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ScienceDirect
Drug and Alcohol Dependence 87 (2007) 94–97
DRUG and ALCOHOL DEPENDENCE
www.elsevier.com/locate/drugalcdep

Short communication

The relationship between temporal discounting and the prisoner's dilemma game in intranasal abusers of prescription opioids

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Received 10 April 2006; received in revised form 11 July 2006; accepted 13 July 2006

Abstract

Previous research on college students has found that cooperation in iterated prisoner's dilemma game is correlated with preference for delayed rewards in studies of temporal discounting. The present study attempted to replicate this finding in a drug-dependent population. Thirty-one individuals who intranasally abuse prescription opioids participated in temporal discounting and iterated prisoner's dilemma game procedures during intake for a treatment study. Rate of temporal discounting was determined for each participant at two hypothetical reward magnitudes, as well as proportion of cooperation in a 60-trial iterated prisoner's dilemma game versus a tit-for-tat strategy. Cooperation in the prisoner's dilemma game and temporal discounting rates were significantly correlated in the predicted direction: individuals who preferred delayed rewards in the temporal discounting task were more likely to cooperate in the prisoner's dilemma game.

Keywords: Opioid-dependence; Temporal discounting; Prisoner's dilemma; Self-control

Temporal discounting, considered a component of the impulsiveness construct, refers to the reduction in the present subjective value of an outcome as the delay to that outcome increases. Various drug dependent populations have been found to discount delayed rewards more than non-dependent controls (for a review, see Bickel and Marsch, 2001). Rate of temporal discounting is typically assessed by determining the immediate, subjective equivalent (indifference point) of a reward that is delayed in time. By determining an indifference point at various delays, a discounting rate can be determined using Mazur (1987) hyperbolic model of discounting. In this equation, the discounted value of an outcome (v_{d}) is equal to the ratio of the undiscounted value (V) and the quantity one plus delay (d) multiplied by a discounting parameter (k).

$$v_{\mathrm{d}} = \frac{V}{1 + kd} \tag{1}$$

This free parameter (k) provides a measure of the tendency to prefer smaller, immediate rewards to larger, delayed rewards.

Several authors (Ainslie, 1992; Rachlin, 2000) have proposed that preference for small, immediate rewards rather than large, delayed rewards in studies of temporal discounting is similar to defection in social dilemmas. Social dilemmas occur when an individual must choose between selfish and utilitarian outcomes, where "individual rationality leads to collective irrationality" (Kollock, 1998, p. 183). One basic model of a social dilemma is the two-player prisoner's dilemma game (PDG). Fig. 1 is a diagram of the parameters of a typical PDG. The outcome for each player (money outcomes located in cells) is dependent on the combination of his/her choice (cooperation/defection) and the other player's choice (cooperation/defection). Independent of the other player's choice, defection always results in the best outcome for a given player (US$ 25 rather than US$ 20, US$ 10 rather than US$ 5), and the worst outcome for the other player. If both players use this reasoning, the result is mutual defection (US$ 10 for both) rather than mutual cooperation (US$ 20 for both).

In an iterated prisoner's dilemma game (IPG), this standard PDG is repeated over a number of trials with the same pair of participants. If player B applies a tit-for-tat (TFT) strategy in an IPG, the optimal strategy for player A would be to cooperate on all trials. Cooperation by player A in trial 1 would be

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0376-8716/$ – see front matter
doi:10.1016/j.drugalcdep.2006.07.007

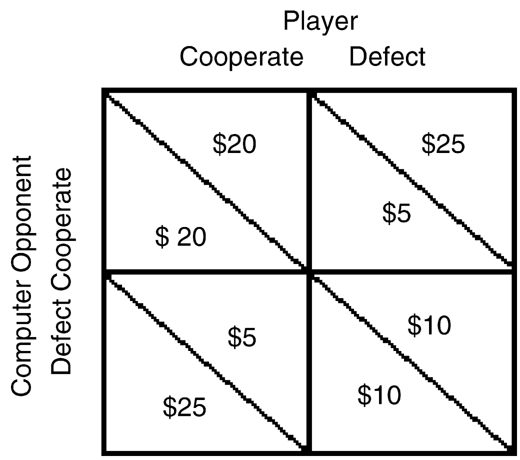

Fig. 1. Choice alternatives (axes) and outcomes (cells) for a prisoner's dilemma game.

reciprocated with cooperation by player B (applying the TFT strategy) in trial 2, and so on. Given that a player applying TFT reciprocates the other player's choice from the previous trial, exclusive cooperation by player A would guarantee cooperation by player B (thereby maximizing total outcome for player A as well as player B); cooperating on trial N would leave player A with the best alternatives (US$ 25 or US$ 20 in Fig. 1) in trial $N+1$ while a defection on trial N would result in a higher outcome for that trial (US$ 25 instead of US$ 20, US$ 10 instead of US$ 5) but the worst alternatives (US$ 10 or US$ 5) in trial $N+1$. Exclusive cooperation would result in a mean outcome per trial of US$ 20, exclusive defection would result in a mean of US$ 10, and alternation of cooperation and defection would result in a mean of US$ 15 ((US$ 25 + US$ 5)/2 trials).

Cooperation by a participant when the opponent is playing TFT in IPG is similar to preference for delayed rewards in temporal discounting because both require delay of gratification for a later time. The relationship between these constructs has received empirical support. In a laboratory study of blue jays, Stephen et al. (2002) found that cooperation in an IPG versus TFT increased when the effect of discounting was reduced. This relationship has also been supported in studies of college students (Harris and Madden, 2002; Yi et al., 2005), with rate of discounting negatively correlated with cooperation in IPG versus TFT.

The purpose of the present study was to examine this relationship between preference for immediate rewards in temporal discounting procedures and defection in an IPG versus TFT in intranasal abusers of prescription opioids. We are not aware of any studies that have examined this relationship in a drug-dependent population. The examination of this relationship is particularly important in the study of populations (i.e., drug-dependent) with demonstrated inability to defer gratification. Participants completed temporal discounting and IPG procedures during intake for a buprenorphine treatment study. Like previous findings for non-dependent populations, it was expected that those individuals more likely to prefer smaller, immediate alternatives in the temporal discounting procedure were more likely to defect in the IPG (resulting in a negative relationship), and that this correlation was significant.

1. Method

1.1. Participants

Twenty male and 11 female ($N=31$, mean age = 28.55) treatment-seeking intranasal opioid dependent individuals during intake for a buprenorphine treatment study participated in this study. All participants abused prescription opioids, with six also abusing heroin. Drug-use status was determined using DSM-IV criteria for opioid dependence and confirmed with urinalysis.

1.2. Procedure

A computerized temporal discounting procedure for hypothetical US$ 1000 and US$ 10,000 rewards was employed. This double limit procedure (Richards et al., 1999) determined indifference points at each of eight delays (range: 1 day–25 years). In each trial, two choice alternatives were presented on the monitor. The alternative presented left-of-center was a hypothetical sum of money (based on the programmed algorithm) available immediately. The alternative presented right-of-center was a hypothetical sum of money (US$ 1000 or US$ 10,000 depending on the magnitude condition) available following some specified delay. Participants used a mouse-click to indicate the preferred alternative. The immediately available alternative adjusted from trial to trial until settling in on a single indifference point for each delayed alternative (see Johnson and Bickel, 2002, for a thorough discussion of the algorithm).

A computerized IPG with the parameters outlined in the introduction (Fig. 1) was employed. Participants were told they were playing for hypothetical money versus a computer opponent. In each trial, two choice alternatives were presented left- and right-of-center: cooperation and defection, respectively. After the participant indicated preference with a mouse-click, a feedback screen indicating the participant's choice, the computer's choice, and earnings (for that trial and total) appeared for 10 s. The computer opponent applied a TFT strategy and participants played the IPG for 60 trials.

2. Results

Indifference points from the temporal discounting procedure were fitted to Mazur (1987) model of hyperbolic discounting. Discounting parameter k was determined for each participant at each magnitude. Because the distribution of discounting parameters was positively skewed, natural logarithm data transformations were conducted. The US$ 1000 reward ($\bar{X}=-3.61$) was discounted more than the US$ 10,000 reward ($\bar{X}=-4.59$), consistent with the magnitude effect observed in many studies of temporal discounting, though this difference was not statistically significant ($F(1, 30)=2.30$, $p=.14$). Proportion of cooperation was determined in the IPG for each participant, and the mean of all participants was .69. To examine the possibility of learning over the IPG session, proportion of cooperation was determined separately for the first and last half of the session. The overall proportion of cooperation did not change overtime (.69 and .70 in the first and last half, respectively).

Correlations were conducted between transformed discounting rates and overall proportion of cooperation. Discounting rate and proportion of cooperation were negatively correlated for both the US$ 1000 ($r=-.41$) and US$ 10,000 ($r=-.45$) magnitude conditions, and significant at $p=.05$ (Fig. 2). When the same correlations were conducted with proportions of cooperation from the two halves of the IPG session, correlation

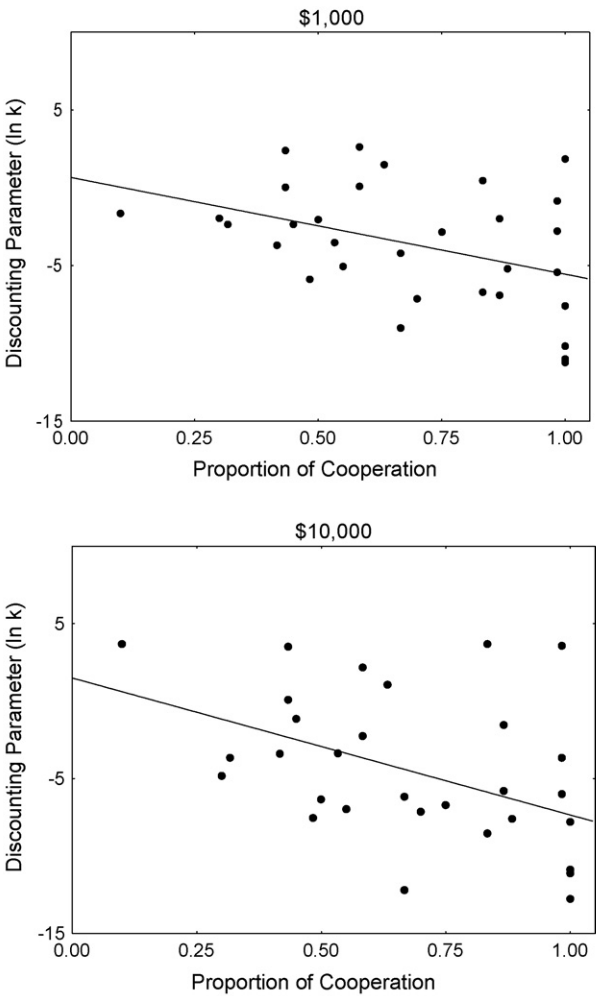

Fig. 2. Scatter plots of natural logarithm-transformed k as a function of proportion of cooperation against TFT, with linear regression lines.

coefficients did change. Specifically, the correlations between discounting rates for the two magnitude conditions and the proportion of cooperation in the first half of the session were high ($r = -.52$ and $-.53$ for US$ 1000 and US$ 10,000, respectively), but decreased in the second half of the session ($r = -.19$ and $-.25$ for US$ 1000 and US$ 10,000, respectively).

3. Discussion

Overall, the relationship between performance in IPG versus TFT and rate of temporal discounting was replicated with intranasal abusers of prescription opioids. The results suggest that even for individuals who abuse opioids, low discounters are more likely to cooperate in an IPG versus TFT while high discounters are less likely to cooperate.

An interesting and novel observation of the present study was the decrease in correlation coefficients from the first half to the second half of the IPG session. Previous research with college students (Yi et al., 2005) found that the relationship between temporal discounting and performance in IPG increased over time. The present study, in contrast, found the opposite. Detailed review of the data indicate that this decrease was due to a number of moderate discounters who decreased their cooperation rate over time to near-floor levels. Though this outcome was not expected, it is not surprising. In IPG, behavior is stable at exclusive cooperation or exclusive defection. A participant caught in a pattern of mutual defection (defection by the participant with ensuing defection by the computer) might find it difficult to escape this trap because she/he must cooperate in the face of a computer defection (resulting in the smallest reward) on the most immediate trial. Furthermore, it is not surprising that this occurred with moderate discounters rather than low or high discounters: low discounters generally cooperated in IPG and are able to make this short-tem sacrifice while high discounters generally defected in IPG and never made the short-term sacrifice.

A limitation of the present study was the use of hypothetical rewards in both the IPG and temporal discounting tasks. Temporal discounting studies comparing data from real and hypothetical money conditions (Johnson and Bickel, 2002; Madden et al., 2003, 2004) have found that there is no difference between human behavior for real and hypothetical rewards. Nonetheless, there always remains the possibility that participants in the present study would have behaved differently for real rewards. A second limitation is that all participants were exposed to the discounting procedure prior to the IPG, though previous research has found the same relationship between self-control and cooperation independent of the order of procedures (Harris and Madden, 2002; Yi et al., 2005). A third limitation is the absence of a control group. These participants were part of a treatment study where only drug-dependent individuals were enrolled, and thus there was no basis for the inclusion of control participants. However, a control group might have provided some insight into the possibility of a unique relationship between discounting and IPG for drug-dependent populations, in particular as it relates to the decrease in correlation coefficients over time.

The present study provides some indication that various self-control procedures (temporal discounting and IPG versus TFT) are related in a drug dependent population. Future studies on this topic in drug-dependent populations may manipulate other variables that may be important in temporal discounting and IPG. For instance, it is unclear (Baker and Rachlin, 2001) what will happen to cooperation rate in drug-dependent individuals when the opponent is believed to be another person, and what effect this will have on the relationship of cooperation with temporal discounting. Another topic of study that has not received much attention is the effect on cooperation, and the resulting effect on the relationship with temporal discounting, when the reward during IPG is a drug rather than money.

Acknowledgement

The data for this research were collected at the University of Vermont and funded by National Institute on Drug Abuse Grants R01 DA012997, R01 DA1 1692, and T32 DA07242. The authors thank Matthew Johnson, Amy Prue, and Racine Harris for their assistance.

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