Cocaine behavioral economics: From the naturalistic environment to the controlled laboratory setting

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ABSTRACT

Background: We previously observed that behavioral economic factors predict naturalistic heroin seeking behavior that correlates with opioid seeking in the experimental laboratory. The present study sought to replicate and extend these prior findings with regular cocaine users.

Methods: Participants ($N = 83$) completed a semi-structured interview to establish income-generating and cocaine-purchasing/use repertoire during the past month. Questions addressed sources/amounts of income and expenditures; price (money and time) per purchase; and frequency/amounts of cocaine purchased and consumed. Naturalistic cocaine purchasing and use patterns were: (1) analyzed as a function of income quartile, (2) perturbed by hypothetical changes in cost factors to assess changes in purchasing/use habits, and (3) correlated with experimental cocaine seeking.

Results: Income was positively related to naturalistic cocaine seeking/use pattern (i.e., income elastic), and behaviors were cost-efficient and sensitive to supply chain. Income was unrelated to proportional expenditure on cocaine (≈55%) but inversely related to food expenditure. In all hypothetical scenarios (changes in income or dealer, loss of income assistance from government or family/friends, and increasing arrest risk when purchasing), the high-income group reported they would continue to use more cocaine daily than other groups. Number of laboratory cocaine choices significantly correlated with cocaine purchase time (positively) and purity of cocaine (negatively) in the naturalistic setting.

Conclusions: These results replicate and extend findings with regular heroin users, demonstrate the importance of income, cost-efficiency and supply-mindedness in cocaine seeking/use, and suggest that this interview-based approach has good external validity.

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1. Introduction

Regular cocaine use can be conceptualized as a behavioral economic problem, in which cocaine functions as a reinforcer (i.e., maintains seeking behaviors leading to its consumption) and certain environmental features can promote or constrain cocaine use. One key factor is income, which broadly influences purchasing of commodities. However, few studies have systematically examined income-generating activities and expenditures among cocaine users. In one careful analysis of urban African American individuals, Cross et al. (2001) found that, compared to non-frequent users, frequent crack-cocaine users (≥15 of past 30 days) were less likely to engage in full-time work or receive aid to families with dependent children, and more likely to generate income from petty criminal activities and from friends, family, governmental assistance, and panhandling. However, that study did not investigate how income was expended or the cocaine-related behavioral repertoire of those individuals.

Evaluating the income and expenditures of regular cocaine users who are *not* seeking treatment may be useful in understanding factors that maintain cocaine demand. Studies from our laboratory showed that heroin-dependent, non-treatment volunteers had predictable purchasing repertoires (Roddy and Greenwald, 2009; Roddy et al., 2011). When assessed in simulation scenarios, only potent economic challenges such as 33% reduction in income, discontinuation of living subsidies from friends/family, and 4-fold greater likelihood of arrest during drug purchasing, altered these behaviors (Roddy et al., 2011).

The present study adapted this approach to studying regular cocaine users (whose behavior may differ from heroin users) and

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expands work on income-generating activities of cocaine users (Cross et al., 2001). Previous evidence that higher baseline rate of cocaine use is related to worse treatment outcome (Alterman et al., 1997; Ehrman et al., 2001; Kampman et al., 2001, 2002; Kosten et al., 2005) suggests that behavioral economic metrics could be useful for understanding and predicting treatment response. This study used interview methods to (1) ascertain naturalistic patterns of cocaine purchasing and use (demand metrics) in relation to past-month income; (2) determine in simulation scenarios whether these behaviors are susceptible to change by a variety of cost-related factors; and (3) evaluate whether these naturalistic behaviors predicted experimental cocaine seeking in a laboratory study that included 15 of these participants (Greenwald et al., 2014). We hypothesized that naturalistic cocaine purchasing/use would be (1) income elastic; (2) sensitive to simulated cost factors; and (3) associated with cocaine seeking in the laboratory setting.

2. Methods

2.1. Participant recruitment

The local Institutional Review Board approved all procedures. A certificate of confidentiality was obtained. Regular cocaine using, non-treatment seeking males and females, aged 18–55 years, were recruited by newspaper advertisements and word-of-mouth referral in the Detroit/metropolitan area for participation in experimental cocaine self-administration studies. All volunteers provided written informed consent. The present analyses are based on data from two clinical studies registered on www.clinicaltrials.gov as NCT00946660 and NCT01392092.

2.2. Measures

Participants completed a novel semi-structured interview, Cocaine Purchasing and Use Patterns (CPUP), adapted from our study with heroin users (Roddy et al., 2011), to assess past-month income generating and cocaine seeking/use repertoires. In part one of the interview, data were obtained on amounts of income from legal sources including employment (both taxable and non-taxed earnings from bartering work such as handyman services, babysitting, yard work, hair styling/cutting, housework/cleaning), unemployment insurance, pension or Social Security, public assistance (e.g., food stamps), family and friends (without lying about its intended use), net earnings from approved gambling venues, borrowing on credit, and various illegal sources (e.g., selling drugs, stealing, "con game" or lying, prostitution, scrapping metal).

Interview questions evaluated the past-month number of and distance from cocaine/crack dealers; unit price, money spent and round-trip time per average cocaine purchase; frequency, amounts and estimated purity of cocaine purchased; and expenditures on other goods besides cocaine such as food, shelter/utilities, cigarettes, alcohol, other drugs, and non-drug items (e.g., transportation, clothing, and personal care). Measures of cocaine use were confirmed with collateral indices from a standardized, comprehensive, and locally developed Drug History and Use Questionnaire (DHUQ) and qualitative urine toxicology (positive result $\geq$ 300 ng/ml).

An internal validity check was established during each interview: If past-month total income and total expenditures did not closely agree ($\pm$3%), the participant's data were excluded from analysis. Only a few participants' data failed to meet this criterion.

In the majority of this sample (time allowing, due to required demographic, medical and psychiatric screening procedures for the laboratory studies), part two of the interview assessed, in a sequence of related questions, how the participant would adapt to this hypothetical situation: "If your current primary cocaine/crack dealer was arrested or unavailable for the next month and you had to go to another dealer from whom you've previously bought cocaine/crack"—

(1) Would the time you'd have to travel differ from what it is now? (>10 min shorter, $\leq$10 min shorter, same time, $\leq$10 min longer, or >10 min longer)
(2) Would your primary mode of transportation have to change from what it is now? (no, yes)
(3) How much would a bag/rock cocaine/crack cost from the new dealer compared to what it is now? ($3–$5 less per unit, <$2 less per unit, same cost, <$2 more per unit, $3–$5 more per unit, or $\geq$$5 per unit)
(4) Would the purity of the new dealer's cocaine/crack change from what you buy now? ($\geq$20% decrease, 10–20% decrease, no big change [$\pm$10%], or 10–20% increase ($\geq$20% increase)
(5) Would the reliability of the new dealer (his ability to get you what you need) change from what you are used to now? (much less reliable, somewhat less reliable, no significant change, somewhat more reliable, or much more reliable).

In a follow-up sequence of questions, each participant was then asked: "How much cocaine/crack (dollar amount) would you buy on each day (on average)"—

(1) If you had to switch to the new cocaine/crack dealer?
(2) If your next month's income decreased 50% from its current level?
(3) If your next month's income increased 50% from its current level?
(4) If your family or friends no longer paid for your housing/other living expenses?
(5) If you no longer received any governmental assistance (e.g., no food stamps, social security or unemployment compensation)?
(6) If you had to buy from a cocaine/crack dealer who sold in a neighborhood where you would be: 25% (one-quarter) as likely to be arrested? 50% (one-half) as likely to be arrested? 2 times as likely to be arrested? 4 times as likely to be arrested? 8 times as likely to be arrested?

A subset of 15 participants completed one inpatient laboratory study for which they were screened (Greenwald et al., 2014). In one session (presented randomly in the context of other conditions that are not central here), these participants could work for 10-mg units of intranasal cocaine or $1.00 money units on an 11-trial choice, progressive ratio schedule. The participant could allocate these choices in any manner, e.g., earn the maximum cocaine dose of 110-mg (i.e., 11 trials X 10-mg per trial, but no money would be earned) or $11 (i.e., 11 trials X $1 per trial, but no cocaine would be earned), or a mixture of cocaine and money (but not the maximum amount of either).

2.3. Data analyses

Participants were included in the data analyses if they reported recent cocaine use and completed at least part one of the CPUP interview. All analyses were conducted using SPSS v. 21. The sample was divided into quartiles based on the distribution of total past-month income (independent variable). Dependent measures that were not normally distributed were transformed (log$_{10}$) then used in analyses.

Correlations were computed among CPUP measures, and with cocaine seeking in the laboratory (Greenwald et al., 2014). Pearson correlations were computed between continuous measures, Spearman correlations were used with income quartile (ordinal) data, and Kendall's *tau* correlations were used with cocaine urinalysis (positive/negative) results.

Regression analyses from two independent samples of regular heroin users (Roddy and Greenwald, 2009; Roddy et al., 2011) led to creation and use of the CPUP in this project. In those earlier studies, we observed that (1) total past-month income was significantly related to drug purchasing and/or use; (2) drug purchasing measures (weekly purchases, purchase time, purchase amount) were significantly related to one another; and (3) drug use was significantly related to purchasing measures (positively) and unit price (negatively). Based on these findings, we hypothesized these variables might be related among cocaine users. Thus, we decided that using strict family-wise error adjustment for multiple correlation tests shown in Table 4 would be overly conservative and increase Type 2 error rate (Curtin and Schulz, 1998). Thus, we employed the Benjamini and Hochberg (1995) step-up procedure. To reduce the dimensionality of selected CPUP measures, we conducted a Varimax-rotated principal component analysis, toward parsimonious interpretation of these measures.

For examining associations between naturalistic and laboratory cocaine seeking, we computed Pearson correlations between the number of cocaine 10-mg unit choices (vs. $1 unit alternative) and five measures related to naturalistic drug acquisition: cocaine unit price and purity, purchase time, purchase amount, and number of weekly purchases.

One-way Analyses of Variance (ANOVAs) and Tukey *post hoc* tests were conducted to identify income-quartile group differences in the CPUP interview and simulation data. A mixed model ANOVA was used to analyze hypothetical change in cocaine purchasing in relation to risk of arrest. For all statistical analyses, significance level was set at $p < .05$.

3. Results

3.1. Participant characteristics

CPUP interview data were available for 83 participants. The overall sample was primarily male (66 male, 17 female) and African-American (64 AA, 15 white, and 4 multi-racial or Hispanic). Mean ($\pm$1 SD) age was 45.4 ± 6.9 years and most participants had at least a high school education ($M = 13.1 \pm 1.6$ years). Demographic characteristics (gender, race, age, education level) and body mass index ($M = 26.5 \pm 4.9$) did not significantly differ across income quartile groups.

Reported duration of lifetime cocaine use was 21.1 ± 7.7 years. Smoking 'crack' (90.4%) or insufflating/'snorting' cocaine (9.6%)