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Using a Novel Alternative to Drug Choice in a Human Laboratory Model of a Cocaine Binge: A Game of Chance

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Abstract

Human laboratory studies have shown that, once initiated, cocaine self-administration is difficult to disrupt using non-drug alternatives. This inpatient study examined whether binge self-administration of cocaine could be altered by an immediate, non-drug reinforcer. Ten cocaine-dependent participants completed 5 consecutive laboratory session days with 2 sessions per day (a model binge), 9 days where cocaine was not available, and subsequent 2 laboratory session days where cocaine was again available (a second model binge). In each laboratory session, participants could choose to either self-administer smoked cocaine or play a game of chance by drawing a pre-determined number of balls from a bingo wheel. Balls were worth monetary amounts from \$0 – \$20. Participants' choice to smoke cocaine varied as a function of number of balls drawn. Thus, this game of chance served as an alternative reinforcer to smoking cocaine. Choice varied lawfully as a function of the number of opportunities to earn money indicating that an immediate behavioral alternative can reduce cocaine self-administration after initiation of use. The current model could be used to evaluate whether behavioral and pharmacological manipulations shift choice from cocaine to a non-drug alternative.

Keywords

Self-Administration; Cocaine; Binge; Behavior

1. Introduction

The cocaine “binge,” or, the repeated administration of cocaine followed by a period of abstinence, is a characteristic pattern of cocaine use. Human laboratory studies have modeled essential elements of the binge (Hatsukami et al., 1994a), and revealed that upon repeated opportunities to self-administer intravenous or smoked cocaine, cocaine was self-administered on the majority of occasions, with acute tolerance developing to cardiovascular, and some, but not all, subjective effects (Foltin and Fischman, 1997a, 1997b; Ward et al., 1997a, 1997b, also see Walsh et al., 2001). Cognitive and physiological changes have also been described during periods of binge and subsequent abstinence (Morgan et al., 2006; Pace-Schott et al., 2005a, 2005b, 2008).

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Models of self-administration attempt to capture essential features of cocaine dependence in order to develop potential treatment interventions. Cocaine users outside of the laboratory continually decide whether to spend their money or resources on cocaine or on non-drug reinforcers. Laboratory models attempt to develop interventions that shift choice away from cocaine toward these non-drug reinforcers. However, it has been difficult to find a nondrug reinforcer that competes with cocaine (Haney and Spealman, 2008) once cocaine-taking has been initiated (Foltin and Fischman, 1994; Walsh et al., 2001). That is, varying the magnitude and availability of alternative, nondrug reinforcers has been examined as a means to shift cocaine self-administration (Haney et al., 1998; Hart et al., 2000; Hatsukami et al., 1994b; Higgins et al., 1994; see Higgins, 1997, for a review), however, studies have revealed that the value of the alternative reinforcer has less impact on drug choice once cocaine administration has been initiated. For instance, even when the cost was \$16 per dose, most participants chose to self-administer cocaine (Walsh et al., 2001; Donny et al., 2003), and some administered cocaine at a cost of \$19 per dose (Donny et al., 2004). Thus, one of the challenges in developing laboratory models of the binge has been to find an alternative, nondrug reinforcer that can interrupt or shift cocaine self-administration (Haney, 2009).

In designing the present study, we first conducted a pilot study to shift cocaine self-administration with varying amounts of money. Participants drew slips of paper from a container that contained dollar amounts, and decided whether to keep that amount of money, or smoke a dose of cocaine (25 mg). Two participants chose cocaine 100% of the time rather than \$2, \$4, or \$8; two participants chose cocaine 100% of the time rather than \$4, \$8, and \$12, and one participant chose cocaine 98% of the time when the alternatives were \$8, \$12, and \$16. This participant chose \$8 instead of cocaine as the final choice of the Day 2 morning session, and \$16 instead of cocaine as the final choice of the Day 2 afternoon session (see Section 2.2. Design, and 2.3. Laboratory Sessions). We subsequently concluded that it was not possible to shift self-administration with money solely as the alternative, and designed a game of chance.

The game of chance enabled the examination of the effects of an immediate, alternative reinforcer during a 5-day binge before, and a 2-day binge after, a period of abstinence. Participants could choose between smoking a dose of cocaine (25 mg) and drawing balls from a bingo wheel with varying monetary value. Immediately prior to making the choice between drug or drawing balls from the bingo wheel, participants underwent a random process to determine how many balls (2, 4, or 6) could be drawn. The monetary value represented by each ball ranged from \$0–\$20, and when picked, this amount was kept as study earnings. In total, there were 6 sets of choices (2 sets of 3 ball picks) per laboratory session. Thus, this study was designed to investigate if cocaine self-administration would vary as a function of the: magnitude of the alternative reinforcer (number of balls drawn), time within the laboratory session, and length of the binge. The inclusion of two different binge lengths (5-day vs. 2-day) enabled comparisons between the long and short binge periods to be made, while modeling choice in blocks of time enabled detection of within-session effects. Participants were thereby engaged in a game of chance where the effects of an immediate, random, nondrug alternative reinforcer on binge cocaine self-administration could be examined.

2. Methods

2.1. Participants

Nineteen participants signed consent. Participants were solicited via word-of-mouth referral and newspaper advertisements in New York City, and gave informed consent before any study procedures were initiated. Before study enrollment, participants passed comprehensive medical and psychiatric evaluations, including a Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders (DSM-IV SCID). Participants met a cocaine use

criterion that had been set in advance: each had smoked cocaine at least 2 times a week for the past 6 months, and was currently spending at least \$70 per week on cocaine. None were seeking treatment for their cocaine use. No participant met criteria for any other Axis I disorder. Ten non-treatment seeking research volunteers (9 males: 7 black, 1 hispanic, 1 white; 1 female: black) with an average age of 39 years (± 5 yrs; Mean $\pm$ SD), and 12 years (± 1 yr) of education completed this study. Three of the 19 participants were discharged for cardiovascular irregularities, one was discharged due to the emergent desire for treatment, two left the study due to personal reasons, one never showed up for admission, one participant did not contribute a complete data set, and one participant was non-compliant with study procedures.

Participants who completed the study reported using cocaine 4 days (± 2 days) per week and spending \$281 ($\pm$ \$152) per week on cocaine. On average, participants reported using cocaine for 15 years (± 6 years) years. Nine participants reported smoking approximately 14 (± 7) tobacco cigarettes per day, and one participant used snuff. Eight participants reported current alcohol use (range 1–28 drinks per week), while five participants reported smoking marijuana cigarettes (2 reported rare use, 1 reported using one marijuana cigarette per month, 1 reported spending approximately \$20 per month, and 1 reported spending approximately \$120 per month). Two participants reported occasional heroin use. All procedures were approved by the Institutional Review Board of the New York State Psychiatric Institute.

2.2. Design

This was a within-subject, inpatient study. Participants were admitted to Columbia University's Irving Institute for Clinical and Translational Research on a Friday, and discharged 21 days later. After the Friday admission, participants had a training session to expose them to the laboratory and playing the game of chance. Participants resided on the drug-free research unit over the weekend without any laboratory sessions. Participants then had 5 laboratory session days, with 2 sessions per day (pre-abstinence, described below). These sessions were followed by 9 days of cocaine abstinence, that is, residing on the research unit without laboratory sessions, followed by the final 2 laboratory session days (post-abstinence). Participants were then observed for 24 hours before being discharged.

2.3. Laboratory Sessions

Participants were instructed that they would have 5 days where cocaine would be available, 9 days where it would not be available, and 2 days where cocaine would again be available in laboratory sessions. Laboratory sessions were introduced as involving a game of chance. Participants were presented with a container that held three slips of paper. Each slip bore a single numeral (2, 4 or 6) with no duplications. Participants were instructed to blindly pull one slip of paper from the container. The number that was pulled from the container represented the number of balls the participant could draw from a bingo wheel. After drawing a number from the container (2, 4, or 6), participants then chose whether to draw that number of balls from the bingo wheel (i.e., 2, 4, or 6 balls) or smoke a 25 mg dose of cocaine (See Figure 1 for a graphical representation of the design and laboratory session). Slips of paper were not returned to the container until all three numbers had been drawn once (sampling without replacement); participants were aware when the three slips were being returned to the container.

There were 20 balls in the bingo wheel, and each ball was labeled with a monetary amount ranging from \$0 – \$20. Participants did not know the dose of cocaine, but were told that the dose would be the same throughout the protocol. Thus, there were two sets of three choices per laboratory session (the choice between drawing bingo balls out of the wheel versus smoking cocaine), or six total choices per morning and afternoon sessions. Each set of 3 choices is referred to as a "Block" of choice, thus, there were 2 blocks per laboratory session, and 4 blocks of choices per day of laboratory sessions (Figure 1). The blocks are referred to as AM1, AM2,

PM1, and PM2. The 25 mg dose of smoked cocaine was chosen because in an earlier study (Foltin & Haney, 2000) no dose had to be withheld due to elevated cardiovascular activity. Cocaine free-base was prepared by the New York State Psychiatric Institute Pharmacy (Foltin et al., 1990).

2.4. Apparatus

During sessions, participants sat in a reclining lounge chair in a quiet test room in front of a computer monitor that displayed subjective-effects questionnaires. The electrocardiogram was continuously monitored via chest electrodes (Tektronix 413 Monitor®, Beaverton, OH; MAC PC®, Marquette Electronics, Milwaukee, WI), while HR and blood pressure [systolic (SP) and diastolic (DP)] were recorded every 2 minutes (Sentry II, Model 6100 automated vital signs monitor, NBS Medical, Costa Mesa, CA) beginning 20 minutes before each session. An Apple Macintosh computer located in an adjacent room was used for automated data collection.

2.5. Procedure

While inpatient, participants had access to television, radio, telephone, videotaped/DVD movies, and tobacco cigarettes while not participating in a session. They could not leave the unit unescorted by research staff and could not receive visitors. Each participant completed a total of 14 laboratory sessions that were approximately 2.5 hour long: two sessions per day were conducted on study days 4, 5, 6, 7, 8, 18, and 19. Participants made 6 choices during each laboratory session. During sessions, research nurses located in the adjacent room continuously observed participants through a one-way mirror, and communication was possible via an intercom system. For ease of reference when describing results, laboratory session days are the only days counted, and are referred to as Session Days 1–5 (the pre-abstinence binge), and Session Days 6–7 (the post-abstinence binge).

Sessions started at approximately 09:30 and 13:30. Intravenous access was maintained via a saline lock (placed before sessions) as a precaution in case of an untoward reaction to cocaine; none occurred during the study. Baseline measurements of cardiovascular activity and subjective-effects were obtained during the first 20 minutes. At the start of each session, participants received an explanation of the procedure, then proceeded directly to picking numbers for the game of chance from the container, and making their choice. Cocaine smoking was accomplished by placing a metered dose of cocaine base in an 10 cm glass tubing, or 'stem,' packed with fine metal mesh. Participants held the glass stem while the research nurse vaporized the cocaine with the flame from a cigarette lighter; the dosing procedure was considered finished when the participant had completely inhaled the vaporized cocaine. Participants were blindfolded to maximize the likelihood that subjective responses were based on the effect of the cocaine dose rather than the perceived size of the rock.

Choices occurred at 14 minute intervals. A cocaine dose was not given on any trial in which cardiovascular activity was above our established criteria for drug administration. Cardiovascular criteria for withholding a dose were as follows: (1) Systolic Pressure >160 mm Hg, sustained for longer than 6 minutes (i.e., > 3 consecutive readings); or (2) Diastolic Pressure > 100 mm Hg, sustained for longer than 6 minutes immediately prior to dosing ; or (3) HR > $(220 - \text{participant's age}) \times 0.85$ bpm, sustained for 6 minutes immediately prior to dosing. No doses were withheld due to vital signs exceeding these criteria.

2.6. Participant Fees

Participants were paid \$15 for each visit during pre-admission screening. Once admitted, participants were paid \$60 per night if they completed the study (\$30 per night if they left the study early) during the drug free days. During the days involving laboratory sessions, participants' base pay was \$30 per night, and money earned from the game of chance was the

bonus payment for that day. Total actual amounts earned from playing the game of chance ranged from \$0 to \$1,565. Participants were not presented with the money immediately when they earned it (although most kept a tally of their earnings), rather, they received their payments in weekly installments commencing upon discharge.

2.7. Statistical Analyses

Number of choices for cocaine was nested by Day, Block, or Number of Balls Drawn, and was treated as a continuous measure. It was hypothesized that the choice for cocaine would vary as a function of the magnitude of the alternative reinforcer (number of bingo balls drawn from the wheel). We additionally hypothesized that the choice for cocaine would increase after a period of abstinence, and would be greater once a binge was underway ($AM2 > AM1$, $PM2 > PM1$). Thus, repeated measures analyses of variance were employed to analyze these data. Within-subjects factors included magnitude of the alternative reinforcer (3 levels: two, four, or six bingo balls drawn); binge (2 levels: pre-abstinence, post-abstinence); time within session (4 levels: AM1, AM2, PM1, PM2) or day (2 levels: Day 1, Day 5; or Day 6, Day 7). Planned contrasts were conducted to examine the differences within the levels of each factor, and between the two binge periods. To avoid potential Type 1 errors, comparisons were only considered significant if $p \leq .01$. SuperANOVA (Abacus Concepts, Inc.) software was employed for data analysis.

3. Results

Effects of Alternative Reinforcer

Figure 2A depicts the average percentage of choices for cocaine as a function of the magnitude of the alternative reinforcer, pre- and post-abstinence. There was a main effect of the number of bingo balls drawn from the wheel [$F_{(2,18)} = 10.70$, $p = .0009$], yet there was no significant interaction with binge. During the pre-abstinence binge, cocaine was chosen an average of 86% of the choices when the alternative was 2 bingo balls, 73% of choices when the alternative was 4 bingo balls, and 51% of the choices when the alternative was 6 bingo balls. During the post-abstinence binge, cocaine was chosen on 90%, 89%, and 64% of the choices where the alternatives were 2, 4, and 6 bingo balls, respectively. Planned comparisons revealed that there were fewer choices for cocaine when the alternative was the opportunity to draw 6 bingo balls versus when the alternative opportunities were to draw 4 or 2 bingo balls within both pre-abstinence and post-abstinence binges (all p 's $\leq .01$).

The dollar amounts per draw from the wheel ranged from \$0 – \$58, while the largest amount won per block of choices was \$95. Amount won varied as a function of number of balls drawn. The average ($\pm$ SD) dollar amounts won, pre-abstinence, when 2, 4, or 6 balls were drawn, were \$1 (± 3), \$5 (± 7), and \$15 (± 11), while the average amounts won post-abstinence were \$2 (± 5), \$4 (± 8), and \$12 (± 13). Average dollar amounts earned per block pre-abstinence were approximately \$7 (± 10), while average amounts earned per block post-abstinence were approximately \$6 (± 9). There were no differences between pre- and post-abstinence amounts won, nor between blocks of winning amounts.

Effects of Abstinence

There were no significant differences in mean proportion of choices for cocaine as a function of binge period: pre-abstinence binge $M = 70\%$, post-abstinence binge $M = 81\%$ choices for cocaine (Fig 2A). However, planned comparisons investigating the effects of abstinence as a function of number of bingo balls drawn revealed that even when there was a greater potential to earn money, participants chose to smoke more cocaine post-abstinence than pre-abstinence [4 bingo balls: $p = .002$; 6 bingo balls: $p = .008$].

Effects of Time Within-Session

Figure 2B depicts the proportion of choices for cocaine as a function of pre- and post-abstinence binge and time within session. There was a significant effect of time within session during the pre-abstinence binge [$F_{(3,27)} = 4.92$, $p = .008$], with participants choosing cocaine more once the first binge session was underway (AM2 > AM1; 75% vs. 67%, $p = .01$). There were no differences between the first and second blocks of afternoon choices during the pre-abstinence phase, although the effect approached statistical significance (PM1 = PM2, $p = .02$). Participants also chose fewer doses during the first afternoon session than they had during the second morning session (PM1 < AM2; 75% vs. 65%, $p = .001$). These subtle shifts did not exist within the post-abstinence binge. Planned comparisons of time within sessions between the pre-abstinence and post-abstinence binges revealed that cocaine was chosen a greater percentage of the time in the post-abstinence binge during both afternoon blocks (PM1: Post > Pre, $p = .0001$, and PM 2: Post > Pre, $p = .01$), while the difference approached statistical significance for the AM1 block ($p = .02$).

Effects of Binge

Figures 3A and 3B depict the average percentage of choices for cocaine during the first and last day of the pre-abstinence binge as a function of number of bingo balls drawn (3A) and time within session (3B). Figures 3C and 3D depict the proportion of choices for cocaine during the two-days of the post-abstinence binge, again as a function of number of bingo balls drawn (3C) and time within session (3D). These data reflect the differences in pattern of self-administration within each binge, namely, session Day 1 versus session Day 5, and session Day 6 versus session Day 7. While there was no main effect of Day, and the effect of the magnitude of the alternative reinforcer only approached statistical significance ($p = .02$), participants chose less cocaine on Day 1 than Day 5 when the alternatives were four balls ($p = .007$) and six balls ($p = .007$), Figure 3A. Participants also chose less cocaine on Day 1 versus Day 5 during each block: AM1 ($p = .004$), AM2 ($p = .001$), PM1 ($p = .004$), PM2 ($p = .01$), Figure 3B. These differences did not exist across Days 6 and Days 7 (Figures 3C and 3D). To summarize, cocaine choice was greatest after a 9 days of abstinence (post) and at the end of a 5-day binge.

4. Discussion

This model of cocaine self-administration involved playing a game of chance for monetary gain. For each of 3 consecutive choices, participants drew 1 number from a container (that held the numbers 2, 4, or 6) and subsequently chose between selecting that number of balls from a bingo wheel (where balls were worth varying amounts of money), or smoking a dose of cocaine. After each set of 3 choices, the numbers were returned to container for the next set of 3 choices. In this way, the order of selected choices was different for each participant within each block of 3 choices. Thus, the choice to self-administer cocaine was not related to the order in which the alternative reinforcer was presented, nor the number of cocaine doses received previously, as has been the case with prior studies (Donny et al., 2003, 2004; Richardson and Roberts, 1996; Walsh et al., 2001). This game of chance was a competitive option that led to a decrease in choice to self-administer cocaine during a 5-day binge before, and a 2-day binge after 9 days of abstinence.

Cocaine self-administration is a robust behavior that typically does not respond to alternatives once cocaine use has been initiated (Donny et al., 2003, 2004; Haney, 2009; Haney and Spealman, 2008; Walsh et al., 2001). It is notable, then, that choices to play the game of chance were made when cocaine taking was already underway: when the shift took place, it was always in response to the option of drawing 6 bingo balls, i.e., the largest alternative reinforcer. To the best of our knowledge, this is the first model to shift cocaine self-administration during a

binge. Thus, this novel procedure has strengthened our current laboratory model of cocaine self-administration by providing a salient, immediate, non-drug alternative to cocaine, while taking into account the impact of recent drug-use history (e.g., recent abstinence).

When participants picked the alternative of drawing 6 balls from the bingo wheel, they chose to smoke cocaine 30% less on average than when the alternative was 2 bingo balls. The size of this difference was somewhat larger during the pre-abstinence binge (35% less) than the post-abstinence binge (26% less) suggesting that abstinence decreases the elasticity of cocaine self-administration, at least for non-treatment seekers. In support of this hypothesis, these data show that participants smoked more after the period of abstinence, particularly in the face of greater potential opportunities to win money. However, participants also smoked more at the end of the pre-abstinence binge than the beginning, perhaps because they were aware of the period of impending abstinence, suggesting that there was a smaller effect of the magnitude of the alternative reinforcer both at the end of the binge and after a period of abstinence.

Further insight into the pattern of cocaine use can be gained by examining the data within the pre-abstinence (Day 1 vs. Day 5) and post-abstinence (Day 6 vs. Day 7) binges. Participants chose less cocaine as a function of increasing bingo balls on both the first and last day of the pre-abstinence binge indicating that the effect of the alternative varied systematically and consistently with the perceived value of the alternative. However, participants chose more cocaine on Day 5 than Day 1 when 4 and 6 balls were drawn from the wheel, indicating that even though the number of choices for cocaine decreased as a function of number of balls drawn, it also increased as a function of binge length, i.e., the value of a fixed cocaine dose increased as the binge progressed. Further support for this conclusion is based on the finding that participants always chose more cocaine on Day 5 than on Day 1 across the pre-abstinence binge regardless of the value of the alternative reinforcer. These differences did not exist within the post-abstinence binge. This suggests that it either was more difficult to shift smoking patterns with an alternative reinforcer after an extended period of abstinence, or after 1 day of cocaine taking, but not 4.

That cocaine self-administration was greater and the alternative was less reinforcing after the 9-day period of abstinence is perhaps not surprising, given data that has been generated in preclinical studies. It has been suggested that both the length of access to cocaine as well as the period of abstinence (7–10 days as compared to 1 day) are important variables to contemplate when studying the reinforcing efficacy of cocaine (Morgan and Roberts, 2004; Roberts et al., 2007). It is unclear what accounts for the increase in cocaine choice during the first 5-day binge. Perhaps the decrease in the value of the alternative reinforcer reflects the experience of several days of repeated cocaine self-administration, during which cocaine became a more valued reinforcer. However, it is also possible that the reinforcing efficacy of cocaine increased because participants knew that a cocaine-free phase was beginning after the fifth session day. The former hypothesis provides information about the difficulty of stopping a binge that is in progress, while the latter hypothesis provides information about how perceived drug availability affects drug use.

There is something appealing in this game of chance that is not present with money alone. Even though the money won was, in itself, a delayed reinforcer, the act of playing the game of chance was an immediate reinforcer, supporting the notion that immediate alternative reinforcers may be a critical component of self-administration paradigms (Haney and Spealman, 2008). There was an inherent risk involved in drawing the balls (there were four \$0 balls, so it was possible that when 4 or fewer balls were drawn, the amount won could have been \$0; some monetary gain had to occur when the number of balls chosen exceeded 4) but also a chance of larger earnings which made it appealing (see Petry et al., 2000, 2004, 2005).

Concerns have been expressed about similar games of chance raising the likelihood of increased gambling, yet data have shown that such procedures do not increase gambling behaviors *per se* (Petry et al., 2006). In fact, in alcohol-dependent individuals, playing a game of chance that involved drawing vouchers that represented no prize, or small, medium or large prizes from a bowl, was shown to increase treatment retention, increase time to first alcohol use, and increase time to relapse, when compared to those who only received a standard treatment without the opportunity to draw vouchers worth prizes (Petry et al., 2000).

Limitations within the study temper our conclusions. Although participants were given a tally sheet, money was still not physically given to them until the end of the study, which may have had an effect on the perceived value of this alternative. It is possible that the value and the effect of game playing would have been greater if participants received the monetary reinforcer in the same proximity to the choice point as the cocaine reinforcer. A potential solution to this predicament would be to have participants hold their money during the sessions so they would have a direct and physical sense of money earned. The laboratory could then hold the money for safe-keeping until the conclusion of the study.

While the shifts in self-administration were encouraging, overall, participants still selected cocaine far more than playing the game of chance to earn money, perhaps because cocaine use was initiated after they chose their first dose. Nevertheless, this also suggests possible areas in which to improve the model. For instance, it might be interesting to work with a greater range of alternative magnitudes, for example, from 2 to 10 bingo balls. Many questions could be answered with a wider range of choices, such as if there were a value that represented the 50/50 mark whereby participants were just as likely to select money as cocaine, or if there were a value whereby participants would not smoke cocaine. Finally, it would be of interest to estimate the reinforcing value of both cocaine and playing the game of chance independently by using progressive ratio procedures. It could then be determined how well the breakpoint values predicted choice behavior, and if the independent values established during the progressive ratio procedure determined the concurrent value of the choice. To conclude, in human laboratory models of medication development, better alternative reinforcers are needed. The game described herein may be such an alternative, and may allow more sensitive detection of medication effects (Haney and Spealman, 2008).

To conclude, better immediate, alternative reinforcers are needed in human laboratory self-administration models. The game described herein may be useful in this regard. In addition to providing an intriguing new set of possibilities for laboratory models, this procedure also lends itself to medications development, where an increase in number of choices to play this game of chance may be one manner by which to measure medication effects (Haney and Spealman, 2008). Thus, this game of chance may assist in the development of methods by which to shift cocaine self-administration in the laboratory.

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Figure 1.
Schematic of Laboratory Session Procedures: Morning (Upper) and Afternoon (Lower) Choice Sessions.

Figure 2. Average Percentage of Cocaine Choices as a Function of: the Magnitude of the Alternative Reinforcer, or Number of Balls Drawn (**A**); and Time Within Session, or Block (**B**). Lines connecting bars represent within- binge period differences, * represents between binge period differences ($p \leq .01$ for all comparisons).

Figure 3.

Average Percentage of Cocaine Choices Pre- and Post-Abstinence as a Function of: Magnitude of the Alternative Reinforcer (Number of Balls Drawn), Days 1 and 5 (**A**); Time Within Session (Block), Days 1 and 5 (**B**); Magnitude of the Alternative Reinforcer (Number of Balls Drawn), Days 6 and 7 (**C**); and Time Within Session (Block), Days 6 and 7 (**D**). Lines connecting bars represent within-binge period differences, * represents between binge period differences ($p \leq .01$ for all comparisons).