, spatial normalization to Montreal Neurological Institute space, and smoothing with an 8-mm full-width-at-half-maximum Gaussian kernel. Events were modeled with a general linear model time-locked to the onset of the proposals.

Statistical analysis

Paired-sample *t*-tests were performed in a voxel-by-voxel manner with SPM5 (Wellcome Department of Cognitive Neurology) between the two groups, based on the difference between averaged brain activation signals measured between the proposal of fair offers in the ultimatum game and the dictator game. Findings (voxels in the whole-brain showing significant differences) were considered statistically significant at a height threshold of $P < 0.004$, and an extension threshold of 10 voxels.

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Conflicts of interest: None declared.

Ethical approval: The study protocol was approved by the ethics committee of Beijing Normal University, China.

Author statements: The manuscript is original, has not been submitted to or is not under consideration by another publication, has not been previously published in any language or any form, including electronic, and contains no disclosure of confidential information or authorship/patent application/funding source disputations.

REFERENCES

[1] Camerer C, Loewenstein G, Prelec D. Neuroeconomics: How neuroscience can inform economics. J Econ Lit. 2005;43(1):9-64.
[2] Fehr E, Schmidt KM. A theory of fairness, competition, and cooperation. Q J Econ. 1999;114(3):817-868.
[3] Huettel SA, Song AW, McCarthy G. Functional Magnetic Resonance Imaging. 2nd ed. Massachusetts: Sinauer. 2009.
[4] Camerer C, Thaler RH. Anomalies: ultimatums, dictators, and manner. J Econ Perspect. 1995;9(2):209-219.
[5] Sanfey AG, Rilling JK, Aronson JA, et al. The neural basis of economic decision-making in the Ultimatum Game. Science. 2003;300(5626):1755-1758.
[6] Koenigs M, Tranel D. Irrational economic decision-making after ventromedial prefrontal damage: evidence from the ultimatum game. J Neurosci. 2007;27(4):951-956.
[7] Knoch D, Pascual-Leone A, Meyer K, et al. Diminishing reciprocal fairness by disrupting the right prefrontal cortex. Science. 2006;314(5800):829-832.
[8] Bibnia GA, Satpute AB, Lieberman MD. The sunny side of fairness: Preference for fairness activates reward circuitry (and disregarding unfairness activates self-control circuitry). Psychol Sci. 2008;19(4):339-347.
[9] Dickinson DL. Ultimatum decision-making: a test of reciprocal kindness. Theory Decis. 2000;48(2):151-177.
[10] Huck S, Oechssler J. The indirect evolutionary approach to explaining fair allocations. Games Econ Behav. 1999; 28(1):13-24.
[11] Van Dijk E, Vermunt R. Strategy and fairness in social decision making: Sometimes it pays to be powerless. J Exp Soc Psychol. 2000;36(1):1-25.
[12] Forsythe R, Horowitz JL, Savin NE, et al. Fairness in simple bargaining experiments. Games Econ Behav. 1994;6(3):347-369.
[13] Kraut MA, Pitcock JA, Calhoun V, et al. Neuroanatomic organization of sound memory in humans. J Cogn Neurosci. 2006;18(11):1877-1888.
[14] MacDonald AW, Cohen J, Stenger VA, et al. Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. Science. 2000; 288(5472):1835-1838.
[15] Botvinick M, Nystrom LE, Fissell K, et al. Conflict monitoring versus selection-for-action in anterior cingulated cortex. Nature. 1999;402(6758):179-181.
[16] Miller EK, Cohen JD. An integrative theory of prefrontal cortex function. Annu Rev Neurosci. 2001;24(1):167-202.
[17] Tom S, Fox C, Trepel C, et al. The neural basis of loss aversion in decision-making under risk. Science. 2007; 315(5811):515-518.
[18] Miller LA. Impulsivity, risk-taking, and the ability to synthesize fragmented information after frontal lobectomy. Neuropsychologia. 1992;30(1):69-79.
[19] Fuster JM. The prefrontal cortex. Anatomy, physiology, and neuropsychology of the frontal lobe. New York: Raven Press, USA. 1996.
[20] Dawes CT, Loewen PJ, Schreiber D, et al. Neural basis of egalitarian behavior. Proc Natl Acad Sci U S A. 2012; 109(17):6479-6483.
[21] Corradi-Dell'acqua C, Civai C, Rumiati RI, et al. Disentangling self-and fairness-related neural mechanisms involved in the ultimatum game: an fMRI study. Soc Cogn Affect Neurosci. 2012.
[22] Oldfield R. The assessment and analysis of handedness: The Edinburgh inventory. Neuropsychologia. 1971;9(1): 97-113.
[23] Falk A, Fehr E, Fischbacher U. On the nature of fair behavior. Econ Inq. 2003;41(1):20-26.

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