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Decision biases and persistent illicit drug use: an experimental study of distributed choice and addiction

Gene M. Heyman *, Brian Dunn

Behavioral Psychopharmacology Research Laboratory, McLean Hospital, East House 3, Belmont, MA 02478, USA

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Abstract

This experiment tested the hypothesis that differences in drug use are correlated with differences in decision making. The subjects were 22 drug clinic patients who had used either opiates or stimulants for an average of 10 years, and 21 community residents who reported that they had rarely used illicit addictive drugs. The procedure consisted of a series of binary choices with two consequences; they earned money and determined the intervals that separated choice trials. Each choice earned the same amount of money, but one initiated a shorter delay to the next trial, whereas the other initiated a shorter delay as averaged over the next two trials. Shorter delays were advantageous in that they increased the overall rate of earnings and they reduced the time spent waiting for the next trial. Thus, one choice was better from the perspective of the current trial, while the other choice was better from the perspective of two or more consecutive trials. Drug-clinic patients were more likely to favor the one-trial solution compared with control subjects, who were more likely to favor the two-trial solution. There were five different choice games, with different versions varying in the magnitude of the advantage for switching from the two-trial to the one-trial solution. Drug clinic and control subjects differed most in the games in which the immediate advantage of the one-trial solution was larger, and all subjects were more likely to choose the global solution when the incentive for switching to the one-trial solution was lower. The results support the view that individual differences in decision making influence the course of illicit drug use.

Keywords: Addiction; Individual differences; Decision making; Distributed choice; Drug clinic patients; Methadone maintenance patients

1. Introduction

1.1. Distributed choice

In a paper on psychological and economic approaches to the study of choice, Herrnstein and Prelec (1991) emphasized a distinction that is especially pertinent to the study of addiction. They point out that some choices are distinct and unitary, whereas other choices are aggregates of 'many smaller decisions, distributed over a period of time'. For instance, at a particular time one can decide to buy an exercise machine, whereas to be physically fit one must decide many times, over an extended period, to go exercise. This second case Herrnstein and Prelec aptly labeled 'distributed choice'. Its relevance for the study of drug use is that addiction can be seen as an instance of distributed choice. One Friday night binge does not turn a social drinker into an alcoholic, and, similarly, a weekend without a drink does not turn an alcoholic into a teetotaler. Rather, addiction and recovery are states that reflect the cumulative effects of many small decisions.

1.2. Relations between the experimental procedure, distributed choice, and addiction

The procedure for the experiment described in this report is based on distributed choice experiments that evaluated the predictive accuracy of economic and psychological models of behavior ('maximizing versus matching law studies', Herrnstein et al., 1993; Heyman, 1982; Vaughan, 1981). The subjects had two options on each trial. One gave a higher rate of return on the current trial; the other gave a higher rate of return

* Corresponding author. Tel.: +1-617-855-2719; fax: +1-617-855-3711

E-mail address: gmheyman@mclean.harvard.edu (G.M. Heyman).

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overall. Or, put another way, there were two optimums: one, from the perspective of the current trial (a local optimum), and the other, from the perspective of two or more consecutive trials (the global optimum).

Elsewhere, it has been argued that the structure of this experiment is similar to the dilemma faced by drug users who are trying to abstain (Herrnstein and Prelec, 1992; Heyman, 1996). For example, it seems plausible that there are individuals for whom the reward value of a shot of heroin changes markedly as a function of the frame of reference. If the user considers the costs and benefits of competing activities in terms of a limited context, say the next few hours, heroin provides more value than does any other option. However, when the same user considers the advantages of different activities relative to a lifestyle, say a secure job and family versus the risks inherent in using an illegal substance on a daily basis, then its just the reverse, conventional activities trump drug use. Similarly, a smoker may prefer to have another cigarette if the frame of reference is the next few moments, but given the health risks of smoking, the same smoker may prefer a lifetime without cigarettes. Put more generally, under the conditions of distributed choice, preferences can systematically reverse as a function of whether the frame of reference is local or global.

1.3. Expected findings on the basis of earlier studies

Research on distributed choice problems with two or more optimums has been conducted with humans and non-humans. In experiments with pigeons, the typical non-human subject, the distribution of choices usually settled on the local optimum (e.g. Heyman and Herrnstein, 1986; Vaughan, 1981). However, pigeons could be taught to choose the global solution if the experiment included a stimulus that was correlated with higher overall reinforcement rates (Heyman and Tanz, 1995). In the initial experiments with humans, there was considerable individual variability, with some subjects stabilizing at the global optimum and others stabilizing at the local optimum (Herrnstein et al., 1993). Subsequently, Rachlin and his colleagues found that the temporal pattern of intertrial intervals influenced distributed choice. For example, if trials were presented three in a row followed by a pause, more subjects chose the global solution (Kudadjie-Gyamfi and Rachlin, 1996; Rachlin and Siegel, 1994). The pattern may have made trial-to-trial interactions (the global solution) more salient, which, in turn, suggests that individuals may differ in their sensitivity to the relationships between present and future consequences.

The present experiment investigated whether individual variation in distributed choice procedures was correlated with individual variation in drug use. In particular, we tested the hypothesis that drug clinic patients were more likely than control subjects to choose the local optimum in a series of distributed choice problems.

2. Methods

2.1. Subjects

Subjects were recruited from the North Charles Center for Addictions, McLean Hospital's Alcohol and Drug Abuse Treatment Unit, and neighborhoods near the two clinics. The North Charles clinic provides counseling services and methadone for opiate (usually heroin) addicts. The McLean drug treatment clinic is primarily a non-residential day program that provides counseling and daily drug screening. The methadone patients were tested at their counseling center, approximately 5 h after their daily methadone dose. The McLean patients were tested at the Behavioral Psychopharmacology Research Laboratory of McLean Hospital, after their daily treatment session. Control subjects were recruited by newspaper ads from neighborhoods near the methadone and McLean clinics and were tested at the Behavioral Psychopharmacology Research Laboratory.

The North Charles patients were randomly tested for drug use, and the McLean patients were tested daily. On the basis of the tests, the McLean patients were drug free. The test results for the North Charles patients were not known at the time of testing. However, drug use was not permitted at the counseling center, and this prohibition was generally obeyed. On the two occasions that we thought a methadone subject was intoxicated, we terminated the testing session. Control subjects were not tested for drug use.

2.2. Procedure

2.2.1. Overview

The experimental session included five computer-run distributed choice procedures (referred to as 'games'), the Wechsler Abbreviated Scale of Intelligence (WASI) vocabulary and matrix reasoning tests (Psychological Corporation, 1999), Barratt's Impulsivity Scale (version 11, Patton et al., 1995), the Structured Clinical Interview for Substance Abuse and Dependence (DSM IV), demographic and drug use questionnaires, and a board game that mimicked some of the properties of the computer game. Games were always separated by at least one other task, and their order was the same for all subjects. The session took about 1.5–2 h, depending on how much time was spent completing the drug-use history forms. The primary focus of this report is performance in the distributed choice procedure. It worked as follows.

2.3. Apparatus

The game was played on a laptop computer. Two keys, in the second row from the bottom, were designated the 'A' and 'B' response keys. The 'A' key was the second from the left end, and the 'B' key was the 7th from the right end. The screen provided instructions and gave updated, trial-by-trial feedback on how much money had been earned and how many 'opportunities' for earning more money remained.

2.4. Game contingencies

2.4.1. Overview

The game lasted for 300 'ticks'. Each choice used up a specified number of ticks and earned five cents. The screen displayed total earnings, the current number of available ticks, and the countdown. For instance, if the first response used up six ticks, the display began at '300' and counted down to '294'. During the countdown period, responses had no programmed consequences. Thus, it was a timeout from reinforcement. (Each tick lasted for 0.333 s.) When the countdown was over, the display signaled that the next choice would earn five cents. The display identified timer ticks as 'opportunities', since once the 300 ticks were used up, responses no longer earned money. Thus, each choice produced three consequences: (i) it earned five cents, (ii) it triggered a *n*-tick timeout from reinforcement, and, (iii) it used up *n* opportunities for reinforcement (from the initial budget or reserve of 300).

2.4.2. The better key on the current trial (the 'local solution')

One key always triggered a shorter timeout period for the current trial. For example, in the 75% procedure (see Table 1 below), the 'A' key always used up three fewer ticks than the 'B' key. Thus, from the perspective of the current trial, this key was the better choice, and, hence it is referred to as the 'local solution'.

2.4.3. The better key for two or more trials (the 'global solution')

However, each choice also influenced the length of future 'A' and 'B' intertrial intervals. The key associated with the shorter current intertrial interval increased intertrial durations for the next two trials. In contrast, the key with the longer current intertrial interval decreased intertrial durations for the next two trials. The magnitudes of wait times were set so that the key that was the poorer choice from the perspective of the current trial was the better choice from the perspective of two or more trials. Consequently, the key that caused future wait times to decrease was called the 'global solution'.

Table 1 lists the three possible intertrial intervals for each of the five games. For example in Game 1, a 'Local' choice after two 'Global' choices, produced a 1-tick wait time, whereas a 'Global' choice produced a 4-tick wait time. However, following a 'Local' choice, the alternatives were now 6- or 9-tick wait times, whereas following a 'Global' choice, the alternatives remained at 1- and 4-tick wait times (which, from a global perspective, is more desirable). After two consecutive responses of the same type, the wait times remained the same until the subject switched to the other key. That is, the system looked back two responses (a two-response moving window).

The point of different combinations of timeout periods was to test the idea that preference for the local solution would increase as the advantage of switching to the local solution increased. For instance, from the perspective of relative change, it is more tempting to switch to a 1-tick from a 4-tick wait time than to switch to a 4-tick from a 7-tick wait time. For one set of games, the advantage was in relative terms (75, 60, and 43% decrements in wait times), with the absolute differences held constant at three ticks. For the other two games there was an absolute as well as a relative difference. In Game 4, switching from the global optimum to the local solution reduced the immediate intertrial interval by 4-ticks, whereas in Game 3, switching from the global optimum to the local solution reduced the immediate intertrial interval by 2-ticks. Thus, in the percentage series, we predicted that preference for the global solution would be strongest in the 43% game (Game 5) and weakest in the 75% game (Game 1), and in the absolute difference set, we predicted that preference for the global solution would be strongest in the '2-tick' game (Game 3). We varied both ways of manipulating the contingencies as there was no way of knowing before hand whether relative or absolute differences in wait times (or both) would influence the subjects' behavior. (The games are named in accordance with the decrement in waiting time that follows a switch from the best global solution to the best local solution. For example, Game 1 is called a '75% game' because the best local solution reduces the intertrial interval by 75%.).

Prior to each of the five choice games, the screen displayed instructions on how to play. The Appendix lists the instructions for the first game. For subsequent games, the instructions were modified to acknowledge that the next game might vary from the previous game. Other relevant procedural details include the starting point and game length. Each game began with a 'history' of one local and one global choice. Game length was set at 300-ticks. This was determined on the basis of pilot data and our concern that the entire session last no longer than 2 h. In preliminary studies used to evaluate game parameters, we found that 300 ticks provided enough time for subjects to become

Table 1
Intertrial intervals (wait times until the next choice opportunity) for the five choice procedures as a function of number of global choices in the last two trials (a moving window, updated each trial)

Number of global choices in last two choices	75% Game		60% Game		2-Tick Game		4-Tick Game		43% Game	
	Loc (R)*	Glb (L)	Loc (L)	Glb (R)	Loc (L)	Glb (R)	Loc (R)	Glb (L)	Loc (R)	Glb (L)
2	1	***4*****	2	5	1	3	2	6	4	7
1	6	9	7	10	6	8	7	11	9	12
0	11	14	12	15	11	13	12	16	14	17

The table also shows the order in which the games were played. *'R' and 'L' refer to right and left buttons. **Underlined, bolded, and italicized numbers identify the intertrial intervals that remain in place for two or more consecutive responses of the same type. Note that the button associated with the shorter current intertrial interval (the local solution) generated longer intertrial intervals, e.g. ***11*** in the 75% game. Whereas the button associated with longer current intertrial interval (the global solution) generated shorter intertrial intervals, e.g. ***4*** in the 75% game.

familiar with the procedure and settle on a stable preference pattern.

2.5. Reimbursement

Subjects earned $20 plus their winnings from the computer and board games. Summing over the five procedures, exclusive preference for the global solution earned approximately $16.00, whereas exclusive preference for the local solution earned approximately $6.15. Total earnings varied between about $30.00 and 45.00. At the request of the North Charles Clinic, methadone clinic subjects were paid in coupons that were exchangeable for groceries at a major Boston area supermarket chain. The control subjects and McLean drug clinic subjects were sent a check. The methadone patients received the store coupons at the end of the session. The other subjects were issued check requests within 1 day of the session.

2.6. Questionnaires and tests

We also obtained information about demographic background, drug use history, and cognitive functioning. The drug use questionnaire asked about duration, frequency, and patterns of drug use (e.g. weekdays as well as weekends). The demographic questions obtained information on age, weight, height, ethnic background, income, education level, marital status, and occupation. Depending on the subject's answers to the drug use questionnaire, the Structured Clinical Interview DSM IV (SCID) for substance use disorders was administered.

Cognitive functioning was assessed with the vocabulary and matrix reasoning subtests of the recently revised Wechlser Abbreviated Scale of Intelligence subtests (WASI, Psychological Corporation, 1999). The vocabulary subtest is a list of 42 words, similar to the vocabulary subtests of the WISC-III and WAIS-III, and, like its predecessors, is defined as an index of crystallized or acquired intelligence. The matrix reasoning subtest is a series of 35 two-dimensional graphic patterns that the subject completes by identifying the correct stimulus from a set of five choices. It is similar to the matrix reasoning subtest in the WAIS-III, and, like this test, is said to provide an estimate of 'non-verbal fluid reasoning and general intellectual ability'. On the basis of national norms, these two tests provide an estimate of full scale IQ. In a national sample, the correlation between this estimate and the WAIS III IQ was 0.87 (Psychological Corporation, 1999). Neither test is timed.

We also included the Barratt's Impulsivity Scale, version 11 (Patton et al., 1995), a paper and pencil test for impulsivity. The questions focus on issues such as planning ahead and seeking out thrilling activities. In two recent studies, individuals with a history of drug dependence had higher Barratt scores than did control subjects (Mitchell, 1999; Patton et al., 1995).

2.7. Drug exposure

On the basis of responses to the drug use questionnaire, we estimated overall drug exposure. The estimate was based on the two illicit drugs used most frequently and was calculated by simply adding together years of use for each drug.

2.8. Analyses and statistics

At the start of each game, the subjects chose the local and global solutions about equally often and then with experience shifted toward one or the other. Consequently, the results were analyzed in terms of within-game changes in preference. The change scores were calculated by dividing a game into three equal sized blocks of trials, first, middle, and last third, and subtracting the percentage of global responses in the first third from the percentage of global responses in the middle and last thirds. (Note: the length of the last block was within two trials of the length of the first two blocks.) The decision to use thirds was based on two opposing considerations. More trials per block meant more reliable choice proportions. But as the number of trials per block increased, within-game fluctuations would disappear because of averaging. For example, in the limit, there is but one average choice proportion and no within-game dynamics. Thirds seemed a reasonable compromise.

For most of the analyses, changes in choice proportions were pooled. For example, to determine whether there was a group difference, the change scores for the middle and last thirds of each game for each subject were analyzed ($2 \times 5 \times 43$). However, to determine whether game performance was correlated with psychosocial measures such as IQ and years of school, it was most convenient to determine a single change score for each subject. This was done by simply averaging together a subject's middle and last block change scores across the five games. Analysis of variance (ANOVA) and t-tests were used to evaluate group and game differences. The calculations were performed with SYSTAT®9 (SPSS Inc., 1999) computer software.

2.9. Informed consent and institutional review

All procedures were approved by the McLean Hospital Internal Review Board for Human Subject Research, and all subjects gave written informed consent.

3. Results

3.1. Choice results: global and local preferences

Fig. 1 summarizes performance in the five distributed choice games. The game numbers refer to the order in which each procedure occurred. On the x-axes, '3rds' refers to the first, middle, and last third of a game. On the y-axes is the percentage of global responses for each third of the session. The average number of trials in each game was approximately 42. For panels one to five, the statistical analysis was conducted on the change in global response proportions in the middle and final third of each game for each subject ($2 \times 5 \times 43$). Panel 6 shows the averaged choice proportions across all games and all subjects. These data were analyzed in terms of the percentage of global responses in each trial block (3×43).

Fig. 1 shows that in the first third of each game, control and drug clinic subjects chose the global and local solutions about equally often. However, with further exposure to the contingencies, control subjects consistently shifted to the global solution, with the magnitude of the shift increasing as a function of the number of choices that had been made. In contrast, drug clinic subjects did not consistently gravitate toward either the local or global solution. In two games (3 and 5), global choices became slightly more frequent, whereas in three games (1, 2, and 4), local solution choices slightly increased. Although, there were between-game differences, in the block-by-block pattern of choices, in the last block of trials, control subjects always made more global solution responses than did drug clinic subjects. The statistical analysis of the block-by-block change in global responses showed a clear group difference ($F(1, 428) = 13.41$, $P < 0.0004$). For the averaged data, shown in panel 6, there was a significant group by trial-block interaction ($F(2, 82) = 4.97$, $P = 0.01$).

3.2. Between-game effects

Fig. 1 shows that the pattern of within-game changes in preference varied across the five games. For example,

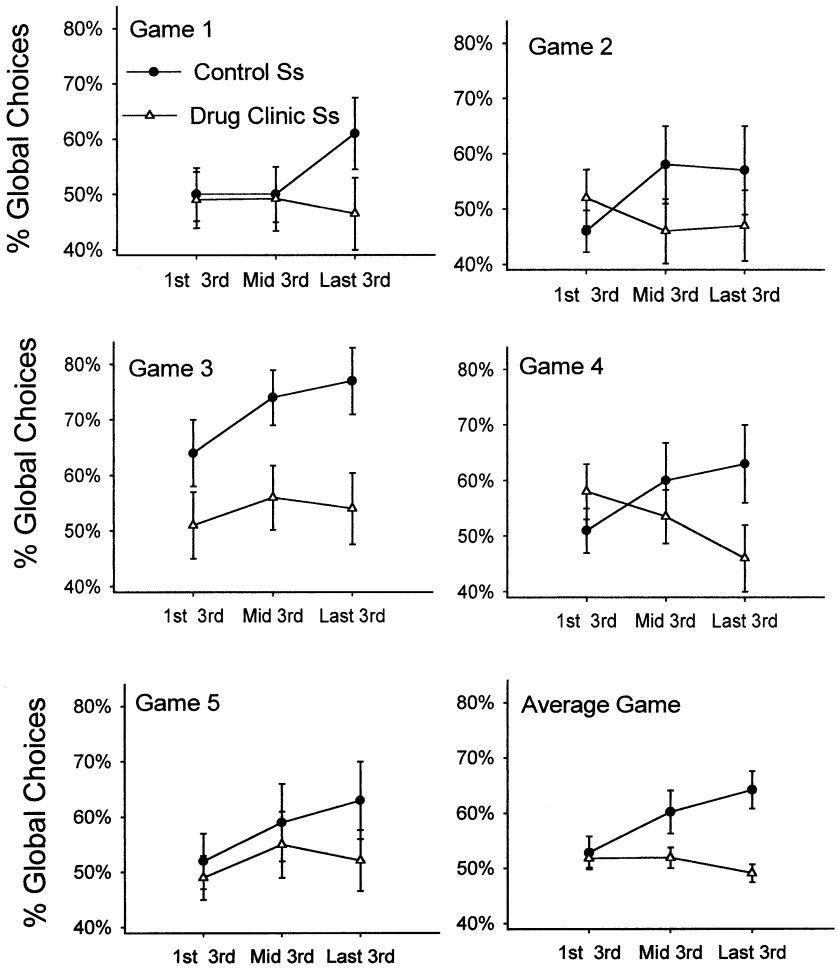

Fig. 1. The percentage of global choices in each procedure ('game'). The game numbers refer to the order in which the procedure occurred. However, the choice procedures were separated by other tasks, such as questionnaires and IQ subtests. There were approximately 14 trials per third. Error bars show standard errors. Filled circles indicate control subjects. Open triangles indicate drug clinic subjects. Statistical results are presented in the text.

drug clinic subjects shifted slightly toward the local solution in the middle and last thirds of Game 4, but shifted slightly toward the global solution in Game 5. We tested whether these differences were related to quantitative differences in the contingencies summarized in Table 1. Three analyses were conducted. Two were in terms of the nature of the comparisons (absolute or relative, as described in Section 2), and one included all five games. For the inclusive comparison, the game with the smallest absolute decrement (Game 3) and smallest relative decrement (Game 4) were the combined to form a 'low local solution incentive' pair, and the other three games were combined to for a 'high local solution incentive' trio. (Recall that the games that offered the smallest advantage for switching to the local solution should support the highest global choice proportion scores.)

When there was only a 2-tick advantage for switching to the local solution (Game 3), drug clinic subjects tended to shift to the global solution, whereas when the immediate advantage for choosing the local solution was larger (Game 4), they tended to shift to local solution. The difference in change scores was significant ($F(1, 43) = 4.68$, $P = 0.036$). For control subjects, the change scores were indistinguishable in Games 3 and 4. However, control subjects were more likely to choose the global solution in each third of the game with the lower incentive for local solution responses (Game 3). For example, the average percentage of global solution choices in Game 3 was 72%, whereas in Game 4 it was 57% ($F(1, 62) = 10.78$, $P = 0.002$).

In the three games that differed in terms of the percentage decrease in the current intertrial interval for a switch to the local solution (Games 5, 2, and 1), both groups were more likely to choose the global solution when the local solution incentive was smallest. However, these effects were small and not statistically significant.

Fig. 2 summarizes the between-game effects. The open circles show the average percentage of global responses for the combination of games that provided the smallest incentive for switching to the local solution (Games 3 and 5). The filled triangles show the percentage of global responses for the three games with larger local solution incentives. For drug clinic subjects, the pattern of changes was in the predicted direction, with global solution choices slightly decreasing and slightly increasing as an inverse function of the magnitude of the local solution incentive ($F(1, 41) = 8.80$, $P = 0.005$). For control subjects, the direction and magnitude of change in global solution responses were about the same in the two types of games. However, the absolute level of global responses was higher when the incentive for switching to the local solution was lower ($F(1, 41) = 9.70$, $P = 0.003$).

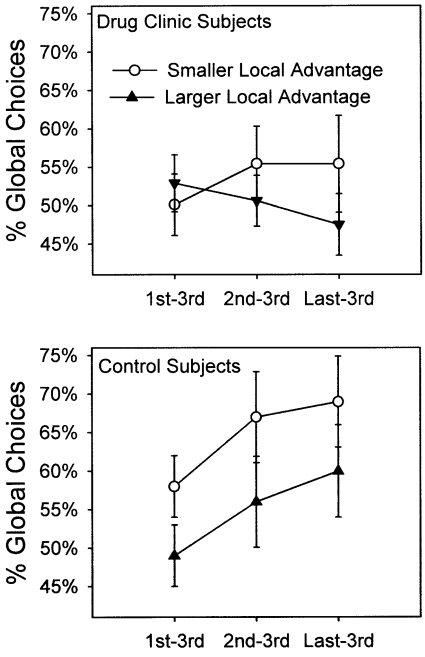

Fig. 2. The percentage of global choices as a function of the incentive for switching to the local solution, where incentive is defined as a shorter intertrial interval in the current trial. The open circles indicate the set of games in which the difference between the local and global intertrial intervals was relatively small. The filled triangles indicate the set of games in which the difference between the local and global intertrial intervals was relatively large. See text for statistics.

3.3. Earnings

Earnings varied as a function of preference for the global solution and, to some extent, as a function of the game contingencies. Across the five games, the correlations between global choice percentages and earnings varied from $r = 0.80$ to 0.92 and were highest in games that had the most trials (e.g. Game 3 which had the shortest intertrial intervals). However, group differences in overall earnings were not large. The control subjects earned on average \$10.50 ($\pm$2.05) and the drug clinic subjects earned on average \$9.45 ($\pm$1.50). This difference was associated with a likelihood of more than 0.05 ($t(41) = 1.82$, $P < 0.08$).

3.4. Demographic and cognitive correlates of drug use

Table 2 summarizes the psychosocial characteristics of the drug clinic and community control subjects. The groups differed most in terms of age, IQ, school achievement, and income, with control subjects exceeding the drug clinic subjects on each of these measures (Ps < 0.05). These differences are similar to trends reported in nationwide surveys, such as the Epidemiological Catchment Area study (e.g. Anthony and Helzer, 1991). Drug clinic subjects had higher scores on the Barratt impulsivity questionnaire, as in other studies

Table 2
Psychosocial measures

Measure	Controls (21)	Drug (22)	t	P	Correlation (r) with increase in global choices[c]
Education level (years)	16 (2.2)	13 (2.4)	4.2	0.0001	0.272
IQ WASI short form	114 (15.1)	101 (21.0)	2.4	0.02	0.205
Performance T score	57 (9.6)	51 (12.2)	1.9	0.06	0.133
Verbal T score	58 (10.4)	48 (15.6)	2.5	0.02	0.211
Income	$30 000 (13 500)	$13 500 (14 500)	3.9	0.0001	0.320[b]
Age	49 (15.4)	40 (9.1)	2.2	0.03	0.192
Gender (female)	57%	41%	1.3[a]	ns	-
Ethnic (white)	91%	82%	0.8 [a]	ns	-
Body mass index	25.2 (5.6)	27.7 (6.7)	1.3	0.21	−0.124
Impulsivity scale (Barratt)	76.4 (19.3)	82 (13.2)	1.2	0.25	0.037

[a] Chi-square sum.
[b] $P < 0.05$.
[c] This column shows the correlation (r) between psychosocial measures for the entire sample ($n = 43$) and the average within-game change in the percentage of global solution responses.

(e.g. Mitchell, 1999). However, this difference was not statistically significant.

Among the control subjects, the correlations between increases in preference for the global solution and psychosocial variables varied from −0.162 to 0.310, with vocabulary, educational achievement and household income (in ascending order) yielding the highest r values. Among the drug clinic subjects the correlations were considerably smaller, varying from −0.038 to 0.064. For both groups, none of the correlations met the 0.05 probability criterion (e.g. Ps > 0.18, using uncorrected (non-Bonferroni) calculations). However, combining control and drug clinic subjects into a single group did yield more robust associations. These are shown in the last column of Table 2. For the larger sample, the three highest correlations were with household income ($r = 0.320$), educational achievement ($r = 0.272$) and vocabulary ($r = 0.211$). For education this correlation was significant ($P = 0.042$).

In contrast to the correlations between psychosocial variables and game performance, the correlations among the psychosocial variables were larger and more robust. For instance, the correlations between household income, IQ, and education level varied from $r = 0.429$ to 0.591 and had uncorrected null hypothesis likelihoods of less than 0.006.

As a further check on the relationship between psychosocial measures and changes in preference for the global solution, the analysis associated with Fig. 1 (pooled change scores) was redone with education level and IQ as covariates. The ANCOVA-adjusted means were similar to the untransformed means, and between-group differences in global choices remained statistically significant: $F(1, 427) = 9.27$, $P = 0.002$ with IQ as the covariate and $F(1, 427) = 5.85$, $P = 0.016$ with years of education as the covariate. In other words, analytically removing group differences in IQ and education had little effect on group differences.

3.5. Drug history

Table 3 summarizes drug use history for the two groups. As the questionnaire was restricted to the two illicit drugs that were used most, the results may underestimate differences between those who used less than three illicit drugs and those who used more. Nevertheless, there were large group differences in drug use. All of the clinic subjects had used cocaine and/or heroin regularly for an average duration of about 10 years. Of the 18 who had ever smoked on a regular basis, 17 still did, and of the 13 who met the SCID criteria for lifetime alcohol dependence or abuse, four were still problem drinkers. Many of the drug clinic subjects smoked marijuana, but none listed it as one of the two drugs that he or she used most.

In contrast, none of the control subjects reported that they had ever used heroin regularly, and among those who had used either stimulants or marijuana regularly, most had been drug free for several years. In regards to licit drugs, about half of the control subjects who ever were regular smokers were currently ex-smokers, and three of the four who met the SCID criteria for lifetime alcohol abuse or dependence reported that they currently did not drink alcohol. Thus, the two groups differed in terms of the onset of drug use and its duration.

3.6. Duration of drug use and distributive choice performance

Fig. 3 compares drug use history with performance in the distributed choice games that best distinguished the two groups, the three games with higher incentives for a switch to the local solution (shown in Fig. 2). The questionnaire asked about three parameters of drug use: intensity ('years of heavy use'), pattern ('days/week that drugs were used') and duration ('years of use'). The

Table 3
Drug use (illicit drugs, methadone, alcohol, and cigarettes)

Group	Drug	Ever use regularly	Current regular use	Duration (years)
Drug clinic (22)	Heroin	15	6	9.8 (6.2)
	Stimulants	12	7	13.4 (9.1)
	Benzodiaz.	5	4	7.8 (1.6)
	Methadone	14	14	10.1 (104 mg/kg day)
	Lifetime drug dep. or abuse[a]	22		
	Lifetime alcohol dep or abuse[b]	12		
	Days/week primary drug[c]	5.0 (2.26)		
	Days/week secondary[c]	3.5 (2.86)		
	Cigarettes	18	17	23.4 (2.3)
Controls (21)	Heroin	0	–	–
	Stimulants	4	1	3.0 (2.2)
	Benzodiaz.	0	–	–
	Marijuana	7	2	10.0 (7.4)
	Lifetime drug dep. or abuse[a]	1		
	Lifetime alcohol dep. or abuse[b]	5		11.6 (4.5)
	Cigarette	11	5	16.5(3.8)
	Days/week primary drug[c]	2.2 (2.80)		
	Days/week secondary[c]	0.5 (2.86)		

[a] Substance dependence or abuse by SCID criteria.
[b] Alcohol abuse or dependence by SCID criteria.
[c] Frequency of use during periods of heavy use.

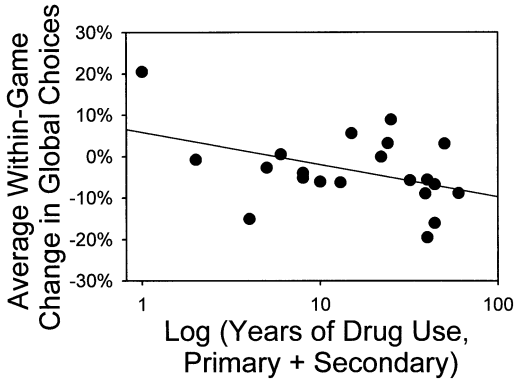

Fig. 3. The change in preference for the global solution as a function of years of drug use for drug clinic subjects. The choice data are from the three procedures that best distinguished drug clinic and control subjects, the high incentive games (1, 2, and 4). On the x-axis is the sum of the number of years of primary and secondary drug use. The scale is logarithmic. On the y-axis is the average change in percentage of global choices in the last third of the session relative to the first third of the session. As noted in the text, this measure of drug use was most highly correlated with choice biases. See text for statistics.

measure that was most strongly correlated with the change in global solution scores was years of use, counting both the primary and secondary drug. Fig. 3 shows the results. On the x-axis is the sum of years of primary drug use and years of secondary drug use (in logarithmic coordinates, as this reduced the variability), and on the y-axis is the average change in global choices in the middle and last thirds of the session ($r = -0.432$, $P = 0.051$). The negative correlation says that individuals who had used drugs longer were more likely to switch to the local solution in the middle and last thirds of the choice games. We also evaluated the correlation between this data set and IQ and educational achievement. The correlations were $r = 0.14$ and 0.11 for IQ and education, respectively (Ps > 0.05). It may also be of interest that including alcohol consumption did not markedly change the correlations. For example, combining years of alcohol use with years of drug use increased the correlation with game performance by about 3%.

4. Discussion

This study tested the hypothesis that individual differences in a distributed choice procedure would predict individual differences in drug use history. In accordance with the hypothesis, individuals with a history of long-term illicit drug use were more likely to choose the local solution than were subjects that did not have histories of long-term illicit drug use. ANCOVA revealed that the statistical significance of these differences remained after the groups were analytically equated for either educational achievement or IQ. Differences between the two groups emerged as a function of experience with the contingencies, becoming larger in the middle and final thirds of each game. Moreover, the magnitude and even the direction of change in preference for the global solution was correlated with quantitative differences between games, namely the size of the decrease in the wait time to the

next choice opportunity for a local solution response. These results suggest that the putative contingencies actually influenced the subjects' choices. However, there are several issues to consider in relation to the interpretation of the results.

4.1. Were group differences related to the choice contingencies

First, within-session changes raise questions regarding the stability of the data. For example, for the control group, global choice proportions leveled off only in Game 2, and it is possible that the drug clinic subjects would have selected the global solution more often if the games had run for more trials. Thus, the graphs may show differences in acquisition and/or different asymptotes.

Second, although group differences emerged as a function of exposure to the choice contingencies, it is possible that these differences reflect some other aspect of the procedure. For example, there were two reimbursement schemes. The methadone subjects were paid in coupons that could be redeemed for groceries, whereas the control subjects and McLean clinic subjects were sent checks. The coupons were handed out at the end of the session, and the check requests were initiated within 24 h of the end of the session. This may be relevant as an earlier study found a correlation between 'self-control' choices and the delay separating the end of the session and reimbursement (Hyten et al., 1994). However, in the self-control study, the delay to reimbursement was on the order of weeks (not days), and the longer delays were correlated with impulsive choices, whereas in the present study, preference for the local solution was correlated with the most immediate payment schedule. Also, the McLean clinic subjects were reimbursed in the same manner as control subjects, yet their performance was like that of the methadone clinic subjects.

Third, the correlation between the contingencies and within-session changes in preference shown in Figs. 1 and 2 are silent as to which consequences mattered. Each choice influenced the wait times that separated choice opportunities and the rate of monetary earnings. Just one or both may have influenced preferences. In addition, the subjects may have been motivated by the desire to figure out how the game worked independently of intertrial wait times and earnings. Thus, the contingencies appear to have influenced preferences, but whether the 'currency' was the delay to the next trial, money, or satisfying curiosity is not clear.

4.2. Distributed choice and delay discounting

In several recent experiments, long-term illicit drug users discounted future consequences more steeply than did non-drug using controls (e.g. Kirby et al., 1999; Madden et al., 1997). This may be relevant to the present study, since a distributed choice task can be seen as a series of discount problems. For example, the global solution requires a longer time horizon than the local solution. However, there are also important differences between the two procedures. In the discounting procedure, delays are usually on the order of days, weeks, and months. In contrast, in this distributed choice procedure, delays were on the order of seconds. In discounting procedures, present choices do not alter the value of future choices. In contrast, in distributed choice procedures there are explicit choice-dependent changes in value (see, e.g. Table 1). These differences raise the possibility of two kinds of impulsivity. One that is based on discounting future rewards at excessively high rates, and another that is based on framing contingencies in terms of their most immediate consequences, while ignoring more removed yet important consequences. On the other hand, performance in both procedures can be explained in terms of varying discount rates or varying frames of reference. That is, performance in both procedures may reflect common psychological processes.

4.3. Limitations, questions, and extensions

Heavy drug users are a heterogeneous group, and hence the generality of the findings presented in this report requires further investigation. For instance, the drug clinic subjects were all long-term users so that it is not known if the findings would apply to heavy drug users who do not seek treatment or who quit after a few years. In other words, the results may be more relevant to the persistence of addiction than to the transition from experimentation to heavy use. Second, the long-term drug users who were in treatment. Thus, it is reasonable to suppose that long-term drug users who were not in treatment might show even greater preferences for the local solution. Third, it is not known if the differences in performance are a consequence of drug use or of differences that preceded and perhaps abetted long-term drug use. For example, drug users who seek treatment are about twice as likely to be afflicted with additional psychiatric disorders than drug users who do not seek treatment (e.g. Regier et al., 1990). Thus, preference for local solutions could be causally linked to psychiatric distress rather than to addiction. Fourth, the procedure is new and as performance varied according to game parameters, there may be parameters that better differentiate drug users and control subjects. Possibly, games that used longer intertrial intervals, larger monetary rewards, or simply more trials would lead to larger group differences.

4.4. Summary

Whether experimentation with illicit drugs leads to addiction varies markedly between individuals. Similarly, the duration of heavy use varies markedly between individuals, with many stopping after a few years (e.g. Anthony and Helzer, 1991) and others remaining long-term chronic addicts (e.g. Hunt et al., 1971; Wasserman et al., 1998). The experimental results summarized in Figs. 1–3 suggest that individual differences in susceptibility to addictive drugs are in part due to individual differences in decision making. However, this research is based on long-term illicit drug users from two clinics, and as drug users are a heterogeneous population, the generality of the findings requires further study.

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Appendix A: Subject instructions for distributed choice procedures

Welcome to the 'NICKEL-A-CHOICE' game. Today we would like you to play our computer game and earn some money. In this game you will make choices. Each choice earns a nickel. This may not seem like much, but there are many opportunities to choose in each game, and you will play five games.

In each game you will be able to earn from about $1.00 to 5.00 so you can earn from $5 to 25 in a short time. This will be added to your payment for coming in and filling out the questionnaires.

1) There are two keys, marked on the keyboard 'A' and 'B'. Your job is to press one or the other.
2) You begin each game with a limited number of opportunities to choose KEY A or KEY B. When you make a choice you use up opportunities. After each choice the screen will tell you how many opportunities your last choice used up and how many are left. The game continues until you have used up all of your opportunities.
3) KEY A and KEY B earn the same amount of money (a nickel), but differ in how many opportunities each one uses up. For example, choosing KEY A might use up 14 opportunities (and earn a nickel). Whereas choosing KEY B might use 11 opportunities (and earn a nickel).
4) The number of opportunities that are used up by choosing KEY A or KEY B may vary, but never in a random way.
5) There are several different ways to play the game and earn money. Find the way that is best for you.

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