Alcohol use and discounting of delayed and probabilistic gain and loss

Taiki Takahashi , Yu Ohmura, Hidemi Oono, Mark Radford
Department of Behavioral Science, Hokkaido University, Sapporo, Japan

Correspondence to: Taiki Takahashi,
Department of Behavioral Science, Hokkaido University
N.10, W.7, Kita-ku, Sapporo, 060-0810, Japan.
TEL: +81-11-706-3057; FAX: +81-11-706-3066; E-MAIL: taikitakahashi@gmail.com

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Abstract

OBJECTIVE: Little is known about the relationship between alcohol and discounting of loss, one of procrastinative behaviors. This study examined the relationship between the frequency of alcohol use and discounting delayed and probabilistic gain and loss, which is of interest in neuroeconomics of addiction.
METHODS: Thirty-three subjects conducted tasks of delay and probability discounting of gain and loss. Their alcohol use was also assessed.
RESULTS: The frequency of alcohol use was significantly correlated with the degree to which delayed monetary losses were discounted.
CONCLUSIONS: Frequent use of alcohol may associate with an increased degree of procrastination. Further, the degrees of delay discounting of loss could be a predictor of a frequent alcohol intake.

INTRODUCTION

Humans and animals generally discount the value of delayed and uncertain outcomes (e.g., Green *et al.,* 1999; Mobini *et al.,* 2002). These tendencies are called "delay discounting" and "probability discounting", respectively. Delay/probability discounting is thought to be a form of impulsivity and to be closely related to our daily life, monetary saving (Frederick *et al.,* 2002), school study (Jaroni, Wright, Lerman, & Epstein, 2004), gambling (Holt *et al.,* 2003), and dependence on legal drugs such as nicotine and alcohol (Reynolds, 2006, for a review), etc. Moreover, some studies have indicated the causal effects of legal addictive drugs on discounting behavior (Bickel *et al.,* 1999; Petry, 2001; Dallery & Locey, 2005), while one study demonstrated that the degree of delay discounting could be a predictor of alcohol dependence in mice (Mitchell *et al.,* 2006).

While most previous studies have focused on delay discounting of gain, decision making regarding loss is also closely related to daily decision making. Given that the number of personal bankruptcy is increasing in Japan (General Secretariat, Supreme court, 2005), and that decision-making regarding loss is often critical for humans, as it often difficult to recover losses (e.g., debts, health, life, friends, lovers), examining the relationship between drugs and discounting of loss is also important. It should be noted that one cannot simply extrapolate the relationship between addictive drugs and discounting of loss from the results regarding discounting of gain because several studies have shown that there is gain-loss asymmetry in discounting behavior (Baker *et al.,* 2003) and that distinct brain regions are activated in response to monetary gains and losses (Knutson *et al.,* 2000; Breiter *et al.,* 2001). Furthermore, a recent neuroimaging study reported that discounting future losses and gains occurs asymmetrically in the brain (Xu *et al.,* 2009). Indeed, our previous study found

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significant correlation between smoking and discounting of gain, but not loss in mild smokers (Ohmura *et al.,* 2005). It is important to note that greater discounting of delayed loss indicates a higher degree of unwillingness to pay costs immediately, even if delaying the costs could result in larger loss in the future; while greater discounting of gain indicates a higher degree of willingness to consume a reward immediately. In other words, rapid discounting of loss indicates a high degree of procrastination; while rapid discounting of gain indicates a high degree of impulsivity in intertemporal choice.

Therefore, we examined whether the frequency of alcohol use is correlated with delay/probability discounting of loss as well as gain. In this study, we focused on never smokers to exclude confounding factors because several studies have demonstrated that discounting behavior is associated with smoking behavior (e.g., Bickel *et al.,* 1999; Ohmura *et al.,* 2005).

METHOD

Participants

Participants were 33 never smokers, and they were recruited through advertisements posted on bulletin boards at Hokkaido University in Sapporo, Japan. Participants' demographic data is summarized in Table 1. They signed an informed consent form before participating, and received 1 000 yen (about US $10) following completion of the experiment.

Procedure

Participants were required to select one of two cards repeatedly displayed on their computer monitor. In the delay-discounting task, the left card indicated the sum of hypothetical money (from 100 000 to 5 000 yen in 5 000 yen increments) that could be received immediately, whereas the right card always indicated 100 000 yen (about US $1 000) that could be received after a certain delay (1 week, 1 month, 6 months, 1 year, and 5 years). In the probability-discounting task, the delay was replaced by probability (90%, 70%, 50%, 30%, and 10%). In the loss-frame task, the sum of hypothetical money ranged from –100 000 to –5 000 yen. These changes are designed to determine the point at which the participant switches his or her preference from the left card (right card) to the right card (left card). The switching point (indifference point) was used to calculate the value of the discounting measures. The algorithm employed in this study is based on a previous study (Richards *et al.,* 1999). This procedure can prevent unreliable responses of participants (for more details, see Richards *et al.,* 1999).

Following the computer task, all participants were asked to answer how frequently (every day = 4, four–six times per week = 3, one–three times per week = 2, once or twice per month/occasionally = 1, rarely/never = 0) they drink alcohol. The entire experimental procedure took between 30 and 60 minutes to complete.

Data Analysis

To determine the degree to which each subject discounted delayed and uncertain monetary gains and losses, we calculated the Area Under the Curve (AUC: Myerson, Green, & Warusawitharana, 2001) for each of the four discounting tasks. The value of AUC is the area under a line graph made by plotting indifference points when normalizing the horizontal axis (delay or odds-against=1/probability–1) and the vertical axis (subjective value) (for the detail of calculation procedure, see Myerson *et al.,* 2001). Smaller AUC values indicate more dramatic discounting. AUCs do not depend on a fitting function, there is no data loss and equation type-dependent systematic errors that might result from a poor fit. Given that the purpose of the present examination was to investigate the relationship between discounting behavior and the frequency of alcohol use rather than to determine the best discounting function to fit the data, AUCs appear to be an appropriate measure.

Additionally, we fitted hyperbolic discounting functions (Mazur, 1987) to the indifference points at each level of delay and probability to confirm data quality in the present study. The hyperbolic function was defined as:

$$V = A/(1+kD),$$

where V is the subjective value of a reward, A is the (objective) amount of the reward (the monetary gain or loss), k is a free parameter and an index of the steepness of the discounting function, and D is the length of the delay (in delay discounting) or the odds-against (odds-against=1/probability–1, in probability discounting).

To test statistical significance of correlation, Spearman's correlation analysis was conducted. Alpha level was set at 5% throughout.

Tab. 1. Mean and standard deviations for demographic variables and drug use.

	Never smokers	
	M	**SD**
Sex (% men)	69.70	
Age (years)	23.81	5.53
Education (% graduate)	36.36	
Frequency of alcohol use	1.33	1.02

Note. Frequency of alcohol use (every day = 4, four-six times per week = 3, one-three times per week = 2, once or twice per month/occasionally = 1, rarely/never = 0)

RESULTS

The frequency of alcohol use was significantly negatively correlated with the AUCs for delay discounting of loss (ρ =–.36, p<0.05, see Figure 1). That is, the more frequently participants used alcohol, the more strongly they discounted delayed monetary losses. On the other hand, the frequency of alcohol use was not signifi-

cantly correlated with the AUCs for delay/probability discounting of gain (delay: ρ=–.28, p=0.11; probability: ρ=.29, p=0.10) and probability discounting of loss (ρ=–.31, p=0.08).

When we fitted the hyperbolic function to the data, the medians of R-square values in this sample (delay discounting of gain: .88; delay discounting of loss: .95; probability discounting of gain: .90; probability discounting of loss: .88) were similar to values reported in previous research (e.g., Bickel *et al.,* 1999; Richards *et al.,* 1999), indicating that the present subjects discounted delayed and probabilistic outcomes in a manner as systematically as those in previous studies. This confirms the quality of the present data.

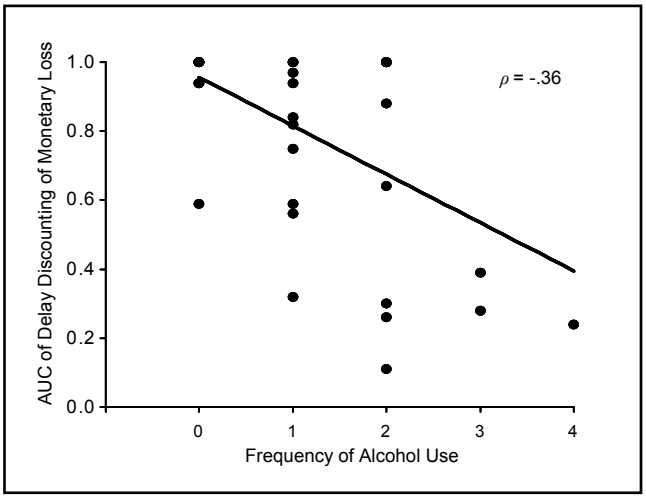

Fig. 1. Scatterplot of the frequency of alcohol use and the AUC for delay discounting of monetary loss in never smokers. A significant negative correlation was observed (N=33, p<0.05). Note that a smaller AUC indicates a higher degree of discounting.

DISCUSSION

Frequency of Alcohol Use and Discounting of Loss

In the present study, delay discounting of loss was significantly correlated with the frequency of alcohol use, indicating that heavier alcohol use is associated with greater discounting of loss. This study is the first investigation into the relationship between alcohol intake and discounting delayed and probabilistic losses in mild drinkers (non-alcoholics). Our results indicate that heavy drinkers may more dramatically procrastinate when they have a problem, in comparison to light drinkers. There are at least two possible interpretations for this correlation between the frequency of alcohol use and the degree of discounting:

(1) neuroadaptation caused by regular alcohol use (for a review see Fadda & Rossetti, 1998) increases the degrees of delay discounting of loss; and
(2) people who strongly discount delayed losses tend to drink more.

In fact, one study demonstrated that the degree of delay discounting could be a predictor of alcohol dependence in mice (Mitchell *et al.,* 2006), though Mitchell *et al.*, used only discounting of gain. Although further studies are required to clarify which interpretation is more likely, the latter may be more plausible because the frequency of subjects' alcohol use in the present study was relatively low (Table 1).

Frequency of Alcohol Use and Discounting of Gain

In the present study, the frequency of alcohol use were not significantly correlated with the AUCs for delay/probability discounting of gain and probability discounting of loss whereas several studies have shown the relationship between delay discounting of gain and alcohol use (e.g., Vuchinich & Simpson, 1998; Petry, 2001). This inconsistency may due to the characteristics of present subjects: subjects in the present study were relatively light drinkers compared to those who have participated in previous studies (e.g., Vuchinich & Simpson, 1998; Petry, 2001).

Limitation and Future Direction

Since the present study employed hypothetical money, we cannot be entirely sure that the same results would be obtained if discounting real money was used. Nevertheless, our results probably reflect the degree to which real money is discounted because

(a) discounting both hypothetical and real money follows a hyperbolic function (e.g., Kirby, *et al.,* 1999; Green *et al.,* 1999),
(b) previous studies have not observed a significant difference in the degree of discounting hypothetical money versus real money in a delay discounting task (Johnson & Bickel, 2002; Madden *et al.,* 2004), and
(c) the degree of discounting hypothetical and real money has been demonstrated to correlate significantly (Johnson & Bickel, 2002).

Another possible area of concern is that we asked subjects about the frequency of alcohol use, but to what degree the frequency of alcohol u se reflects the amount of alcohol reaching receptors affected by alcohol, such as GABA and glutamate receptors, is unknown. Although self-report measures regarding alcohol may be reliable and valid (for detailed reviews see Brener *et al.,* 2003; Del Boca & Darkes, 2003), future studies will need to utilize biological markers to control for the individual difference of metabolic function in the liver or to conduct animal studies to control for the amount of alcohol reaching the brain.

Despite these limitations, this study indicated that the parameter of discounting of loss could be one predictor of frequency of alcohol use. Further studies are required to examine whether discounting of loss is associated with vulnerability to alcoholism.

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