Two-month stability of hyperbolic discount rates for delayed monetary gains in abstinent inpatient alcoholics

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Abstract

OBJECTIVES: Alcohol dependence has been associated with disrupted neuroendocrine systems, impulsivity in intertemporal choice (delay discounting). However, little is known regarding stability of discount rates in alcoholics. This study examined both differential stability (stability of individual differences) and absolute stability (stability of group mean) of hyperbolic discount rates for monetary gains in severe alcoholic inpatients (diagnosed with DSM-IV) over a 2-month period during abstinence.

METHODS: We estimated male alcoholics' discount rates for delayed monetary rewards on the basis of their pattern of choices between smaller immediate rewards (1,100–8,000 yen) and larger, delayed rewards (2,500–8,500 yen; at delays from 1 week to 6 months), two times at 2-month time-interval during hospitalized alcohol withdrawal.

RESULTS: It was observed that the alcoholics' mean hyperbolic discount rates for gains had both differential and absolute stability over 2 months, although a slight non-significant decrease in the group mean of the discount rates was observed.

CONCLUSIONS: The results indicate that abstinent alcoholic's discount rates are stable over a relatively long-term period. The usefulness of assessing discount rates of addicts in psychoneuroendocrinology and neuroeconomics of addiction is discussed.

ORIGINAL ARTICLE

INTRODUCTION

Impulsivity in intertemporal choice (delay discounting) is a core deficit in neuropsychiatric/neuroendocrinological illnesses such as drug-dependence, attention-deficit-hyperactivity disorders (ADHD), pathlogical gambling, and psychopathy [5,9,28]. Becker and Murphy's economic theory on addictive behavior predicts drug addicts may have stronger delay discounting in comparison to non-drug-using controls [4], In the nascent field of neuroeconomics [11], several neuroscientists and economists have collaborated to reveal neurobiological substrates mediating economic decision-making, including those governing discounting delayed rewards. For instance, we have reported low cortisol levels, i.e., hypoactivity of hypothalamic-pituitary-adrenal (HPA) axis, and severity of nicotine dependence are associated with strong discounting of delayed monetary gains [19,25]. The volumes of reward-processing brain regions have been reported to be reduced in alcoholics [24]. Regarding the relationship between discounting and regular alcohol intake, several studies demonstrate that alcoholics and heavy problematic drinkers have higher discount rates than light or non-alcohol drinkers [16,22,27].

Some studies suggest that subjects' discount rates may be changeable, and drug intake/abstinence may be associated with changes in discount rates. Several studies compared discount rates in current versus former drug-dependent individuals. Petry (2001) found that currently drinking alcoholics had higher discount rates for hypothetical money and alcohol than currently abstinent alcoholics [22]. Bickel *et al.* (1999) reported that current cigarette smokers had higher discount rates for delayed monetary gains than ex-cigarette smokers [6], and the health economist Bretteville-Jensen's economic analysis of addiction (1999) demonstrated that current injecting substance misusers had higher discount rates than former injectors [7]. Moreover, Giordano *et al.* (2002) reported that a mild opioid deprivation increased discount rates in heroin addicts [10], and Richards *et al.* (1999) and Ortner *et al.* (2003) observed that healthy subjects with acute alcohol intake discounted delayed rewards at smaller rates than sober subjects [21,23]. Therefore, it is of great importance to examine the stability of discount rate in alcoholics during alcohol withdrawal over a relatively longer period, in order to establish more effective behavioral/pharmacological treatment of alcohol dependence and associated impulsive behavior. It is noteworthy that we have already reported the stability of hyperbolic delay discount rates over a 3-month period in healthy non-drug using subjects [20], which may help the interpretation of stability of discount rates in drug addicts during withdrawal.

Our present study was aimed to examine the stability of alcoholic inpatients' discount rates for delayed monetary rewards of different magnitudes over a 2-month period during hospitalized alcohol withdrawal. Because stability of behavioral measures/personality scales such as discount rate consists of two components, i.e., differential stability (stability of individual differences) and absolute stability (stability of the group mean) [8,20], we examined both types of stability of alcoholics' discount rates in the present study. Additionally, we examined effect of reward magnitudes on the inpatient alcoholic's discount rates because previous studies on delay discounting have reported that larger rewards are more slowly discounted than smaller ones [5,13,14,15]. Determination of discount rates for distinct reward sized may help estimate at which reward size subject's intertemporal choice is impulsive. In the present study, we strictly evaluated DSM-IV to diagnose inpatients' alcohol dependence at National Kurihama Alcoholism Center (Japan). The present examination may help predict and prevent relapse into alcoholism before the onset and establish effective treatment for alcoholism.

METHOD

Subjects

A total of 33 male alcoholic inpatients (average age: 52) under hospitalized alcohol abstinence at Kurihama Alcoholism Center (the largest national organization for study and clinical treatment of alcoholism in Japan, and certified as a qualified alcoholism research center by WHO) participated in the present longitudinal study. We used a structured clinical interview from the DSM-IV to diagnose alcohol dependence [2]. It should also be noted that we have significant experience in diagnosis and cognitive-behavioral therapy of alcoholics and published a number of neurocognitive/genetic studies of various types of alcoholism [12,17]. The participants answered Kirby's questionnaire [15] for the assessment of their discount rates of delayed gains at the time-interval of 2-month. The first assessment was conducted one-month after hospital admission (Time 1) and the second was at the day of hospital discharge (Time 2), i.e., after a 3-month complete alcohol withdrawal under hospitalization. The reason why one-month after hospital admission was selected as Time 1 is that most alcoholic patients are usually suffering from severe physical withdrawal symptoms before the time-point (one-month after hospital admission). All participants signed an informed consent form. This study was approved by the ethical committee on the use of human subjects at Kurihama Alcoholism Center.

MATERIALS

Kirby's MCQ (monetary choice questionnaire)

We adopted exactly the same procedure for assessing subject's discount rates as previous neuroendocrinological and neuroimaging studies of intertemporal choice [18,26]. Studies in neuropsychopharmacology, psychoneuroendocrinology, and behavioral neuroeconomics have repeatedly observed that human and animal subject's delay discounting is well described by the hyperbolic discount function [1,5,18,26]:

$$V(D)=1/(1+kD) \quad \text{(equation 1)}$$

where V(D) is a subjective value of delayed rewards at delay time D, and k (a hyperbolic discount rate) is a free parameter indicating subject's impulsivity in intertemporal choice (larger k values correspond to more rapid/steeper discounting; while smaller k values indicate self-control in intertemporal choice). In order to assess subject's discount rate k, as defined in equation 1, Kirby's MCQ [13,15] was used. Kirby's MCQ consists of 27 questions relating to a choice between smaller immediate rewards and larger but delayed rewards (e.g. "Would you prefer 54 dollars today or 55 dollars in 117 days?"). According to the standard analysis procedure of MCQ, established by Kirby and colleagues [13,15], we calculated subjects' discounting rates (i.e. ks) of three different sizes (small, medium, and large) of monetary gains. A total of three discount rates (i.e., small, medium, and large gains) were obtained for each subject. Geometric-mean discounting rates for different sizes were calculated, following Kirby's procedure [13,15]. We then examined relationships between the hyperbolic discount rates of gains and sAA levels. In our Kirby MCQ form, all gains were expressed in terms of Japanese yen, with an exchange rate of one dollar to 100 yen. Because the distribution of the discount rate k is known to be skewed, we used logged k in the following analysis, according to a standard analytical procedure [13,15].

Data analysis and statistical procedure

After the geometric mean of logged discount rates of gains was calculated for each participant, according to a standard procedure in examination of stability of behavioral measure, we then conducted paired t-tests for examining absolute stability (stability of the group mean) between hyperbolic discount rates at Time 1 and Time 2, and Pearson's product-moment correlation analysis for examining differential stability (stability of individual differences). Note that the absence of significant difference in the t-test indicates absolute stability, while the presence of significant correlation in the Pearson's analysis indicates differential stability [8,20]. For the examination of the magnitude effect, we compared the group means of discount rates for each reward size, by utilizing t-tests, according to a standard procedure [13,15]. Data are expressed in terms of Mean ± SD. Significance level is set at 0.05 throughout.

RESULTS

Characteristics of discount rates for delayed monetary gains in abstinent alcoholic inpatients

The group mean of the logged hyperbolic discount rates (k in equation 1), estimated with Kirby's standard procedure, at Time 1 and Time 2 are presented in Table 1. The present observed discount rates were within a range similar to the values previously reported in drug addicts such as heroin abusers and cocaine addicts, and alcoholics by employing Kirby's MCQ method [13,15].

Table 1. Hyperbolic discount rates at Time 1 and Time 2.

	Time 1	Time 2	t-value	p-value
k (mean)	0.0337 (s.d. 0.059)	0.0284 (s.d. 0.059)	1.043	0.152
k (small gain)	0.0446 (s.d. 0.065)	0.0357 (s.d. 0.063)	1.465	0.071
k (medium gain)	0.0384 (s.d. 0.066)	0.0313 (s.d. 0.060)	1.002	0.162
k (large gain)	0.0321 (s.d. 0.060)	0.0247 (s.d. 0.059)	0.531	0.299

Although all discount rates at Time 2 are smaller than Time 1 and decrease in hyperbolic discount rate for small rewards tended towards significance ($p<0.1$), no significant difference between Time 1 and Time 2 in the group means of logged discount rate for mean, and each reward size (small, medium and large reward) was observed. The t-statistic parameters are calculated for logged hyperbolic k. and p-values were one-tailed.

Stability of group mean of discount rate (absolute stability)

As shown in Table 1, all the group means of the discount rates for delayed monetary gains (impulsivity in intertemporal choice on gains) were smaller at Time 2 than Time 1. This raises the possibility that alcoholic inpatients' discount rates were statistically significantly reduced during a 2-month withdrawal under hospitalization. In order to test this possibility, we examined the absolute stability of the hyperbolic discount rates. Paired t-tests revealed that although decrease in hyperbolic discount rate for small rewards tended towards significance ($p<0.1$), there were no statistically significant differences in the discount rates for small, medium, or large rewards, nor for the mean discount rate for the three reward magnitudes at Time 1 and Time 2 (Table 1); in other words, discount rate had absolute stability (stability of the group mean) over two months in the abstinent alcoholic inpatients, implying that impulsivity of the abstinent alcoholics in intertemporal choice on gains did not significantly increase or decrease by the 2-month complete alcohol withdrawal.

Stability of individual differences in delay discount rate (differential stability)

The existence of absolute stability of the discount rates does not necessarily imply that individual differences in discount rates are unchanged and conserved over the 2-months alcohol abstinence [8]. To examine the stability of individual differences in discount rates, we further tested whether the mean discount rates for the three reward magnitudes (i.e., a single rate estimate for each participant, as noted earlier) at Time 1 and Time 2 were significantly correlated or not. Pearson's correlation analysis found a significant positive correlation ($r=0.37$) between the means of the logged discount rates (for the three reward magnitudes) at Time 1 and Time 2 (Figure 1); in other words, the mean hyperbolic discount

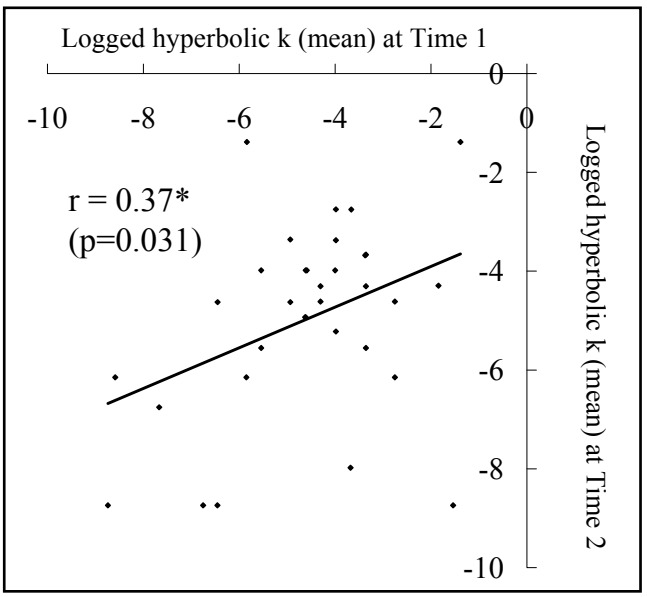

Figure 1. Scatterplot of mean logged hyperbolic discount rate (a single rate estimate for each participant) at Time 1 and Time 2. A significant positive correlation was observed (N=33, p<0.05), implying that mean hyperbolic discount rate has differential stability over 2 months in abstinent alcoholics.

rate has differential stability (stability of individual differences) over two months in the abstinent alcoholic inpatients, implying that the 2-month alcohol withdrawal did not significantly change individual differences in the mean discount rate (a single parameter estimate of impulsivity for each participant) which existed at Time 1 in the present subjects.

In order to examine for which reward size the discount rate has differential stability, we conducted Pearson's correlation analysis for logged hyperbolic discount rates for each reward size, separately. Pearson's correlation analysis revealed that hyperbolic discount rates for small rewards at Time 1 and Time 2 were significantly correlated (Figure 2 A), but none of the hyperbolic discount rates for medium and large reward sizes at Time 1 and Time 2 was significantly correlated (Figure 2 B and C); that is, hyperbolic discount rate for small rewards had significant differential stability, while hyperbolic discount rates for medium and large reward sizes did not have significant differential stability, over two months in the abstinent alcoholic inpatients.

Magnitude effect on hyperbolic discount rates

We further examined the magnitude effect on discount rates by utilizing t-tests for the logged hyperbolic discount rates between the three different reward sizes (small, medium and large), following standard analysis procedure [13,15]. The group means of logged hyperbolic discount rates were significantly smaller for larger reward sizes, at both Time 1 and Time 2 (Figure 3, p<0.01), indicating that alcoholic inpatients in the present study had significant magnitude effect in delay discounting, as

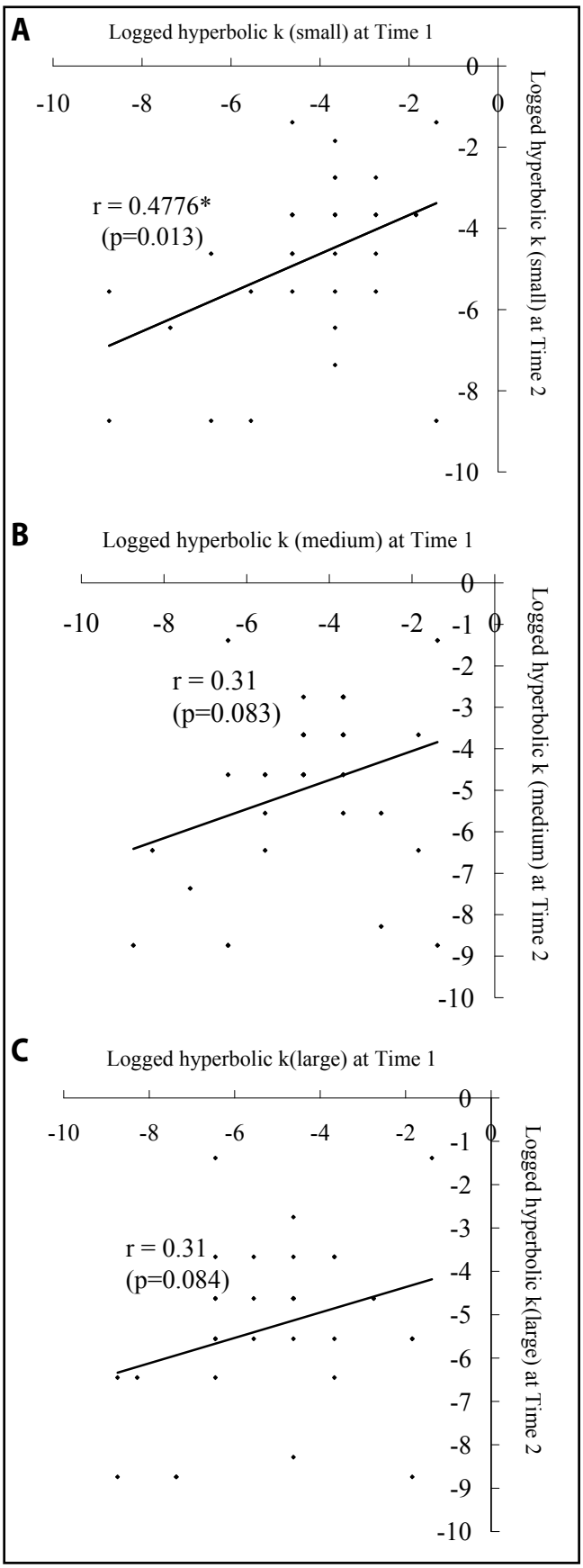

Figure 2. Scatterplots of logged hyperbolic discount rate for small (**A**), medium (**B**), and large (**C**) rewards at Time 1 and Time 2. Significant positive correlation was observed only in discount rates for small rewards at Time 1 and Time 2 (N=33, p<0.05).

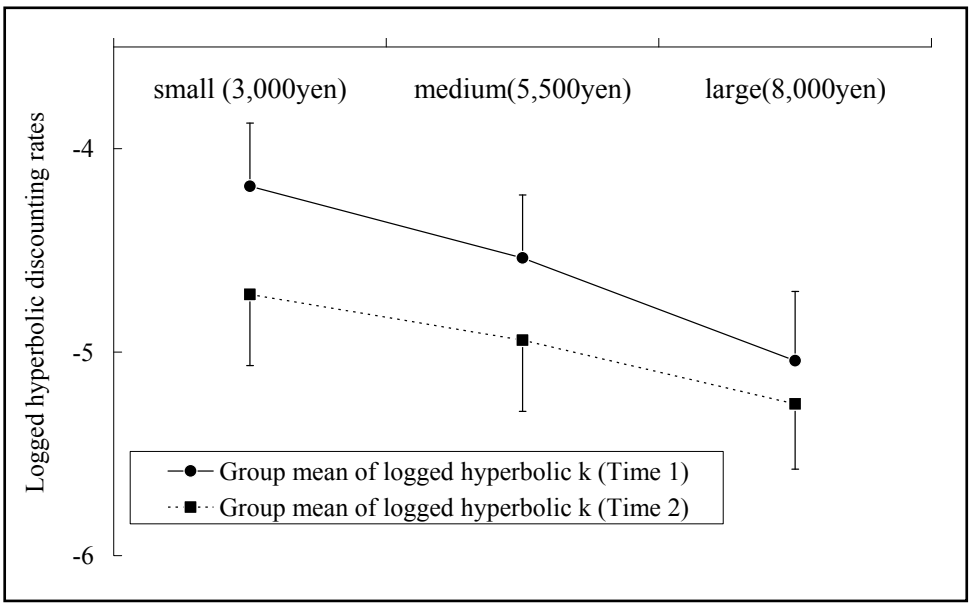

Figure 3. Magnitude effect on delay discounting in abstinent alcoholic inpatients at Time 1 and Time 2. Significant effects of reward sizes were observed at both Time 1 and Time 2. Smaller gains were more steeply discounted than larger rewards by abstinent alcoholics.

previous studies observed in drug addicts (e.g., nicotine, heroin, cocaine, and alcohol addicts) and non-drug-using controls [5,13,15], in spite of the exaggerated severity (in terms of large discount rates, as noted above) of alcohol dependence in the present subjects. As can be seen from Figure 3, two-month alcohol abstinence-induced decrease in discount rate was the largest for small rewards, although this effect was not statistically significant.

DISCUSSION

This is the first longitudinal within-subject investigation into the stability of hyperbolic discount rates for delayed small, medium, and large monetary rewards (and the means of discount rates for the three reward magnitudes as well) in inpatient alcoholics (diagnosed with DSM-IV) over a 2-month period under hospitalized abstinence. Our present results suggest three general conclusions. First, hyperbolic discount rates for gains have absolute stability over a two-month hospitalized abstinence in inpatient alcoholics; in other words, the group means of hyperbolic discount rates for delayed monetary gains (impulsivity in intertemporal choice) is not significantly changed by the two-month alcohol abstinence. Secondly, mean hyperbolic discount rate (a single rate estimate for each participant) have differential stability over a two-month hospitalized abstinence in inpatient alcoholics; in other words, individual differences existing in impulsivity in intertemporal choice is unchanged by a two-month hospitalized abstinence in inpatient alcoholics. This differential stability in mean discount rates is due to the strong differential stability of delay discount rate for small rewards (Figure 2A). Thirdly, the magnitude effect on discount rates stably exists in abstinent alcoholics during a two-month hospitalization. Because discount rates in our present study was assessed with a Kirby's questionnaire with hypothetical money, which requires relatively short time to conduct, our findings may readily be compared to discounting by drug dependents with more severe cognitive impairment such as older aged alcoholics, and heroin and cocaine abusers in future studies.

We have previously observed that healthy non-drug-using subjects' discounting measures (delay and probability discount rates) have both absolute stability (stability of the group mean) and differential stability (stability of individual differences) [8] over a three-month time-duration, indicating that discount rates are relatively unchangeable in the absence of the onset of substance misuse or abstinence from addictive drugs [20]. Our present data indicate that abstinent alcoholics' discount rates are stable over a two-month period, even under a hospitalized complete abstinence from alcohol. This indicates that the assessment of alcoholics' discount rate at the initial phase of their abstinence period (e.g. a period during the several weeks immediately following the onset of abstinence) may be able to predict their possibility of both success in recovery from alcoholism and relapse into alcoholism after relatively long-term abstinence (e.g. several months).

Limitation and future directions

Several studies suggested that disrupted neuroendocrine systems (e.g., hypoactivity of the HPA axis) are associated with addiction such as alcoholism [3]. Consistent with this report, low cortisol levels have been shown to associate with impulsive intertemporal choice in humans [25]. Therefore, future studies should examine the relationship between cortisol levels and discounting by addicts over several months in order to examine the role of the HPA system in addiction and recovery from drug-dependence. Because our current subjects

were middle age males, future investigations should examine whether the present results can be generalized into younger alcoholics. Another future direction is an investigation into longer-term (e.g. several years) lifetime changes in drug addicts' discount rates associated with subjects' time of initiation and history of substance misuse and abstinence (medically guided or non-medically guided) and relapse.

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