

Exploring the Limits and Utility of Operant Conditioning in the Treatment of Drug Addiction

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This article describes a research program to develop an operant treatment for cocaine addiction in low-income, treatment-resistant methadone patients. The treatment's central feature is an abstinence reinforcement contingency in which patients earn monetary reinforcement for providing cocaine-free urine samples. Success and failure of this contingency appear to be an orderly function of familiar parameters of operant conditioning. Increasing reinforcement magnitude and duration can increase effectiveness, and sustaining the contingency can prevent relapse. Initial development of a potentially practical application of this technology suggests that it may be possible to integrate abstinence reinforcement into employment settings using salary for work to reinforce drug abstinence. This research illustrates the potential utility and current limitations of an operant approach to the treatment of drug addiction. Similar research programs are needed to explore the limits of the operant approach and to develop practical applications that can be used widely in society for the treatment of drug addiction.

Key words: operant conditioning, reinforcement, contingency management, drug addiction, drug abuse, treatment

Controlled studies in nonhumans and in humans, in the laboratory and in the clinic, have provided compelling evidence that drug addiction can be viewed as operant behavior and effectively treated through the direct application of operant conditioning. The relevance of operant principles to the understanding of drug addiction was suggested in early laboratory studies that showed that drugs could serve as robust reinforcers in nonhuman subjects (e.g., Pickens & Thompson, 1968; Thompson & Schuster, 1964). Early

studies in rhesus monkeys also revealed the potential devastating consequence of drug reinforcement. Rhesus monkeys given virtually unlimited access to cocaine, *d*-amphetamine, or *d*-methamphetamine persistently self-administered those drugs until death, which occurred within days (Johanson, Balster, & Bonese, 1976). Under more restricted conditions, rhesus monkeys given repeated choice trials between cocaine and food chose cocaine almost exclusively, resulting in high levels of cocaine intake, reduced food intake, weight loss, and behavioral toxicity (Aigner & Balster, 1978). Despite the seemingly overwhelming power of drug reinforcement revealed in these studies, hundreds of studies conducted during and since the 1960s have shown that drug self-administration, like other operant behaviors, is highly malleable; it can be increased or decreased by manipulating the same range of variables (e.g., schedule and magnitude of reinforcement, punishment, reinforcement of alternative incompatible behaviors, price) that have been shown to be effective in modifying other operant behaviors (Johanson & Schuster, 1981;

Preparation of this article was supported by Grants R01 DA12564, R01 DA13107, R01 AA12154, and R01 DA10754 from the National Institutes of Health. I thank all of the colleagues who collaborated on substantial parts of the research program reviewed in this article, including Kenzie L. Preston, Charles R. Schuster, Stephen T. Higgins, Maxine L. Stitzer, George E. Bigelow, Dace Sviki, Conrad J. Wong, and Michael J. Grabinski, and the large numbers of staff who are too numerous to name, but who made important contributions to this research.

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Spealman & Goldberg, 1978). Studies in humans showed remarkable similarities to nonhuman drug self-administration (Griffiths, Bigelow, & Henningfield, 1980).

Operant principles have been applied to the treatment of drug addiction in various ways, from providing a conceptual framework for behavioral counseling (e.g., Budney & Higgins, 1998; Sisson & Azrin, 1989) to contingency management interventions, which arrange direct reinforcement to promote important clinical behaviors (Higgins & Silverman, 1999). Nowhere has the application of operant principles to the treatment of drug addiction been more useful or informative than in the direct reinforcement of drug abstinence (Bigelow, Stitzer, Griffiths, & Liebson, 1981). Reinforcement for drug abstinence is arranged by collecting routine biological measures of drug use (e.g., urine samples), then arranging reinforcement when a biological sample (or series of samples) confirms recent abstinence (e.g., when a urine sample tests negative for drugs), and withholding reinforcement when the sample indicates that a patient had used drugs recently. Many types of drug use can be conveniently and objectively measured through the collection and testing of biological samples. Given the appropriate type (e.g., urine or breath samples) and frequency of collection, and the use of rigorous collection procedures that ensure valid sample collection (e.g., observed collections), most instances of an individual's drug use can be detected, thereby providing an objective measure of drug use and abstinence.

Over almost 30 years, abstinence reinforcement has been shown to be effective in promoting abstinence from all classes of commonly abused drugs and in diverse populations (Higgins & Silverman, 1999). Despite the promise of abstinence reinforcement demonstrated in this research, much work remains to ensure the successful and widespread application of abstinence reinforcement interventions. This arti-

cle describes a focused program of research to develop an effective and practical abstinence reinforcement intervention for a selected treatment population: methadone patients who continue to use cocaine during methadone treatment. This research illustrates the potential utility and current limitations of abstinence reinforcement in the treatment of drug addiction, as well as challenges that remain if abstinence reinforcement is going to be used widely and with optimal effectiveness.

DEVELOPING AN OPERANT TREATMENT FOR DRUG ADDICTION: AN ILLUSTRATIVE EXAMPLE

Baltimore, Maryland, is plagued by high rates of heroin and cocaine addiction. Baltimore had the highest rate of emergency-room mentions for both heroin and cocaine of major metropolitan areas from 1995 through 1999, and continues to report some of the highest rates in the nation (Office of Applied Studies, 2003a). Heroin and cocaine use has been a particular source of concern because of its role in fueling the AIDS epidemic. The sharing of injection equipment is one of the primary means by which human immunodeficiency virus (HIV) is transmitted (Grund et al., 1996). Injection drug use is the second most common means of exposure to HIV in the U.S., accounting for about 25% of the AIDS cases (Centers for Disease Control and Prevention, 2002). In Baltimore, injection drug use is the most common mode of exposure to HIV infection, accounting for about 50% of HIV cases reported (Maryland AIDS Administration, 2003). Heroin and cocaine are two of the most commonly injected drugs (Office of Applied Studies, 2003b).

Methadone is one of the most effective treatments for heroin addiction (National Consensus Development Panel on Effective Medical Treatment of Opiate Addiction, 1998) and is used widely in Baltimore (Maryland Alco-

hol and Drug Abuse Administration, 2003). However, many methadone patients use cocaine at high rates. As much as 40% of methadone patients meet DSM criteria for cocaine dependence (Hser, Anglin, & Fletcher, 1998). Methadone treatment appears to be "relatively ineffective in reducing cocaine use" (Hser et al., p. 513). No pharmacotherapies and few psychosocial treatments have been shown to be effective in reducing cocaine use (Rawson, McCann, Hasson, & Ling, 1994; Silverman, Bigelow, & Stitzer, 1998).

Voucher-Based Reinforcement of Cocaine Abstinence in Methadone Patients

Abstinence reinforcement has been used effectively in methadone patients to promote abstinence from a range of drugs (Stitzer, Iguchi, Kidorf, & Bigelow, 1993). However, by the early 1990s, studies had not shown that abstinence reinforcement could be effective in promoting abstinence from cocaine in this population. At that time, Higgins and his colleagues had developed a promising abstinence reinforcement intervention to treat primary cocaine-dependent patients (Higgins et al., 1991). Under that intervention, patients provided urine samples three times per week and earned monetary vouchers exchangeable for goods and services for cocaine-free urine samples. Vouchers were used instead of cash to reduce the chance that patients could use their earnings to purchase drugs. An important feature of the voucher intervention was that patients earned vouchers under a schedule of escalating reinforcement for sustained abstinence. Under this schedule, the monetary value of the vouchers started low and then increased by a fixed amount for every consecutive cocaine-free urine sample provided. If a patient ever provided a cocaine-positive urine sample or failed to provide a scheduled sample, the patient did not receive a voucher

and the value of the next voucher was reset back to the initial low value. Implemented over a 12-week period, patients could earn up to about \$1,000 in vouchers. Combined with a behavioral counseling intervention, this voucher intervention produced some of the most impressive published results in the treatment of primary cocaine-dependent patients (Higgins et al., 1991, 1993; Higgins, Budney, et al., 1994).

We conducted our first study to examine the effectiveness of voucher-based abstinence reinforcement in treating persistent cocaine use in methadone patients in Baltimore. The participants in this first study were individuals who showed physical evidence of injection drug use (i.e., track marks) and who provided consistent cocaine-positive urine samples during the first 5 weeks of methadone treatment (Silverman, Higgins, et al., 1996). Patients in this study were randomly assigned to a voucher-based abstinence reinforcement group or to a yoked noncontingent control group. Abstinence reinforcement participants received an intervention modeled after the one developed by Higgins et al. (1991) in which they could earn up to \$1,155 in vouchers for providing cocaine-free urine samples three times per week for 12 weeks. Control participants received vouchers yoked in pattern and amount to vouchers received by patients in the abstinence reinforcement group, but the vouchers were delivered independent of their urinalysis results.

The effects of the abstinence reinforcement intervention were dramatic (Figure 1). Almost half of the patients in the abstinence reinforcement group (9 of 19 patients) achieved between 7 and 12 weeks of abstinence during the 12-week period. In contrast, no patient in the yoked control group achieved over 6 weeks of abstinence. In a field that had failed to find effective treatments for cocaine abuse in methadone patients, these effects were striking.

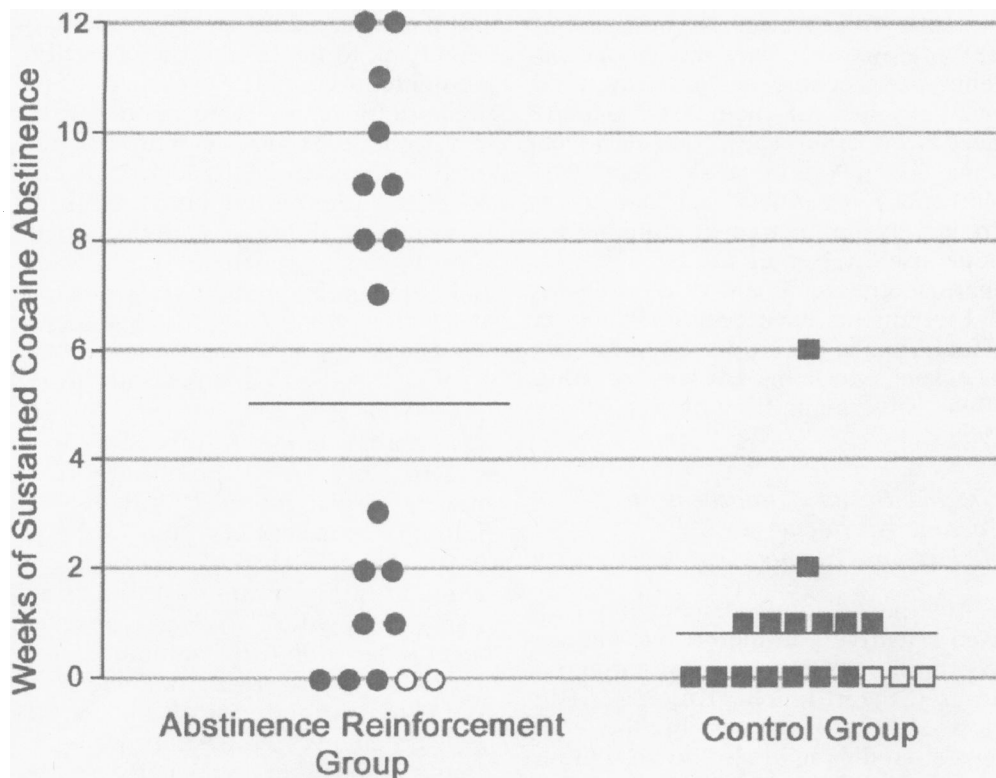


Figure 1. Longest duration of sustained cocaine abstinence achieved during the 12-week voucher condition. Each point represents data for an individual patient, and the lines represent group means. The 19 abstinence reinforcement patients are displayed in the left column (circles) and the 18 control patients in the right (squares). Open symbols represent patients who dropped out of the study early. From Silverman, Higgins, et al. (1996, p. 413; copyright by the American Medical Association, reprinted with permission).

Improving the Effectiveness of Voucher-Based Abstinence Reinforcement

The initial study showed the potential effectiveness of this intervention for many methadone patients. However, the study also revealed an obvious limitation of the intervention. About half of abstinence reinforcement patients (10 of 19 patients) failed to achieve over 3 weeks of abstinence. Addressing treatment failures is important, for both clinical and conceptual reasons. Clinically, the patients who fail to achieve abstinence appear to have the highest rates of cocaine use (Preston et al., 1998; Silverman, Higgins, et al., 1996). Whatever adverse consequences are associated with persistent injection of cocaine, these treat-

ment-resistant patients must pose the greatest risks to themselves and society. Conceptually, the treatment failures raise questions about our understanding of the persistent cocaine use in these patients. The study failed to show that the cocaine use of these treatment failures is sensitive to its consequences and is operant in nature.

Manipulating the schedule of reinforcement. To promote abstinence in a larger proportion of patients, a second study examined the effects of a modified schedule of voucher reinforcement (Silverman, Wong, et al., 1998). The initial study used an escalating schedule of reinforcement for sustained abstinence in which patients could earn low-magnitude vouchers at the start of treatment. The magnitude of the

vouchers then increased gradually as the duration of a patient's abstinence increased. Suspecting that the small reinforcement magnitude available early in the program might have been insufficient to initiate abstinence, a second study evaluated a schedule that combined large start-up bonus vouchers (\$50 vouchers) with the schedule of escalating reinforcement for sustained abstinence. In this study, injection-drug-using methadone patients who continued to use cocaine during treatment were randomly assigned to receive the novel schedule that combined the start-up bonus vouchers with the schedule of escalating reinforcement for sustained abstinence, to receive an escalating schedule of reinforcement for sustained abstinence alone, or to a noncontingent voucher control condition. Participants in the two abstinence reinforcement groups achieved significantly higher rates of cocaine abstinence than participants in the control condition; however, the addition of the start-up bonuses had no additional benefit over the escalating schedule alone. This study confirmed the overall effectiveness of voucher-based abstinence reinforcement, but it also provided an early and humbling indication of the difficulty of succeeding with a substantial proportion of patients who continued to use cocaine despite our best efforts to arrange effective abstinence reinforcement.

Effects of reinforcement magnitude in treatment-resistant patients. Faced with the difficult challenge of promoting abstinence in the most treatment-resistant patients, we designed research to examine an obvious and simple parameter of the abstinence reinforcement intervention: the reinforcement magnitude. Both logic and prior research (e.g., Higgins, Bickel, & Hughes, 1994; Nader & Woolverton, 1991) suggested that increasing reinforcement magnitude should improve the effectiveness of the intervention. Given the persistence of the cocaine use we had seen in previous studies under the standard voucher intervention,

it seemed that a major increase in magnitude would be required to affect the most persistent cocaine use. We considered tripling the standard reinforcement magnitude. Although such an increase seemed reasonable from a scientific and logical perspective, many observers considered such an increase a foolish option, given the obvious impracticality of using magnitudes in that range in current treatment programs. Through conversations and in reviews of prior voucher studies submitted for publication, it was clear that many people considered the standard voucher intervention, in which participants could earn up to about \$1,000 over 12 weeks, extreme. Discussions of the prospect of using magnitudes in the range of \$3,000 in vouchers over a similar period raised still more objections and even emotional responses. Despite such objections, it seemed important to examine the effectiveness of high reinforcement magnitude to explore the limits of this approach. If it was effective, we then could look for a means of practically arranging such reinforcement magnitudes. Indeed, this general philosophy of separating the exploration of scientific principles and practical utility has been a consistent theme in this research program.

We conducted two studies examining the effects of increasing reinforcement magnitude in treatment-resistant patients. One study (Silverman, Chutuape, Bigelow, & Stitzer, 1999) included injection drug users who used cocaine during methadone treatment and continued high rates of cocaine use even when exposed to a standard 12-week voucher intervention in which they could earn up to \$1,155 for providing cocaine-free urine samples. Overall, 96% of the urine samples that these individuals provided during the first 5 weeks of methadone treatment were cocaine positive. When exposed to the standard 12-week voucher intervention, 90% of their samples were still cocaine positive. Following exposure to the standard voucher intervention that failed to promote sustained

abstinence, these patients were exposed in counterbalanced order to three 9-week voucher conditions that varied in magnitude of voucher reinforcement; the voucher periods were separated by 4-week washout periods. Each patient was exposed to a zero-, low-, and high-magnitude condition in which they could earn up to \$0, \$382, or \$3,480 in vouchers for providing cocaine-free urines, respectively. Only 1 patient (5%) achieved more than 2 weeks of sustained abstinence when exposed to a low-magnitude condition, and no patients achieved more than 2 weeks of abstinence in the condition in which vouchers had no monetary value. In contrast, when participants were exposed to the high-magnitude condition, about half (45%) of the patients achieved 4 or more weeks of sustained cocaine abstinence (Figure 2).

This study showed that even the persistent cocaine use of about half of these treatment-resistant patients could be controlled by abstinence reinforcement and was sensitive to its consequences. These data provide additional evidence of the operant and orderly nature of persistent cocaine use in clinical populations. The cocaine use of these patients does not appear to be qualitatively different from others who have responded to lower reinforcement magnitudes.

It is important to note that the study also illustrates the intervention's limitations. Despite offering participants over \$3,000 for providing cocaine-free urine samples over 9 weeks (Silverman et al., 1999), cocaine use persisted essentially unchanged in more than half the participants. It seems likely that the drug use of even these patients could ultimately be controlled by abstinence reinforcement, but that remains to be seen. Similar results were obtained in another study in which reinforcement was arranged for abstinence from both opiates and cocaine (Dallery, Silverman, Chutuape, Bigelow, & Stitzer, 2001).

Shaping abstinence. All of these studies employed standard qualitative

urinalysis testing. Under that testing method, urine samples are considered positive for cocaine if the concentration of the cocaine metabolite, benzoylecgonine, in the urine sample is at or above 300 ng/ml. However, toxicological studies in chronic cocaine users suggest that some individuals, many of whom achieve urinary benzoylecgonine concentrations exceeding 100,000 ng/ml during active use, may continue to provide urine samples that exceed the standard 300 ng/ml threshold for several days after initiating abstinence (Preston et al., 2002). As a result, using standard qualitative testing, a participant may have to remain abstinent for several days before earning a voucher for a negative sample. To develop a more sensitive method of detecting recent cocaine abstinence, Preston, Silverman, Schuster, and Cone (1997) proposed rules for detecting recent abstinence based on amounts of decreases in benzoylecgonine concentrations across days. To implement these rules, Preston et al. employed quantitative testing, which provided more continuous measures of the benzoylecgonine concentrations.

Reinforcement of cocaine abstinence based on decreases in benzoylecgonine concentrations has been examined under limited conditions. In general, it appears that this method can increase the percentage of people who contact the reinforcement contingency (Preston, Umbricht, Wong, & Epstein, 2001; Robles et al., 2000), it can increase cocaine abstinence relative to a no-reinforcement condition (Katz et al., 2002; Robles et al.), and there is evidence that it can produce better outcomes than abstinence reinforcement based on qualitative urine testing (Preston et al.). As with abstinence reinforcement based on qualitative urinalysis, the studies also show that many patients continue to use cocaine even when they are exposed to these contingencies. Research into the use of quantitative urinalysis to reinforce cocaine abstinence has only just begun, and

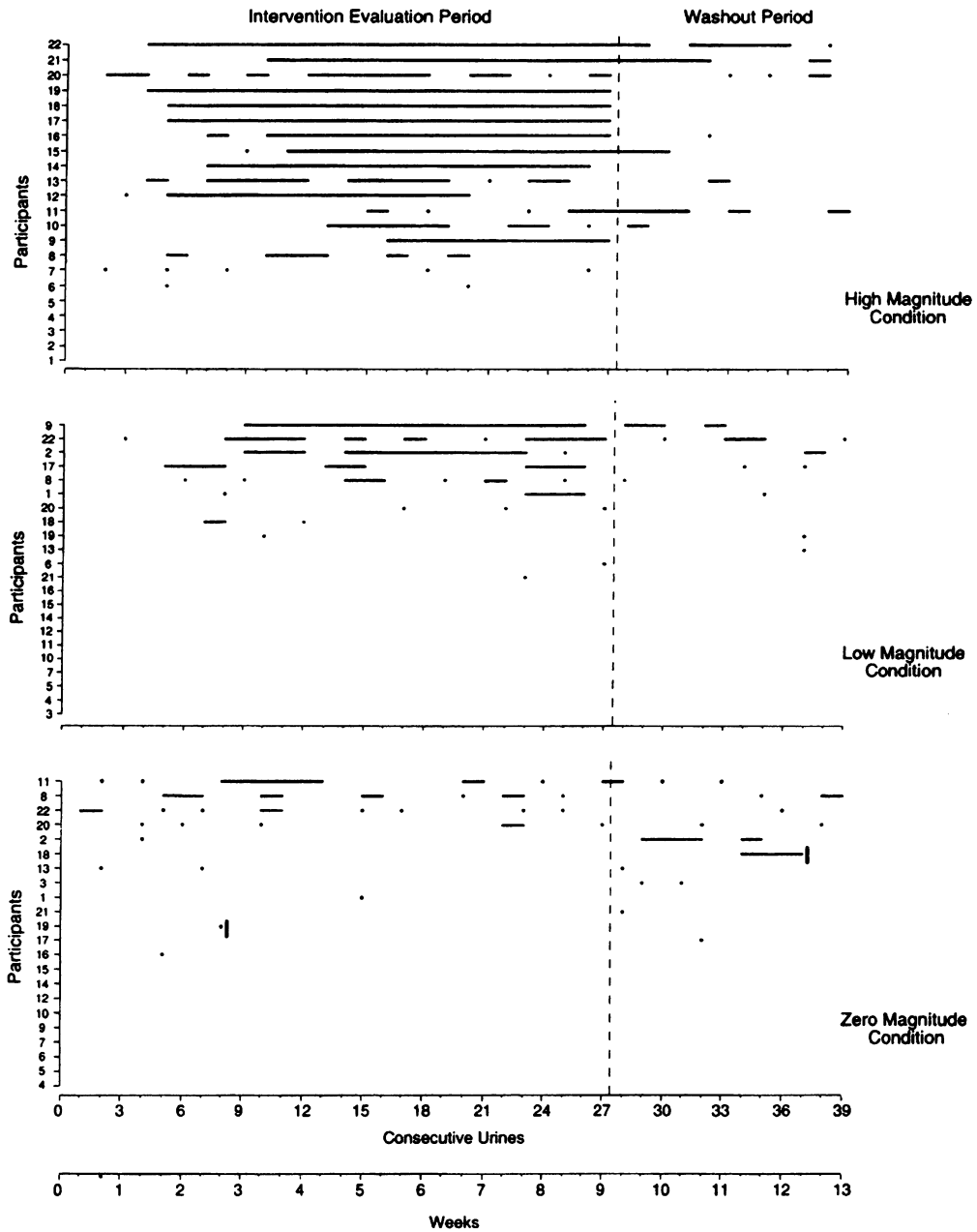


Figure 2. Cocaine urinalysis results across consecutive urine samples for each of 22 participants and for each of their three voucher magnitude conditions. Top, middle, and bottom panels represent data for the high-, low-, and zero-magnitude voucher conditions, respectively. Data for the 9-week voucher conditions are shown in the left portion of each panel; data for the 4-week washout following the voucher condition are shown in the right portion of each panel. Within each panel, each horizontal line represents results for a different individual across the consecutive urine samples of the condition. The solid portions of the lines represent cocaine-negative urinalysis results. Thick vertical dashes indicate when individual participants (Participants 18 and 19) dropped out of the study. In the high-magnitude condition (top), participants are arranged with those showing the least abstinence (fewest cocaine-negative urine samples) on the bottom to participants with the most abstinence on the top. The numerals on the ordinate represent participant numbers. Participant numbers were assigned based on their position in the high-magnitude panel. From Silverman, Chutuape, et al. (1999, p. 134; copyright by Springer-Verlag, reprinted with permission).

much more work will be required to assess the full potential of this method.

*Preventing Relapse After
Discontinuation of the
Voucher Intervention*

Drug addiction is widely considered to be a chronic relapsing disorder (McLellan, Lewis, O'Brien, & Kleber, 2000). Extraordinary studies that have tracked individual life histories of heroin addicts, for example, have shown that patterns of use, abstinence, and relapse repeat over periods as long as 30 to 50 years (Galai, Safaeian, Vlahov, Bolotin, & Celentano, 2003; Hser, Hoffman, Grella, & Anglin, 2001; Vaillant, 1973). Furthermore, many people relapse after treatment is discontinued, and they frequently require multiple treatment episodes (Simpson, Joe, Fletcher, Hubbard, & Anglin, 1999). As with other treatments, in all of the studies described above, many methadone patients exposed to voucher reinforcement of cocaine abstinence have relapsed when the intervention is discontinued. The study that evaluated the effects of increasing reinforcement magnitude in treatment-resistant methadone patients provided a dramatic example of the relapse that can occur (Silverman et al., 1999). The within-subject crossover design used in that study was possible only because patients relapsed to cocaine use soon after an effective voucher intervention was discontinued (Figure 2).

Perhaps the simplest and most likely means of promoting long-term abstinence would be to sustain the intervention for extended periods of time. To examine this possibility, the effects of long-term exposure to voucher-based abstinence reinforcement were examined in 78 injection drug users who continued to use cocaine during the first 10 weeks in a methadone treatment program (Silverman, Robles, Mudric, Bigelow, & Stitzer, in press). Patients were randomly assigned to a usual care control condition or to one of two abstinence reinforcement

groups. After random assignment, all groups received standard methadone maintenance treatment for 1 year, which included daily methadone, weekly counseling, and observed urine sample collections on Monday, Wednesday, and Friday of every week. Patients in the control group received no other services. Throughout the year-long intervention period, patients in one of the abstinence reinforcement groups could earn a take-home methadone dose every day that they provided a urine sample that was negative for opiates and cocaine (take-home-only group). Take-home methadone doses have been shown to function as reinforcers in many methadone patients (e.g., Stitzer, Iguchi, & Felch, 1992). The other abstinence reinforcement group could earn take-home methadone doses under the same rules, but they could also earn vouchers for providing cocaine-free urine samples (take-home-plus-voucher group). Unlike previous voucher studies that restricted voucher interventions to a few months, participants in this study could earn vouchers for an entire year and could earn up to \$5,800 in vouchers for providing cocaine-free urine samples. After the end of the year, all groups continued to receive methadone maintenance for 9 additional weeks. During the postintervention period, patients in the two abstinence reinforcement groups continued to earn take-home methadone doses for providing urine samples that were negative for opiates and cocaine, but no vouchers were available.

Cocaine use by patients in the control group persisted throughout the yearlong study; they provided cocaine-free urine samples on fewer than 20% of the testing occasions. The percentage of cocaine-free urine samples increased to almost 40% in the take-home-only group compared to the control group, although the effect was transient. Cocaine abstinence was greatest in the take-home-plus-voucher group; up to about 60% of their urine samples were negative for cocaine. Re-

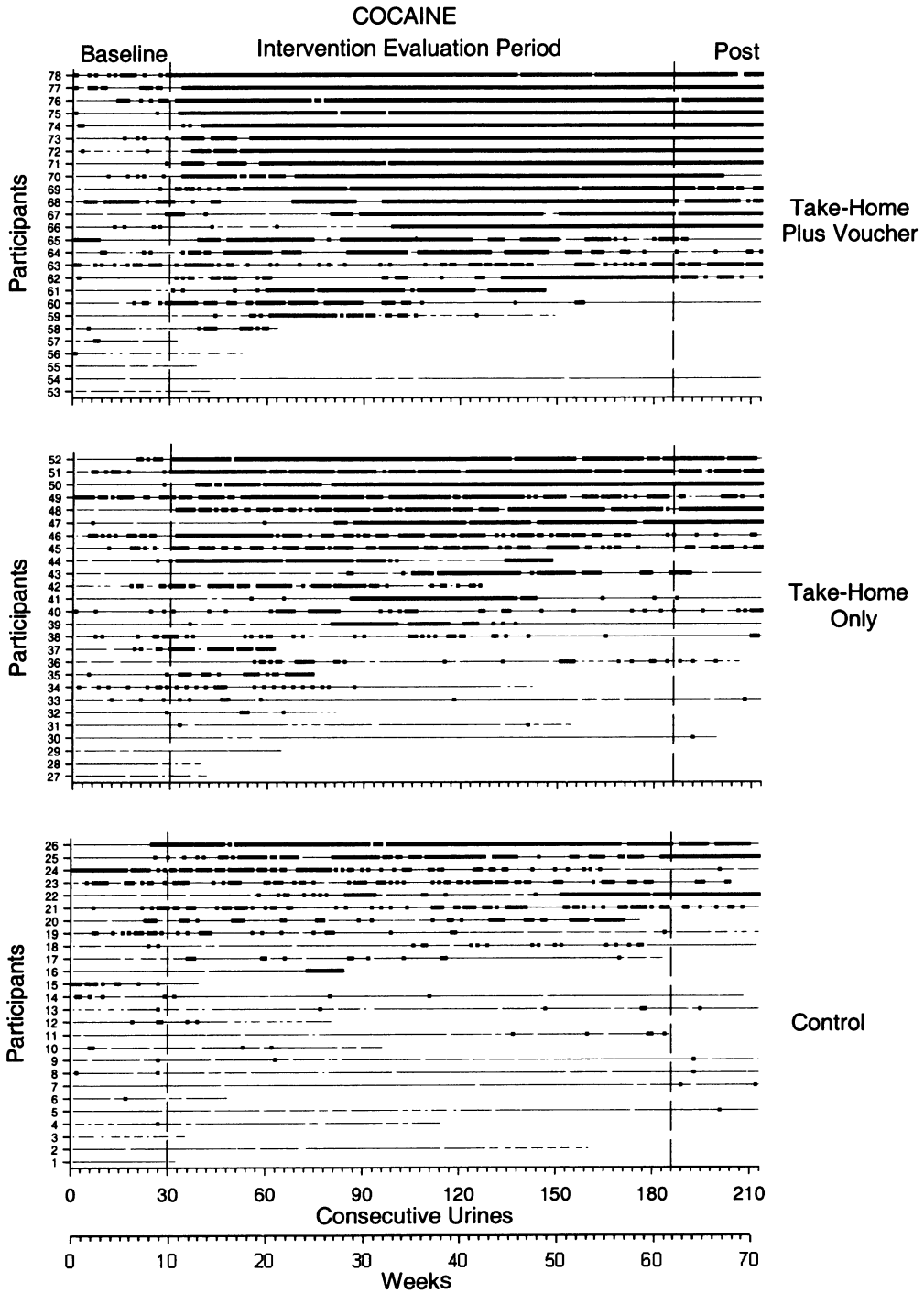
view of the individual urinalysis results shows that patients in the take-home-plus-voucher group who initiated cocaine abstinence usually sustained that abstinence uninterrupted up to the end of the 1-year intervention period (Figure 3). Analyses of data from patients who remained in treatment throughout the intervention and postintervention periods (i.e., completers) showed that take-home-plus-voucher participants maintained the significantly highest rates of cocaine abstinence during the postintervention period, after the voucher intervention had been discontinued. Finally, although participants exposed to the voucher intervention were not required to provide opiate-negative urine samples to earn vouchers, take-home-plus-voucher participants showed dramatic increases in opiate abstinence relative to the other two groups. This indirect effect of voucher reinforcement of cocaine abstinence on opiate use had been seen in previous studies (Silverman, Higgins, et al., 1996; Silverman, Wong, et al., 1998), although the previous effects were much less robust.

Overall, long-term abstinence reinforcement had two important effects on cocaine abstinence. First, it appeared to prevent relapse, at least as long as the intervention was in effect, and possibly longer. The second effect was somewhat unexpected but dramatic. Participants exposed to long-term voucher-based abstinence reinforcement showed a progressive increase in abstinence over the yearlong intervention. This effect was particularly striking in reviewing the percentage of participants who were completely abstinent across each of the four consecutive 13-week blocks of the 52-week intervention period. No more than 4% of the control and the take-home-only participants were cocaine abstinent throughout any of the 13-week blocks. In contrast, 4%, 23%, 42%, and 38% of the take-home-plus-voucher participants were completely cocaine abstinent in the first, second, third, and fourth consecutive 13-week

blocks of the intervention period, respectively. The prior studies of short-term (e.g., 12 weeks) exposure to voucher-based abstinence reinforcement showed rates of complete abstinence that were similar to the rates observed in the first 13 weeks of the 52-week intervention period in this study. In the first study (Silverman, Higgins, et al., 1996), for example, only 2 of 19 participants (10%) were continuously abstinent throughout the 12-week intervention period (Figure 1). The highest rates of continuous cocaine abstinence were not achieved in the present study until after 6 months of exposure to the voucher-based abstinence reinforcement intervention. Review of the data from individual participants (Figure 3) showed that this effect was partially due to the fact that some participants did not initiate sustained cocaine abstinence until after many months of exposure to the reinforcement intervention.

*The Therapeutic Workplace:
A Practical Application of
Abstinence Reinforcement*

The effects of voucher-based reinforcement of cocaine abstinence in methadone patients were encouraging, particularly in the context of a field that is struggling to find effective treatments for cocaine addiction in this population. But the voucher intervention suffers from an obvious limitation that could preclude its widespread application: its apparent impracticality. Application of voucher-based abstinence reinforcement in typical drug-abuse treatment programs seems unlikely, given the considerable costs of high-magnitude, long-duration reinforcement contingencies that appear to be necessary for many patients and given the limited resources of those treatment programs (McLellan, Carise, & Kleber, 2003). Such reinforcement could be utilized to treat cocaine addiction in methadone patients, but practical vehicles for arranging such reinforcement may be required to



move the intervention from concept to application.

Over the past several years, we have been investigating the potential of using employment as such a vehicle. Employment has several features that could make it an ideal candidate for this role:

1. Workplaces control powerful reinforcers, most notably salary, that could be used to reinforce drug abstinence.

2. Individuals maintain regular contact with their places of employment, which could permit the routine collection of urine samples and reinforcement of abstinence based on urinalysis results.

3. Employment is typically maintained over extended periods of time, which could allow for the long-term maintenance of abstinence reinforcement contingencies.

4. Through the growth of employee assistance programs (EAPs), workplaces are becoming common and accepted providers of substance abuse services (Hartwell et al., 1996; Office of Applied Studies, 2002).

5. Workplaces are everywhere, which could facilitate the dissemination of employment-based abstinence reinforcement contingencies.

To investigate the potential of using employment as a vehicle for the treatment of drug addiction, we developed a model "therapeutic workplace." The therapeutic workplace is a novel employment-based intervention that uses salary for work to reinforce clinically important behaviors. Under this inter-

vention, drug-abuse patients are hired and paid as employees in a model work setting. To promote clinically important behaviors, salary is arranged contingent both on work and on the emission of the clinically important behaviors. To promote cocaine and opiate abstinence, patients are required to provide urine samples negative for cocaine and opiates to gain access to the workplace. A participant who provides a drug-free urine sample can work and earn salary until the next urine sample is scheduled for collection; that next sample must also be negative for cocaine to allow the participant to continue working, and so on. A participant who provides a drug-positive urine sample is not terminated from employment, but must leave the workplace that day. An important part of the intervention is that the participant is encouraged to return the following day to try again. Under this contingency, participants can work and earn salary, but only as long as they remain abstinent from drugs. If a participant can perform productive work that has value to the employer, the employment and the salary-based abstinence reinforcement could be maintained indefinitely at little or no cost to society.

A therapeutic workplace prototype. The therapeutic workplace was initially developed and tested in a group of methadone patients who were enrolled in a state-of-the-art comprehensive treatment program for pregnant and recently postpartum women. From that treatment program, patients were selected for participation in the initial

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Figure 3. Cocaine urinalysis results across consecutive urine samples for individual participants in each of the three experimental conditions. Top, middle, and bottom panels represent data for the take-home-plus-voucher, take-home-only, and usual care control conditions, respectively. The vertical dashed lines divide each panel into three periods, the baseline (left), the intervention (center), and the postintervention period (right). Within each panel, horizontal lines represent the cocaine urinalysis results for individual participants across the consecutive scheduled urine collections of the study. The heavy portion of each line represents cocaine-negative urinalysis results, the thin portions of each line represent cocaine-positive urinalysis results, and the blank portions represent missing urine samples. Within each panel, participants are arranged from those showing the least abstinence (fewest cocaine-negative urine samples) on the bottom to participants with the most abstinence on the top. The numerals on the ordinates represent participant identification numbers. From Silverman, Robles, et al. (in press; reprinted with permission).

study if they were unemployed and continued to use opiates or cocaine during that treatment (Silverman, Svikis, Robles, Stitzer, & Bigelow, 2001a). Those 40 patients were randomly assigned to a therapeutic workplace group or to a usual care control group. Both groups could continue in the treatment program for pregnant and recently postpartum women as long as that treatment was available. Both groups were also monitored, initially through an intensive urine-monitoring schedule (Silverman et al., 2001a) and later (Silverman, Svikis, et al., 2002) through monthly urine sample collections and other assessments. Participants in the therapeutic workplace group were invited to attend the workplace for 4 or more years.

Earlier research indicated that many women in the study population were interested in obtaining a variety of office jobs (Silverman, Chutuape, Svikis, Bigelow, & Stitzer, 1995), so the initial therapeutic workplace was designed to employ participants as data-entry operators. However, that earlier research, like research with other populations of patients in drug treatment (Brewington, Arella, Deren, & Randell, 1987), also indicated that many participants lacked the academic and job skills necessary to perform office jobs. It was clear that a training phase would be required prior to true employment. Thus, the therapeutic workplace was designed as a two-phased treatment: In the initial phase, each participant's job was to participate in an intensive training program designed to establish the skills needed to serve as data-entry operators. Once skilled, participants could progress to the second phase, in which they could serve as data-entry operators in a data-entry business.

During the initial phase, trainees were invited to attend the workplace 3 hr per day every weekday and were paid in vouchers instead of cash to reduce the chance that they would use their earnings to purchase drugs. During each day, trainees participated in intensive and individualized teaching

programs designed to teach basic academic skills including reading, writing, spelling, and math; and job-skills training programs designed to teach typing, keypad, and data-entry skills (Silverman et al., 2001a). In this initial test of the therapeutic workplace, it was unclear whether voucher reinforcement could simultaneously maintain abstinence, attendance, and high levels of productivity on the training programs. Therefore, most of the reinforcement was made contingent on abstinence and attendance, and a relatively small proportion was made contingent on productivity on the training programs. Trainees could earn a base pay for completing work shifts under a schedule of escalating reinforcement for sustained abstinence and workplace attendance. Under this schedule, a trainee could earn a base pay voucher worth \$7 for completing the first work shift. The value of that base pay voucher increased by \$0.50 per day to a maximum of \$27 for every consecutive day that the trainee provided a drug-free urine sample, arrived on time, and completed a work shift. If a trainee ever provided a drug-positive urine sample, missed a scheduled sample collection, or failed to fulfill punctuality and attendance requirements, the trainee's base pay was reset to the initial low value of \$7 per day. Trainees also could earn up to \$7 per day under a differential-reinforcement-of-other-behavior schedule for maintaining acceptable professional demeanor and approximately \$3 per day for meeting learning objectives on the academic programs and for performance on the typing, keypad, and data-entry training programs.

Upon meeting criteria of sustained abstinence, sustained attendance, professional demeanor, and typing, keypad, and data-entry skills, trainees were hired as data-entry operators in an income-producing data-entry business, Hopkins Data Services (see Silverman, Wong, et al., in press, for a detailed description of the business). Jobs performed by Hopkins Data Ser-

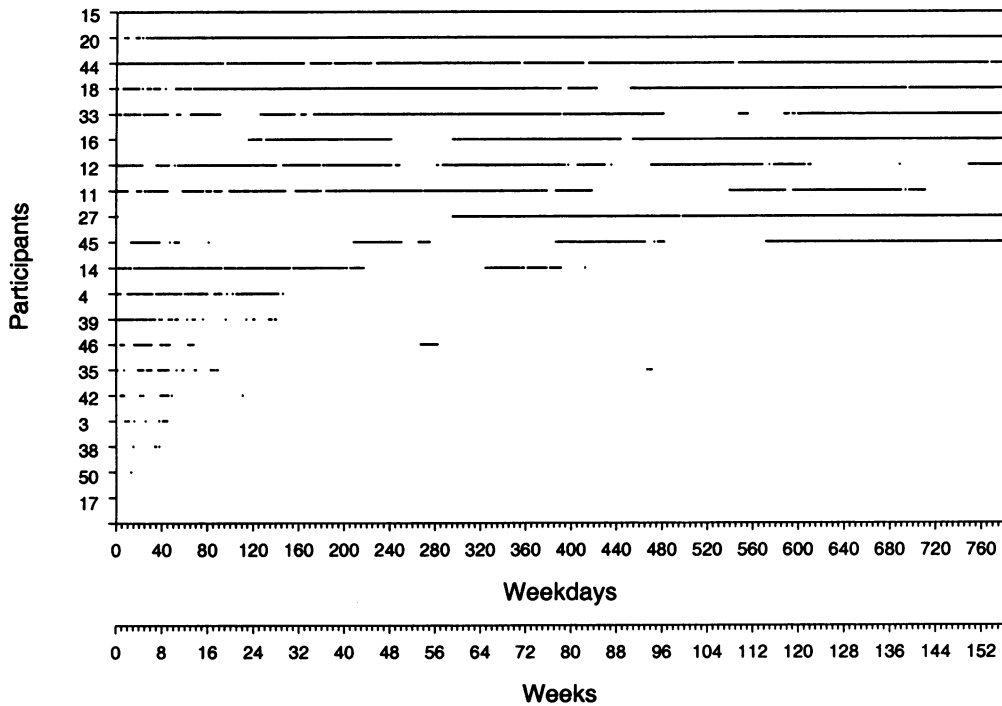


Figure 4. Days in attendance in the therapeutic workplace across consecutive weekdays for each of the 20 therapeutic workplace participants. Each horizontal line represents the attendance results for a different individual across consecutive weekdays during the study. The numerals on the ordinates represent participant numbers. The solid portions of lines indicate that the participant attended the workplace on that day. Participants are arranged from those with the most (top) to those with the least attendance (bottom). Patients were considered in attendance if they attended and completed a work shift or if they had an excused absence (e.g., standard program vacation day, personal day, or sick day with note from physician). Monday, Wednesday, or Friday absences were not considered excused unless a urine sample for that day was provided and was negative. Three participants (S33, S16, S12) had off-site employment included in this figure. Because patients were required to provide drug-free urine samples to gain access to the workplace each day (and on Monday, Wednesday, and Friday of each week even if they took a personal or sick day), continuous solid lines also show consecutive days of abstinence. In addition to showing patterns of attendance and abstinence, a break in a line shows where the voucher value for a patient was reset. From Silverman, Svikis, et al. (2002, p. 236; reprinted with permission).

vices typically involved entering a customer's hand-completed surveys, questionnaires, or interviews into computer data files.

As in the initial training phase, data-entry operators were required to provide drug-free urine samples to work. Operators were invited to work 6 hr per day. Throughout each day, operators entered data printed on customer forms into computer files. The salary system was designed to adhere to minimum wage laws, make maximum possible earnings contingent on productivity, and to differentially reinforce sustained drug abstinence. Operators

earned a base pay salary of \$5.25 per hour and productivity bonuses of \$5 for every batch of data completed (about 2,000 characters), minus \$0.08 for every error in the batch. To continue differential reinforcement of sustained abstinence, the size of the productivity bonus was linked to each operator's duration of sustained abstinence. If the operator ever provided a drug-positive urine sample or failed to provide a scheduled urine sample, the size of the operator's batch completion bonus was temporarily reset \$1.00 per batch (minus \$0.02 per error).

Figure 4 shows patterns of therapeu-

tic workplace attendance during the training phase for the 20 participants across the first 3 years of the study. Nine participants (45%) attended the workplace fairly consistently throughout much of the 3 years. Therapeutic workplace participants had significantly more urine samples that were negative for opiates and cocaine than the usual care controls during the first 6 months (Silverman et al., 2001a; means of 59% vs. 33%, respectively) and significantly more cocaine-negative samples (54% vs. 28% negative, respectively) and opiate-negative samples (60% vs. 37% negative, respectively) in the evaluation that continued up to 3 years after intake (Silverman, Svikis, et al., 2002). Furthermore, significantly more therapeutic workplace participants provided urine samples that were negative for cocaine and for opiates at all of the assessment time points from 18 to 36 months (30%) than usual care controls (5%).

Eight of the 20 therapeutic workplace participants (40%) entered the business at about 3 years after intake. These were the first and only participants to complete the training phase successfully and enter the business. Analyses of monthly assessments conducted during the 4th year of the study (Silverman, Wong, et al., 2002) showed that therapeutic workplace participants still had significantly more urine samples than the controls that were negative for cocaine (55% vs. 25%), opiates (60% vs. 31%), and both cocaine and opiates (47% vs. 18%).

Primarily because therapeutic workplace participants were hired as employees in the business, data collected during the 4th year of the study provided the first evidence that the therapeutic workplace can increase employment (Silverman, Wong, et al., 2002). During the 4th year after intake, control participants were employed an average of 2.1 days per month and earned an average of \$61 per month. In contrast, therapeutic workplace participants worked 9.4 days per month and earned an average of \$472 per month.

The differences both in average days worked per month and in average monthly income were significant. During each person's 1st year of participation in the data-entry business, the 8 operators entered over 15 million characters at an average rate of 2,515 per hour with an accuracy of 99.6% correct. On average, operators earned \$9.88 per hour.

Special contingencies for a special population. Throughout much of the research in the therapeutic workplace, it has become clear that special contingencies are required to ensure the training and employment success of this treatment population. Besides the need to teach academic and job skills as has been described here, special contingencies have been required to promote professional demeanor, to maintain participation in training and employment, and to maximize productivity. An early study showed that trainees reliably attended a data-entry training program only when they earned vouchers for attendance that were at or above minimum wage (Silverman, Chutuape, Bigelow, & Stitzer, 1996). A later study showed that trainees in the therapeutic workplace varied considerably in their data-entry productivity, but that increasing the magnitude of voucher pay could increase the data-entry productivity of most trainees (Wong et al., 2003). Finally, when participants were hired as data-entry operators in Hopkins Data Services, they failed to arrive to work on time or to work complete work shifts consistently. This inconsistent attendance jeopardized the capacity of the business to meet customer deadlines, which could ultimately jeopardize financial viability of the business and its ability to continue to employ the data-entry operators. Two other studies showed that targeted contingency management interventions could increase punctuality and consistent attendance in most participants (Wong, Dillon, Sylvest, & Silverman, 2004a, 2004b). Overall, these experiences show that special contingencies that are not present in most

workplaces may be required if many of these individuals are going to succeed in the workplace.

A Web-based therapeutic workplace training program and business. The research on the initial prototype of the therapeutic workplace intervention suggests that this type of intervention could be an effective treatment for heroin and cocaine addiction and chronic unemployment. But two features of this initial prototype could limit its practical utility. First, the therapeutic workplace includes complex sets of contingencies and training programs that can take an enormous amount of staff time when done manually. To address these issues, we developed a customized Web-based therapeutic workplace application program that automates virtually all aspects of the intervention (Silverman, Wong, et al., in press). Second, the training phase was probably too long and too expensive to be adopted on a large scale. To reduce the time and costs required in the initial training phase, in the Web-based application, trainees are taught only those skills that are critical to performing data-entry jobs (i.e., typing, keypad, and data-entry skills).

The computerized therapeutic workplace intervention is currently being tested in randomized controlled studies in different populations of chronically unemployed adults with long histories of heroin and cocaine addiction, as well as in adults who are homeless and who have long histories of alcohol addiction. Overall, the Web-based application appears to be improving the ease and quality with which the intervention can be implemented. In addition, the focused computerized training program appears to be effective in teaching typing, keypad, and data-entry skills in 3 to 6 months to virtually all participants who attend the program consistently, even participants who begin training with limited academic skills (Dillon, Wong, Sylvest, Crone-Todd, & Silverman, in press).

FURTHER EXPLORATIONS OF PRINCIPLE AND APPLICATION

The program of research reviewed in this article illustrates the potential utility of an operant approach to conceptualizing and treating drug addiction. Cocaine use in methadone patients has been common, persistent and difficult to treat with conventional approaches. Indeed, participants in all of the studies were chosen because they continued to use cocaine at high rates despite exposure to conventional treatments. Yet, relatively pure applications of operant conditioning proved to be unusually successful in promoting and sustaining cocaine abstinence in many patients. Although these studies illustrate the potential of the operant approach, much development will be required to promote the optimal and large-scale application of abstinence reinforcement contingencies for the treatment of cocaine addiction. Operant research at the level of both principle and practical application is required.

Exploring Operant Principles and the Limits of Direct Conditioning

Although many patients have achieved extended periods of abstinence when exposed to voucher-based abstinence reinforcement presented in isolation or integrated in the therapeutic workplace, other patients have been unresponsive to this intervention. Most of the studies in methadone patients have shown success rates at or below 50% of patients. This percentage may be high by some standards, particularly considering the fact that these patients were selected for the studies because they had failed to respond to conventional treatments and considering the very high baseline rates of cocaine use in the study populations. Nevertheless, abstinence reinforcement has been ineffective in many participants.

Exploring principles in isolated voucher-based abstinence reinforcement programs. The overall effectiveness of voucher-based abstinence reinforcement to initiate and maintain

abstinence may be improved by combining the voucher intervention with other interventions, psychosocial or pharmacological, or by modifying the actual abstinence reinforcement contingencies. The effect of combining the voucher intervention with cognitive behavior therapy has been examined (Epstein, Hawkins, Covi, Umbricht, & Preston, 2003; Rawson et al., 2002), although these studies have not yet shown clear benefits of the combined intervention above the voucher intervention alone. Relatively few studies have systematically investigated parameters of operant conditioning that might enhance outcomes, but those studies suggest that success and failure are orderly functions of familiar parameters of operant conditioning. As noted here, increasing both the magnitude of reinforcement (Dallery et al., 2001; Silverman et al., 1999) and the duration of exposure to the abstinence reinforcement contingencies (Silverman, Robles, et al., in press) can be effective in increasing the proportion of methadone patients who achieve sustained cocaine abstinence. Given the success of these parametric manipulations and the vast available knowledge on the effects of variations in reinforcement contingencies (e.g., see the *Journal of the Experimental Analysis of Behavior*), it is reasonable to expect that further studies investigating parametric variations of voucher-based abstinence reinforcement could lead to substantial improvements in the overall effectiveness of this intervention. Few such studies have been conducted, and we know relatively little about the limits of this approach in succeeding with the most resistant patients or in promoting long-term abstinence.

Exploring operant principles in complex arrangements. Practical applications of abstinence reinforcement contingencies will likely involve modifications of parameters of the contingencies and more complex applications than the straightforward superimposition of a voucher reinforcement schedule over existing treatment. The inte-

gration of abstinence reinforcement contingencies into employment settings, as in the therapeutic workplace, provides a good illustration of the complexities that can be encountered in application. In the therapeutic workplace, abstinence reinforcement contingencies are embedded in a network of contingencies designed to promote attendance, skill acquisition, punctuality, professional demeanor, and productivity. Little is known about how these contingencies interact or how to balance the various contingencies to maximize overall success. Our ongoing research provides a hint, for example, that arranging reinforcement sequentially for attendance alone and then for abstinence and attendance simultaneously may improve overall outcomes. Altering the proportions of pay that are contingent on attendance (i.e., the hourly wage) and work productivity may also influence outcome. Increasing the proportion of pay for productivity may improve work performance, but it may essentially increase the response requirement for reinforcement and decrease the overall effectiveness of the salary in promoting abstinence. Similarly, arranging contingencies for punctuality and professional demeanor may improve those behaviors, but might diminish the overall ability of the salary-based reinforcement contingencies to promote abstinence. Systematic studies will be required to learn how these contingencies interact and how to maximize overall effectiveness of using salary for work to reinforce abstinence.

The initial model of the therapeutic workplace was designed to facilitate systematic and fine-grained investigations of the behavior and contingencies in an employment setting when salary for work is used to reinforce abstinence. The work focus of data entry was selected in part because of its amenability to measurement and automation. From a purely behavioral perspective, the data-entry focus has provided an excellent context for initial development of the intervention. Be-

cause of the nature of the training and work required, automation of almost all aspects of the training and business phases of the intervention has been possible through the Web-based application (Silverman, Wong, et al., in press). Conducting research using the Web-based application and data-entry work focus has allowed us to conduct fine-grained analyses of the training (e.g., Dillon et al., in press) and work performance (e.g., Silverman, Wong, et al., in press; Wong et al., 2004a) and to achieve a level of precision in the administration, measurement, and manipulation of the elements of the intervention that is comparable in many respects to highly controlled laboratory research. Continuing research in this controlled environment should permit further investigation of basic principles that are critical to using salary for work to reinforce drug abstinence.

The initial therapeutic workplace was designed for a unique population of unskilled and chronically unemployed adults with high rates of persistent drug use. The focus on this needy population has allowed us to study a full range of contingencies and program features that are required to supply participants with many of the behaviors needed to succeed in the workplace, from the acquisition of job skills, to punctuality and professional demeanor, to sustained abstinence. Continued research will be required with similar populations to improve these contingencies and programs so that we can succeed with the neediest participants who enter treatment with the most limited number of critical behaviors required for workplace success.

Promoting Application of Abstinence Reinforcement Contingencies

The therapeutic workplace intervention is an attempt to incorporate abstinence reinforcement contingencies into a context that might practically be able to support such contingencies: the

workplace. The practicality of this approach has yet to be clearly demonstrated. The therapeutic workplace business, Hopkins Data Services, has not yet achieved a level of financial success sufficient to demonstrate that it can be truly self-sustaining and thus practical, although early experience in the operation of the business has provided some basis for optimism (Silverman, Wong, et al., in press). Reasonable questions of the potential practicality utility of the therapeutic workplace exist (see Petry, 2001, and Silverman, Svikis, Robles, Stitzer, & Bigelow, 2001b, for discussion and response to some concerns). Further research is needed to demonstrate that this model can be financially feasible.

The data-entry business is only one of many possible vehicles to arrange salary-based abstinence reinforcement. Similar models could be developed to train and employ similar populations in other types of jobs (e.g., manufacturing, food service, custodial). Alternatively, the salary-based abstinence reinforcement contingencies could be integrated into existing businesses that are willing to hire employees with drug-abuse problems, or in businesses that have existing employees with substance-abuse problems (McLellan, 2001). As noted by McLellan, salary-based abstinence reinforcement could be "applied in contemporary EAPs, now charged with 'rehabilitating' drug-using employees" (p. 31).

Using salary for work to reinforce drug abstinence is only one possible way to arrange high-magnitude and long-duration abstinence reinforcement. Other practical applications of the abstinence reinforcement technology could be developed. The challenge for developing such applications will be to identify substantial reinforcers that are currently available or could be made available in society, to gain control over those reinforcers, and to arrange effective and sustainable abstinence reinforcement contingencies using those reinforcers. Like the therapeutic workplace intervention, these

other interventions are not likely to emanate from traditional drug treatment programs, which have limited resources and do not control substantial reinforcers that could be employed in abstinence reinforcement contingencies (McLellan et al., 2003). Some potentially practical interventions have been devised, and some are under development. Very early in the history of contingency management research, Crowley (1984) developed a potentially powerful and practical contingency-contracting intervention for drug-abusing physicians, dentists, and nurses. Under that intervention, patients signed contracts that authorized a therapist to collect frequent urine samples and to report to the patient's professional licensing board if the patient provided a drug-positive sample. The routine urine collections and threat of loss of licensure for resumed drug use appeared to be effective in maintaining abstinence. Milby et al. (1996) have provided a combination of abstinence-contingent housing and employment to homeless drug-dependent individuals. Ries and Comtois (1997) have utilized the Social Security Administration's representative payee program to arrange abstinence-contingent access to disability benefits for dually diagnosed adults.

The Role of Operant Conditioning

Research on the direct application and systematic investigation of operant conditioning in promoting drug abstinence could lead to more effective and practical treatments for drug addiction. This research will not be simple, and should be marked by frequent failures. As Baer, Wolf, and Risley (1987) noted, "Technological failure is an expected and indeed important event in the progress of any applied field" (p. 324). Indeed, all of the studies of abstinence reinforcement reviewed here included some treatment failures (i.e., individuals who persisted in using cocaine despite exposure to the reinforce-

ment contingencies). Similar or even higher rates of failures should be expected in future applications, particularly when abstinence reinforcement contingencies are applied to new and complex contexts. Operant conditioners should be uniquely suited to address the challenges that should be expected in conducting this research. Intimate knowledge of principles of operant conditioning should increase the likelihood of success, and confidence in the power of operant conditioning should ensure that investigators persist in the face of the inevitable failures and other obstacles that will be encountered.

The application of operant conditioning in the treatment of cocaine addiction in methadone patients represents only one of many addiction treatment applications. Higgins, Heil, and Lussier (2004) reviewed controlled studies of voucher and monetary reinforcement in persons with substance-use disorders and found that 55 studies had been published since 1991, when the voucher intervention was first introduced (Higgins et al., 1991). Those studies examined the effects of reinforcement interventions in promoting abstinence from cocaine, opiates, cocaine and opiates, multidrug use, cigarette smoking, alcohol, and marijuana; in increasing attendance at counseling and training programs, medication compliance, and work productivity. The results of these studies parallel the results of the evaluations of voucher reinforcement of cocaine abstinence in methadone patients. The reinforcement interventions have been highly and consistently effective. Higgins et al. report that 47 of the 55 reports (85%) found that the reinforcement intervention produced significant changes in at least one of the target behaviors. As in the studies of voucher reinforcement of cocaine abstinence in methadone patients, the reinforcement interventions applied in other populations have never been effective in all participants, relatively few studies have systematically inves-

tigated parameters of operant conditioning that might enhance outcomes, and practical applications are needed for different populations and for different types of addictions.

Extensive and varied research from the laboratory to the clinic provides firm evidence that drug addiction can be viewed and effectively treated as operant behavior through direct application of operant conditioning. The research program reviewed in this article illustrates the potential utility and current limitations of an operant approach for the treatment of a selected population and a selected drug-abuse problem. As illustrated in this research, the operant approach holds considerable promise, but much work remains to improve its effectiveness and practicality. Aggressive operant research programs similar to the one described here could make substantial contributions toward exploring the limits and utility of operant conditioning in the treatment of drug addiction.

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