

Economic decision-making in the ultimatum game by smokers.

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## **Abstract**

**OBJECTIVE:** No study to date compared degrees of inequity aversion in economic decision-making in the ultimatum game between non-addictive and addictive reinforcers. The comparison is potentially important in neuroeconomics and reinforcement learning theory of addiction. **METHODS:** We compared the degrees of inequity aversion in the ultimatum game between money and cigarettes in habitual smokers. **RESULTS** Smokers avoided inequity in the ultimatum game more dramatically for money than for cigarettes; i.e., there was a "domain effect" in decision-making in the ultimatum game. **CONCLUSIONS:** Reward-processing neural activities in the brain for non-addictive and addictive reinforcers may be distinct and the insula activation due to cue-induced craving may conflict with unfair offer-induced insula activation. Future studies in neuroeconomics of addiction should employ game-theoretic decision tasks for elucidating reinforcement learning processes in dopaminergic neural circuits.

**Key words:** Addiction; Game theory; Motivation; Neuroeconomics; Nicotine; Ultimatum game;

## Introduction

Neural and neuroendocrine correlates of fairness, inequity aversion, and social preference such as trust have been attracting attention in neuroeconomics [1,2,3]. It is known that people tend to reject an unfair offer at the cost of their own financial gains [1,2]. This behavioral tendency is paradoxical, with respect to the standard economics' assumption of selfish-utility maximization [1,2].

Because the ultimatum game task has often been utilized for examining the neural basis of fair decision-making and inequity aversion, I now briefly explain the procedure of the ultimatum game. Suppose that there are subject A (a proposer) and B (a responder). The subject A proposes how to divide a sum ( $=X$ ) of money with the subject B. If subject B rejects the proposed division, both subjects A and B obtain nothing. If the subject B accepts the proposal by subject A, subject A obtains one's demand  $X_A$  and subject B receives the rest; i.e., subject B's gain  $X_B=X-X_A$ . It is to be noted that a fair division is  $(X_A, X_B)=(0.5X, 0.5X)$ , and an unfair offer/proposal corresponds to  $X_A > X_B$ . When playing the role of the responder (subject B), People often reject the unfair proposal at the cost of  $X_B$ , which has been referred to as "inequity aversion", because after rejection, there is no inequity, although the responder cannot get anything. Neuroeconomic studies on the ultimatum game, employing monetary payoffs, demonstrated that when a subject B reject an unfair offer in the ultimatum game, the insula, a neural circuit for disgust, activated [1].

In neuroeconomic studies of intertemporal choice, it is known that there is a "domain effect"; namely, people's discount rates differ between money, primary rewards, and addictive substances. Specifically, in intertemporal choice, smokers (and heroin addicts) discount delayed cigarettes (and heroin) more steeply than delayed monetary gain [4]. This finding is important for elucidating neural processes underlying reinforcement learning of addictive substance. However, to date, no study examined the "domain effect" in the ultimatum game, although this examination is also important for understanding the conflict between inequity-induced and cue-induced craving-related negative affects in drug addicts in the ultimatum game. Notably, cue-triggered craving also activates the insula in the brain, even in the absence of withdrawal [5]. In this study, we therefore investigated the difference in the minimum amount of reinforcers at which the responder accepted the proposal between money and cigarettes in habitual smokers (nicotine addicts). The present study may help understand the interactions and conflicts between reward processing neural processing, inequity-aversion-related insula activation, and craving-related insula activation.

## Methods

### *Participants*

A total of 21 male habitual smokers (age:  $23 \pm 2.1$ ) who smoke  $25 \pm 3.5$  cigarettes per day participated in the present study. Participants with neuropsychiatric or neuroendocrine diseases were not included in the study.

### *The Ultimatum game (UG)*

In order to assess participants' degrees of inequity aversion in game-theoretic social interactions, we conducted the ultimatum game task with hypothetical money (a non-addictive reinforcer) and cigarettes (an addictive reinforcer). All participants played roles of the "responders" in the ultimatum game. Namely, they were instructed as (in Japanese): [Suppose that someone (who is a complete stranger to you and you will never meet him again) has proposed the manner of distributing a total of ¥300 (or one pack of cigarettes) between him and you. If you reject his proposal, both he and you will obtain nothing. Please answer whether you will accept his proposal or not, in the following each proposal. Although this task is not about real money (cigarettes), please suppose as if the decision is about real outcomes]. It is important to note that ¥300 is approximately equivalent to US\$ 3 and one pack of cigarettes (=20 cigarettes) typically costs ¥300 in Japan. The proposal list for the UG task of money consisted of (your money, his money)= (¥25, ¥275), (¥50, ¥250), (¥75, ¥225), ... (¥275, ¥25); while for the UG task of cigarettes consisted of (your cigarettes, his cigarettes)=(1,19), (2,18), (3,17), ... (19,1). The participant marked either "accept" or "reject" for the each proposal in the list. The proposal lists were present in both descending and ascending orders (in terms of the responder's gain) and a subject's *minimal amount for acceptance* (MAA) was defined as the average of minimal amounts of money (cigarettes) at which proposal was accepted in both ascending and descending order conditions. Subject's rejection indicates that he wants to avoid inequity in the distribution of money (cigarettes) at the cost of obtaining money (cigarettes). Therefore, larger MAA indicates higher degrees of inequity aversion. By comparing MAAs between money and cigarettes within a participant, we can assess the difference in the degrees of aversion to inequity regarding money and cigarettes.

### *Statistical analysis*

MAA for cigarettes was calculated in terms of Japanese yen, for comparison with MAA for money (Japanese yen). Namely, one cigarettes was supposed to be

equivalent to  $300/20=¥15$ . All statistical procedures were conducted with R statistical language. Data are expressed as mean  $\pm$  SEM. Significance level was set at 0.05 throughout.

## Results

MAAs for money and cigarettes were  $¥91.7\pm 7.1$  and  $¥41.3\pm 8.2$  (i.e.,  $2.75\pm 8.2$  cigarettes, because one cigarette costs  $¥15$ ) for the UG of money and cigarettes, respectively. Then we conducted a  $t$ -test between MAAs for money and cigarettes. Consequently, we observed that there was a significant difference between MAAs for money and cigarettes ( $t=4.98$ ,  $p=5.7\times 10^{-5}<0.05$ ), indicating that the smoker participants had higher degrees of inequity aversion for money in comparison to cigarettes. There was no significant correlation between the subjects' number of cigarettes smoked per day and MAAs for money and cigarettes ( $p>0.05$ ).

## Discussion

This study is the first to report that inequity aversion for an addictive substance (nicotine) is weaker than that for money. As noted earlier, neuroeconomic studies reported that when the proposal in the UG is unfair, the responder subject's insula is activated (feeling disgust) and the responder may try to reduce insula activation (disgust) by rejecting the proposal [1]. Furthermore, neuroimaging studies reported that a cigarette-cue exposure also induces the insula activation. Therefore, when the smokers were presented with unfair offers in the UG with cigarettes, their insula activations may be due to both inequity in the proposal and cue-induced craving. Even if a smoker rejects the unfair offer in order to reduce the inequity-induced insula activation, the craving-induced insula activation may remain, resulting in the reduced rejection (as indicated by small MAAs for cigarettes). The conflict here is between inequity-induced and craving-induced activations in the insula (note that this conflict does not exist in the UG with money). Actually, a recent brain lesion study reported that disruption of the insula eliminated nicotine addiction [6]. These present interpretations should be examined with future neuroimaging studies on the UG with addictive substances.

### *Limitation and future directions*

In this study, we only employed male smoker subjects. Because there may possibly be gender differences in inequity aversion in strategic social interactions, future studies should employ females. Also, because our present study utilized hypothetical money, real money should further be utilized in future studies on the distinction between

non-addictive and addictive reinforcers. Moreover, we did not assess personality scales (measures of trait characteristics) related to reward dependency. Future behavioral game-theoretic studies on inequity aversion should examine the role of reward dependency in inequity aversion for addictive substances. Furthermore, it has been reported that amylase, testosterone and cortisol are associated with self-control in economic decision-making and negative emotion induced by social interactions [7,8,9], future studies should examine the roles of neuroendocrinological substrates in the smokers' economic decision-making in the ultimatum game.

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