Summer 2010

Addressing response requirements and behavioral costs in contingency management for smoking cessation

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Addressing Response Requirements and Behavioral Costs in Contingency Management for Smoking Cessation

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A thesis submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

In

Partial Fulfillment of the Requirements

for the degree of

Master of Arts

Department of Graduate Psychology

August 2010

Acknowledgements

First and foremost, I would like to thank my advisor and academic mentor Dr. Jessica Irons for her unwavering support and guidance over the past two years. Without her patience, hard work, and encouragement, this thesis would not be what it is. I am grateful to Dr. Sherry Serdikoff for introducing me to behavior analysis, for sparking my interests in scientific research, and for providing thoughtful feedback throughout all phases of this project. I would like to acknowledge Dr. Kevin Apple as well, for his helpful comments on the final draft of this manuscript. I would also like to recognize Brad Joachim, Kaitlin Balka, Liz Loveless, Allyson Vasi, Amanda Sorg, and Donna Melchione for assisting with data collection and providing suggestions on early paper drafts.

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Abstract

Despite the efficacy of contingency management (CM) in promoting smoking reduction and abstinence, major barriers continue to hinder its widespread dissemination and adoption. The present study addressed two of these barriers, inefficient response requirements and high behavioral costs, by evaluating a novel payment schedule implemented within a workplace setting. Nine university staff were enrolled in a 6-week ABAB study design. During baseline weeks, participants earned money contingent on session attendance. During CM weeks, participants earned money contingent on smoking reduction or abstention payment arrangements, which were available concurrently. Abstention payments increased in magnitude across treatment weeks whereas reduction payments decreased. The results indicate that participants' biological and self-report measures of smoking did not systematically decrease during CM relative to baseline. Additionally, 3 of the 9 participants did not complete the study. These findings suggest that the current arrangement did not improve barriers related to response requirements and behavioral costs. Significant methodological and practical limitations are discussed as well as their implications for future research and on global concerns of CM for smoking interventions.

CHAPTER 1

Over the last century, the rates and causes of mortality in the United States have changed drastically (Danaei et al., 2009; United States National Office of Vital Statistics, 1976). Unprecedented medical progress and advancements have allowed for the successful treatment of acute illnesses and communicable diseases that once plagued Americans, such as influenza and tuberculosis. Over the last 100 years, medical developments undoubtedly have improved life quality and longevity; however, focus has shifted to the treatment and prevention of chronic, rather than acute, diseases (New Jersey Department of Health and Human Services, 2003). Chronic diseases, such as heart disease and cancer, now account for the majority of deaths in the United States (Heron et al., 2009), and unlike acute illnesses or communicable diseases, chronic diseases are in large part the result of long-term patterns of unhealthy behaviors (Danaei et al.). One such pattern that continues to be a challenge, in treatment and prevention, is smoking.

Smoking in the United States

According to a recent report from the Center for Disease Control and Prevention (CDC, 2009), approximately 20.6% of adults in the United States self report being current smokers. Although the percentage of the population reporting smoking has decreased steadily from 37.4% in 1970 and from 24.1% in 1998, smoking rates did not change dramatically from 2007 (19.8%) to 2008 (20.6%), suggesting that current efforts to prevent smoking and promote abstinence may be inadequate. In the United States, cigarette smoking is the leading preventable cause of mortality and morbidity, accounting for an estimated 394,000 deaths each year, or one of every five deaths (CDC). These estimated mortality rates due to smoking are higher than those caused by HIV, illegal

drug use, alcohol use, motor vehicle injuries, suicides, and murders are combined (McGinnis & Fogue, 1993). In addition to the direct impact on smokers, roughly 50,000 additional annual deaths are attributed to exposure to second-hand smoke among nonsmokers (CDC, 2008).

Despite the numerous jobs and considerable income that tobacco production and sales produce, smoking may weaken the strength of the United States' economy. Each year, an estimated $193 billion dollars are spent unnecessarily due to smoking-related conditions (CDC, 2008). The sources of this deficit are due primarily to direct medical costs and lost productivity, resulting in $96 and $97 billion dollar losses, respectively. Additional economic costs not included in these statistics relate to the finances of smoking itself. The average pack-a-day smoker spends over $1500 annually, money that could be spent on healthier activities and an amount that places a significant burden on smokers, especially among at-risk populations such as those of low socioeconomic status (Julien, Advokat, & Comaty, 2008).

Smoking has negative health effects on virtually every organ in the body, and therefore increases risks for a large range of diseases, including various cancers and forms of cardiovascular disease (CDC, 2004). The impact of these health implications is evident in the average life spans of nonsmokers and smokers, with the latter averaging roughly 14 fewer years as a result of premature death due to smoking (CDC, 2002). Fortunately, individuals who quit smoking can reverse some harmful effects of smoking, greatly reduce their risk of premature death, and experience the immediate (e.g., lower heart rate) and long-term (e.g., lower risk of cancer) benefits associated with smoking cessation (CDC, 1990). Furthermore, cessation may reverse minor problems associated

with smoking such as foul breath, premature wrinkling, and stained nails, which may positively impact an individual's social relationships.

Nicotine Dependence

Each year in the United States, approximately 900,000 new individuals become dependent on nicotine, the psychoactive drug found in tobacco that causes addiction (Julien et al., 2008). Similar to alcohol or cocaine, nicotine exerts numerous and potent anxiolytic and stimulatory pharmacological effects on central and peripheral nervous systems and various organs. Physiological effects of nicotine include decreased activity in afferent nerve fibers, release of antidiuretic hormone, and increased heart rate and blood pressure. Nicotine's psychological or subjective effects include relaxation, increased cognitive functioning and attention, and memory consolidation. Interestingly, nicotine may reduce depressive symptoms, which may explain the high rates of comorbidity of nicotine dependence and major depressive disorder (Salin-Pascual, Rosas, Jimenez-Genchi, Rivera-Meza, & Delgado-Parra, 1996). In the central and peripheral nervous systems, nicotine activates specific cholinergic receptors, facilitating the release of dopamine, which is postulated to modulate the reinforcing actions of nicotine (Julien et al.), whereas nicotine's indirect effects on acetylcholine and glutamate may account for the drug's effects on memory and information processing.

Nicotine dependence, like dependence for other drugs of abuse (e.g., heroin), is considered a clinical substance-related disorder in the DSM-IV-TR and is characterized by (a) drug tolerance, (b) drug withdrawal symptoms, (c) increased use over time, (d) excessive time spent seeking or using a drug, (e) drug use that interferes with daily activities, and (f) persistent drug use despite knowledge of the drug's negative

physiological or psychological effects (American Psychiatric Association [APA], 1994). Tolerance to nicotine is acute, can occur within a single episode of repeated administrations (Perkins et al., 1994), and once developed requires continued use to avoid a large class of physiological and psychological withdrawal symptoms. Symptoms experienced during nicotine abstinence vary across individuals but typically include some combination of insomnia, decreased concentration, impatience, irritability, severe nicotine cravings, anxiety, anger, and increased appetite, among others (Julien et al., 2008). The duration of these symptoms varies also, but individuals experience the most severe symptoms within the first 2 weeks of abstinence (Hughes, Higgins, & Bickel, 1994). The combination of rapid tolerance to, dependence on, and withdrawal symptoms from nicotine make smoking an exceptionally difficult behavior to change. Relapse is common among those trying to quit and most individuals require multiple quit attempts to achieve long-term abstinence (Hughes, Gust, Skoog, Keenan, & Fenwick, 1991).

Common Smoking Cessation Treatments

Since the Surgeon General's publication on smoking and health in 1964, extensive research, evaluation, and implementation of smoking cessation treatments have been national health objective priorities. Most commonly used evidence-based smoking cessation treatments fall into one of two broad categories: pharmacotherapies or psychosocial therapies. The most commonly used pharmacotherapy is nicotine replacement therapy (NRT), which is available in many over-the-counter forms and works to reduce the withdrawal symptoms associated with smoking abstinence (Day, 2008). NRTs accomplish this, as the name suggests, by replacing smokers' source of nicotine (i.e., cigarettes) with nicotine from other sources (e.g., gum, transdermal patch,

inhaler), gradually reducing nicotine levels over time until no nicotine delivery is necessary; however, unlike nicotine administered through smoking, NRTs do not contain high amounts of carcinogens and use nicotine levels significantly lower than those found in cigarettes (Murray, Connett, & Zapawa, 2009). A recent meta-analysis of over 132 trials on NRT's effectiveness found that NRTs increase the likelihood of smoking cessation from 50 – 70% compared to placebo (Stead, Perera, Bullen, Mant, & Lancaster, 2008).

Other less common pharmacological treatments are the prescription drugs bupropion and varenicline. Originally prescribed as an antidepressant (i.e., Welbutrin ®), bupropion (marketed as Zyban® for smoking cessation) reduces nicotine withdrawal symptoms. Although its pharmacological mechanism has not been identified, bupropion inhibits dopamine and noradrenaline reuptake, and may attenuate reductions in these neurotransmitters that occur during nicotine withdrawal (Roddy, 2004). Bupropion treatment for smoking cessation is more effective than NRT, producing abstinence rates roughly twice as high (Jorenby et al., 1999). Varenicline (marketed as Chantix ®), the most recently FDA-approved pharmacological smoking cessation treatment, is not derived from nicotine and is not an antidepressant but is classified as a partial nicotine receptor agonist (Julien et al., 2008). Its success stems from its ability to relieve nicotine withdrawal symptoms and reduce nicotine's effects by allowing partial nicotine receptor stimulation and by increasing dopamine levels. Compared to bupropion, varenicline is significantly more effective in facilitating smoking abstinence, with rates approximately 1.5 times higher (Jorenby et al., 2006).

Evidence-based psychosocial therapies are a prevalent smoking cessation treatment option, especially among those for whom pharmacotherapy is contraindicated (Vidrine, Cofta-Woerpel, Daza, Wright, & Wetter, 2006). Although the formats of the interventions vary widely, many clinicians use a "5A" treatment, which consists of five simple steps to encourage smoking cessation: Ask about tobacco use, advise to quit, assess motivation to quit, assist in quit attempt, and arrange a follow-up (National Institutes of Health [NIH], 2008). Strategies for assisting in quit attempts focus on developing problem solving and skills training to identify high-risk relapse situations, learning coping skills to reduce negative affect and urges to smoke, and providing supplementary materials related to smoking cessation (e.g., list of withdrawal symptoms). In addition, clinicians ensure intratreatment support and promote extratreatment support from family members, friends, and others. For individuals not yet ready to stop smoking, clinicians employ other techniques, such as motivational interviewing.

Psychosocial interventions generally are effective in helping individuals reach long-term smoking abstinence, with long-term abstinence rates of 12-24% compared to no treatment abstinence rates of 8-12 % (NIH, 2008). A number of variables may account for this relatively wide range of long-term abstinence in psychosocial interventions, such as the type and number of clinicians and the length and number of sessions. In a recent meta-analysis (NIH), researchers found that interventions that include a physician and multiple clinicians are more effective than a clinician alone. Additionally, researchers detected a dose-response relationship between session length and number of sessions on long-term abstinence, such that more and longer sessions led to higher abstinence rates. Although psychosocial interventions and pharmacotherapies are effective by themselves,

when combined, long-term abstinence rates improve greatly (e.g., 14.6 vs. 22.1%); thus, the current guidelines recommend multicomponent treatments (i.e., at least one psychosocial intervention plus pharmacotherapy).

CHAPTER 2

A Behavior-analytic View of Smoking

Behavior analysis is an empirical, science-based discipline that asserts that behavior is orderly, lawful, and subject to objective analysis (Pierce & Cheney, 2004). Central to a behavior-analytic approach is the belief that all behaviors, regardless of their social acceptance, complexity, or species of the organism behaving, are the result of an organism's interaction with its environmental contingencies. This interaction is best represented by a four-term contingency (i.e., MO-S^D-R-S^R/ S^P), in which some environmental variable alters the value of a consequence or the frequency of the behavior (motivating operation, MO) in a particular context (discriminative stimulus, S^D), which changes the future probability of responses (R) that have been followed by that consequence (reinforcer or punisher, S^R or S^P; Cooper, Heron, & Heward, 2007). That is, responses are selected (i.e., increased or decreased) by the consequences that follow them under particular circumstances.

To apply the four-term contingency to smoking, consider an individual who has just woken up from a night's rest. Because this individual has not smoked for some time, his or her deprived state increases the value of a cigarette's effects (MO) and increases the likelihood of behaviors that have led to cigarettes in the past. This deprivation also may increase the saliency of discriminative stimuli (S^D) that signal the availability of cigarettes (e.g., lighters, smoking chair). After a series of chained behaviors (e.g., looking for pack, taking out cigarette, lighting it), the individual inhales the smoke and smoking is immediately reinforced by its consequences, which may be the addition of an

appetitive stimulus (e.g., increased alertness), the removal or avoidance of an aversive stimulus (e.g., headache from nicotine withdrawal), or both.

Implicit in the above example is that smoking is an operant that is acquired, maintained, and strengthened through the reinforcing effects of nicotine (Higgins, Heil, & Lussier, 2004). This conclusion is supported by a large number of studies in which nicotine-dependent humans and nicotine-naïve nonhuman animals self administer nicotine (for reviews see Foll & Goldberg, 2006; Rose & Corrigall, 1997). For example, in Shoaib, Schindler, and Goldberg (1997), rats received intravenous injections of nicotine for location-specific nose pokes on a fixed ratio (FR)-1 schedule (i.e., each spatially-correct nose poke resulted in reinforcer delivery), with nose pokes to other holes having no programmed consequence. Shoaib et al. found that nicotine naïve rats readily self administered nicotine and continued self-administration as the reinforcement thinned to an FR-5 schedule (i.e., every fifth nose poke resulted in reinforcer delivery). After acquiring nicotine self-administration, rats underwent one of two extinction conditions: Rats received a saline solution injection rather than nicotine or a presession injection of a nicotine antagonist (mecamylamine). In both conditions, the rats' responding decreased significantly compared to the initial nicotine self-administration sessions, demonstrating that nose poking was maintained by the reinforcing effects of nicotine. Henningfield and Goldberg (1983) found similar results in human smokers and nonsmokers using intravenous nicotine and saline solutions in a concurrent FR-10 schedule (i.e., responses were discrete and consequences were delivered for every tenth discrete response). These studies suggest that humans and nonhuman animals are biologically susceptible to nicotine's effects (i.e., nicotine is an unconditioned reinforcer) and that smoking is an

operant behavior controlled by its consequences (Bigelow & Silverman, 1999). Other characteristics of nicotine self-administration, such as similar response patterns and response requirements to food or water as reinforcers, support these notions (Griffiths, Bigelow, & Henningfield, 1980).

Because smoking is an operant behavior controlled in part by its consequences, it lends itself easily to treatment through manipulation of the contingencies that maintain it (Stitzer & Petry, 2006). One method to reduce smoking is through punishment procedures, in which an individual (e.g., therapist, individual trying to quit) delivers a stimulus (i.e., positive punishment) or removes a stimulus (i.e., negative punishment) contingent on smoking. Powell and Azrin (1968) attempted the former by delivering shocks of varying magnitude to human participants contingent on opening a pack of cigarettes. As expected, they found a significant decrease in cigarette smoking, but because of the aversive nature of the intervention, only 3 of 20 participants completed the study. Therefore, it is unlikely that interventions using positive punishment will be acceptable or used. Negative punishment is employed frequently in behavioral smoking cessation treatments, but typically as a component of a more comprehensive intervention. For example, smokers in Roll and Higgins (2000) earned monetary vouchers contingent on abstaining from smoking that escalated in value for each consecutive day of smoking abstinence (e.g., $3.00, $4.00, $5.00); however, if participants smoked, their next voucher payment reset to the lowest value (i.e., smoking resulted in the removal of a higher-valued voucher). Carefully planned and sparingly used punishment such as that in Roll and Higgins can be socially acceptable and effective in reducing smoking, but because of

potential negative side effects of punishment (e.g., aggression; Newsam, Favell, & Rincover, 1983; van Houten, 1983), reinforcement procedures are preferred.

To comprehend how reinforcement procedures, which by definition increase behavior, are implemented to reduce behavior (i.e., smoking), requires an understanding of operants as choice (McDowell, 1988). Recall the earlier example, in which a four-term contingency ($MO\text{-}S^{D}\text{-}R\text{-}S^{R}/S^{P}$) explained an individual's interaction with the environment that resulted in smoking. Although accurate and useful for discovering the influencing variables of a specific behavior, this explanation is overly simplistic and assumes that no other consequences exist in the individual's environment. Clearly, there are a large number of sources of reinforcement contingent on behavior other than smoking available that the individual could contact, such as brewing coffee, watching television, or taking a shower; yet, smoking occurred to the exclusion of these alternatives. This scenario demonstrates that smoking can be conceptualized as a choice; behavior selected from a variety of alternative, concurrent, and competing behaviors that can result in sources of reinforcement (Vuchinich & Heather, 2003).

The nature of how organisms distribute their behavior across concurrent sources of reinforcement was first quantified by Herrnstein (1961). Using two pigeons as subjects, Herrnstein arranged a two-key concurrent schedule, with each operating on variable-interval (VI) schedules of food reinforcement (i.e., reinforcers were delivered for the first response after a random average length of time since the previous reinforcer delivery). During the procedure, the total amount of reinforcement available for pecks on each key was held constant across sessions, but the intervals were manipulated using one pair of equal schedules (VI-3s VI-3s) and three unequal schedules (e.g., VI-9s VI-1.5s).

Herrnstein found that the pigeons' relative rates of responding equaled or matched the relative rates of reinforcement. That is, whether the pigeons pecked the left or right key depended on the relative rather than absolute rates of reinforcement. For example, during a VI-3s VI-3s session, pigeons would distribute their pecks roughly equally across both keys because each delivers food at the same rate. Whereas during a VI-3s VI-6s session, pigeons would distribute roughly twice as many pecks on the VI-3s key than the VI-6s key because it delivers food at twice the rate. This relation between response rates and reinforcer rates is quantified as the matching law

$$R_1 / (R_1 + R_2) = r_1 / (r_1 + r_2) \quad (1)$$

where R_1 and R_2 represent response rates across two alternatives and r_1 and r_2 represent the reinforcement rates on those alternatives (McDowell, 1988). Although the above equation is suitable for settings in which multiple, readily identified alternatives exist (e.g., two keys on VI schedules), it is not appropriate for settings in which there is a single alternative (i.e., engaging in a target behavior or not). The latter is accounted for easily by substituting response and reinforcement rates for a discrete second choice (R_2 and r_2 in Equation 1) with aggregates representing all extraneous responses and their associated reinforcement rates. This produces

$$R / (R + R_e) = r / (r + r_e) \quad (2)$$

where R and r refer to response and reinforcement rates of a target behavior (i.e., instrumental responding) and R_e and r_e refer to total response and reinforcement rates of behaviors other than the target behavior (i.e., extraneous responding). Because using

response rates as dependent measures is not preferred in all cases (e.g., Conger & Killeen, 1974), the matching law is expressed occasionally in terms of time allocated to alternatives, which accounts for behavior equally well as rate of responding (Baum & Rachlin, 1969).

Since the emergence of the matching law over 40 years ago, researchers have shown its utility in quantitatively accounting for significant amounts of variability in choice (over 90%; Baum, 1979; McDowell, 1988). Also, the matching law's generality has been extended substantially across various human and nonhuman animals, responses, and reinforcers, in both laboratory and natural settings. Furthermore, several studies revealed that known parameters of reinforcement other than rate, including magnitude or amount (Catania, 1963), delay (Chung & Herrnstein, 1967), and quality (Hollard & Davison, 1971), enter into the matching law to provide a comprehensive explanation of choice. Taken together, these studies show that a particular behavior is more likely to occur when reinforcement is richer (i.e., occurs at a higher rate), of larger magnitude, more immediate, and of greater quality than reinforcement available for alternative behaviors.

The matching law revolutionized operant theory in at least two major ways (Vuchinich & Heather, 2003). First, Herrnstein's (1961) approach to understanding choice behavior deviated from the generally accepted molecular view of behavior. Molecular views focus on the controlling variables of particular instances of behavior, whereas Herrnstein's molar view considers aggregated behavior extended over some length of time (Pierce & Cheney, 2004). By demonstrating that meaningful relationships could emerge from a molar interpretation, Herrnstein expanded the scope of operant

analysis. A second and related contribution was the recognition of behavioral relativism. Prior to the matching law, researchers investigated principles of reinforcement using single responses, largely ignoring the influence of alternative sources of reinforcement. Herrnstein's work shows definitively that the extent to which a behavior occurs depends on other contingencies operating in the environment.

In addition to its conceptual advancements of an analysis of behavior, the matching law supported the development of new therapeutic applications of reinforcement (McDowell, 1988). Now, rather than manipulating directly the contingencies of reinforcement associated with the target behavior (Equation 2, r), reinforcement for alternative behaviors (Equation 2, r_e) could be targeted to indirectly increase or decrease the target behavior. For example, to decrease the target behavior of smoking (Equation 1, R_1), one could increase reinforcement associated with other therapeutic behaviors, such as exercise (Equation 1, R_2). The addition of reinforcement for a healthy alternative behavior decreases the relative reinforcing efficacy of smoking, and behavior previously allocated to smoking decreases and is redistributed to exercise. Alternative behaviors may be maintained by adding a contingent reinforcer, such as social praise (i.e., positive reinforcement) or programming the removal or avoidance of an aversive stimulus, such as a fine (i.e., negative reinforcement).

The above procedures and others like them in which reinforcement contingencies are arranged to compete with those maintaining an undesirable behavior have been validated empirically in controlled laboratory experiments investigating nicotine self-administration and smoking in nonhuman animals and humans (for other drugs, see Carroll, Bickel, & Higgins, 2001; for nicotine, see Perkins, Hickcox, & Grobe, 2000). For

example, LeSage (2009) investigated the effects of providing a sucrose alternative to two groups of rats trained to self administer nicotine. For both groups, an FI-3s was in effect for nicotine administration, but the contingencies for sucrose delivery differed. The differential-reinforcement-of-other-behavior (DRO) group received sucrose administration contingent on engaging in any behavior but lever pressing for nicotine administration for periods ranging from 40 – 160s. The fixed-time group (FT) received sucrose administration noncontingently (i.e, independent of responding and based on a specific, constant time interval) whose delivery was yoked to a rat in the DRO group. Consistent with matching theory, both groups reduced nicotine self-administration compared to baseline levels when the alternative reinforcer of sucrose was available. As expected, rats in the DRO group reduced nicotine self-administration significantly more than rats in the FT group. This finding suggests that applications in which reinforcement is contingent on not using nicotine are most effective in reducing nicotine use. Bisaga, Padilla, Garawi, Sullivan, and Haney (2006) found similar results with human participants choosing between three puffs of a cigarette and monetary alternatives. The researchers did not record a baseline measure of choice, but participants chose the money option increasingly more as its magnitude increased from $0.5 - $3, showing that providing monetary alternatives contingent on non-smoking behaviors can decrease smoking.

Although brief, the review above provides rich empirical evidence of four general operant principles of smoking, adapted from Higgins (1997): (a) smoking is an operant behavior subject to analysis through the four-term contingency; (b) nicotine serves as an unconditioned reinforcer, similar to food or water; (c) the extent to which smoking occurs

is dependent on the contingencies of the particular environmental context; and (d) providing alternative, non-nicotine sources of reinforcement can decrease smoking. These principles form the foundation for a powerful behavioral smoking cessation treatment known as contingency management.

Contingency Management: Description and Efficacy

Contingency management (CM) is a scientific, incentive-based behavioral intervention, typically used for the treatment of substance abuse, including smoking (for review see Petry, 2000). Based on core operant principles, CM procedures capitalize on the fundamental laws that govern behavior by manipulating or "managing" directly or indirectly the contingencies maintaining target behaviors involved in drug use (Higgins & Silverman, 2008). In CM for smoking cessation (CMSC), the therapist or researcher programs and implements artificial reinforcement contingencies for behaviors that are incompatible with smoking or are consistent with related therapeutic behaviors. These alternative contingencies are designed to compete with the natural contingencies that maintain smoking, with the intention that the individual will choose the programmed contingencies, thereby initiating smoking reduction, abstinence, or some other therapeutic behavior. The ultimate goal of CMSC is to initiate and maintain behavior change until the individual contacts the natural reinforcers associated with smoking cessation that sustain long-term abstinence.

Essentially, CM involves DRO procedures in which putative reinforcers (e.g., vouchers, money) are provided when an individual can provide evidence of recent smoking abstinence or reduction but are not provided when an individual provides evidence of recent smoking or smoking above a specified level. A central feature that

distinguishes CM from other smoking cessation treatments is its frequent monitoring of smoking using objective (e.g., biochemical markers) rather than subjective (e.g., self-report) measures (Stitzer & Petry, 2006). The use of frequent monitoring with sophisticated measures ensures that individuals are rewarded only when a target behavior is met but also allows researchers and therapists to track individual progress and respond quickly to create a more individualized and effective treatment.

The efficacy of CM and its generality are well established for the treatment of various substances (Bigelow & Silverman, 1999) among diverse populations (Prendergast, Podus, Finney, Greenwell, & Roll, 2006). Abused substances other than nicotine that have been effectively treated using CM include opioids (Petry, & Martin, 2002), alcohol (Petry, Martin, Cooney, & Kranzler, 2000), methamphetamines (Shoptaw et al., 2005), cocaine (Higgins et al., 1994), marijuana (Budney, Moore, Higgins, & Rocha, 2006) and benzodiazepines (Stitzer, Bigelow, & Liebson, 1979). In CMSC studies, the populations treated consist of the mentally ill (Tidey, O'Neil, & Higgins, 2002), adolescents (Krishnan-Sarin et al., 2006), college students (Irons & Correia, 2008a), healthy adults (Stitzer & Bigelow, 1983), pregnant women (Higgins et al., 2004), and methadone-maintained opioid users (Shoptaw et al., 2002). Although the majority of CM studies focus primarily on arranging contingencies directly related to substance use, some have used CM to increase therapeutic behaviors such as treatment attendance (Carey & Carey, 1990) and meeting personal treatment goals (Iguchi, Belding, Morral, Lamb, & Husband, 1997).

To date, three treatment-control meta-analyses have been conducted to evaluate the effectiveness of CM for the treatment of substance use disorders. Lussier, Heil,

Mongeon, Badger, and Higgins (2006) examined all studies, regardless of substance, published from 1991-2004 that included voucher-based reinforcement therapy (VBRT), a form of CM in which individuals receive vouchers exchangeable for goods or services contingent on reducing or abstaining from substance use. Lussier et al. included 30 experimental studies in their analysis and found an overall medium effect size (r = .32) and a slightly larger effect size for studies targeting nicotine (r = .47); however, the latter findings should be interpreted cautiously as the number of inclusive studies was limited. Prendergast et al. (2006) addressed this limitation by extending their meta-analysis' time frame from 1970-2002 and by including all forms of CM (i.e., not just VBRTs). A total of 47 studies that were not limited by substance type comprised the meta-analysis, which revealed an overall medium effect size (d = 0.42). Expressed in terms of treatment success rates, groups in which CM was the primary treatment were 22% more successful than controls. For the 11 studies targeting nicotine, the effect size was slightly lower (d = 0.31). These meta-analyses provide compelling evidence that CM is an efficacious treatment for illicit and licit drug use.

Although Lussier et al. (2006) and Prendergast et al. (2006) highlight the efficacy of CM, no comparisons were made between CM and other commonly used substance abuse treatments. Recently, Dutra et al. (2008) conducted a comparative meta-analysis of psychosocial treatments for substance use disorders from 1840-2005, including CM. They found the largest treatment effect size for CM (d = 0.58) compared to four other treatments. Moreover, CM produced the highest treatment retention rates (70.6%) of all treatments included in the study. Despite these positive results regarding CM, Dutra et al. compared only psychosocial treatments of illicit drugs. Because the researchers did not

include smoking cessation treatments in their analyses, the extent to which these results may generalize is unknown, but given the results of previous meta-analyses and direct study comparisons (see below), it would not be unlikely that similar results would be found for nicotine use.

To determine the differential efficacy of CM and pharmacological treatments for smoking cessation, Tidey et al. (2002) examined NRT and CM among individuals with schizophrenia. Using a within-subject repeated measures design and counterbalanced assignment, participants experienced three conditions: CM with a transdermal nicotine patch (CM + NRT), CM with a placebo patch (CM + P), and noncontingent reinforcement with a placebo patch (NC + P). Each condition lasted 5 consecutive days and was separated by a washout period in which participants could smoke as usual. Tidey et al. found that participants reduced their smoking levels significantly from baseline and submitted more consecutive abstinence samples during CM + NRT and CM + P weeks compared to NC + P. There were no significant differences in smoking reductions between the CM + NRT and CM + P conditions, indicating that CM was the treatment component responsible for the reductions and that the addition of NRT to CM procedures did not increase its efficacy. More recently, Glenn and Dallery (2007) compared the short-term effects of a nicotine patch and CM on smoking; however, unlike Tidey et al., they used a nonclinical sample of heavy adult smokers. Across 4 weeks, participants experienced the following conditions, which each lasted 5 days: baseline, 14mg nicotine patch (NRT), CM, and return to baseline; treatment conditions were counterbalanced across participants. Glenn and Dallery found that during CM, participants significantly decreased their smoking (38%) relative to baseline weeks but did not significantly

decrease their smoking during NRT relative to baselines. Moreover, during CM 24% of the submitted samples met abstinence criteria compared to only 5% of those submitted during NRT. These findings extend those of Tidey et al. to a nonclinical population and provide further evidence that CM is more effective in initiating short-term smoking abstinence compared to NRT.

Only two studies have made direct comparisons between CM and psychosocial treatments for smoking cessation. Krishnan-Sarin et al. (2006) evaluated cognitive behavioral therapy (CBT) and CM in a school-based program for adolescents. Participants were assigned randomly to a CBT-only group or a CBT + CM group for 4 weeks, including weekends. Participants assigned to the combined group achieved significantly higher smoking abstinence rates (one week: 76.7%; one month: 53%) than those assigned to CBT alone (one week: 7.2%; one month: 0%). In another study, Tevyaw et al. (2009) compared CM and motivation enhancement therapy (MET) along with their placebos (noncontingent reinforcement control [NRC] and relaxation control [RC], respectively) in a clinical trial for college student smokers. In a between-groups design, participants were assigned to one of four conditions, each lasting 3 weeks: MET + CM, MET + NRC, RC + CM, and RC + NRC. Tevyaw et al. found that treatments that included CM were significantly more efficacious than those including NRC. Compared to participants in NRC groups, participants in CM groups provided on average significantly lower carbon monoxide levels (5.8 vs. 12.3 parts per million) more abstinent samples (55.2% vs. 17.9%), and more consecutive abstinent samples (10.1 vs. 2.1 readings). Type of psychosocial treatment (i.e., MET, RC) had no significant effect on any smoking-related outcomes. These studies demonstrate not only that CM is an effective smoking

cessation treatment, but also that compared to other commonly used treatments, CM may be more successful in inducing smoking reduction and abstinence. Similar studies comparing CM and psychosocial interventions for the abuse of other substances support this conclusion (e.g., Rawson et al., 2006).

CMSC: Payment Magnitudes and Arrangements

Because of the nature of smoking (i.e., it is prevalent, legal, and individuals attempting to quit are prone to quick relapse), CMSC is typically shorter and more practical than CM studies investigating other drugs of abuse (Roll, Higgins, & Badger, 1996). As a result, smoking serves as a useful exemplar to identify key parameters of CM procedures, such as the effects of payment magnitude. In one of the earliest CMSC studies, Stitzer and Bigelow (1983) evaluated the effects of pay amount on smoking reduction among healthy adults across 6 weeks. Participants were assigned randomly to receive $0, $1, $5, or $10 contingent on reducing their smoking by 50% relative to baseline. Stitzer and Bigelow found an orderly relationship between pay amount and smoking reduction such that as pay amount increased smoking decreased. In a subsequent study, Stitzer and Bigelow (1984) investigated the effects of pay amount on smoking reduction using a sliding scale payment schedule. Participants earned varying amounts of money contingent on smoking reductions over a 4-week period (maximum payments ranged from $1.50 to $12.00), with larger reductions resulting in larger pay amounts. Consistent with their previous findings, Stitzer and Bigelow found that participants reduced their smoking more when pay amounts were higher. These findings and others (e.g., Correia & Benson, 2006) suggest that when feasible, higher pay amounts or more

valued goods (for voucher-based programs) should be implemented to produce potential greater smoking reductions.

Another notable parameter identified through CMSC is the payment arrangement for smoking reduction or abstinence (Roll & Shoptaw, 2006). Although researchers have long been aware of the importance of reinforcement schedules on responding, this area was not systematically studied within CM procedures until more recently. In 1996, Roll et al. evaluated three different payment arrangements over the course of 5 days using smoking as an exemplar. Participants were assigned randomly to one of three payment arrangements: escalating magnitude of reinforcement, constant magnitude of reinforcement, and noncontingent reinforcement. Payments for participants in the escalating magnitude group began at $3.00 for the first negative sample and increased $0.50 for each subsequent consecutive abstinence. For every third consecutive sample indicative of abstinence, participants earned a bonus payment of $10.00. However, if participants provided a positive sample, payment was not provided and reset to the initial amount of $3.00 for the next session. Following three consecutive negative samples, participants' payments returned to the value at which the reset occurred. Participants in the constant magnitude group received a payment of $9.80 for every negative sample without any resets or bonuses. Payments for participants in the noncontingent reinforcement group were yoked to those in the escalating magnitude group. That is, participants in the noncontingent group earned monetary reinforcement independent of their smoking levels. Roll et al. found that participants in the response-contingent groups (i.e., escalating and constant magnitudes) abstained from smoking significantly more than those in the noncontingent group, but did not differ from each other. Although there were

no significant differences between the response-contingent groups in terms of abstinent samples submitted, participants in the escalating magnitude group did show significantly less relapse following a brief period of abstinence compared to the constant magnitude group. These findings demonstrate the influence of payment arrangements in CM procedures and provide evidence that escalating magnitude rather than constant magnitude arrangements may be most effective in CMSC.

To more specifically determine the effective components of this escalating magnitude arrangement, Roll and Higgins (2000) conducted a within-subject systematic replication of Roll et al. (1996) using three payment arrangements: escalating magnitude with a reset contingency, escalating magnitude without a reset contingency, and constant magnitude. During the escalating magnitude payment weeks, participants submitted significantly more consecutive abstinent samples than during constant magnitude weeks. There were no significant differences in smoking levels or number of abstinent samples submitted between the escalating magnitude groups, but participants in the escalating magnitude with reset contingency group were more likely to initiate and sustain abstinence than those in the no reset group. Thus, inclusion of a reset contingency in CMSC treatments may have some positive benefit on smoking outcomes.

CMSC: Contacting Reinforcement Contingencies

One struggle in implementing successful CMSC is determining the optimal behavioral requirement(s) necessary to contact the reinforcement contingencies (Sigmon, Lamb, & Dallery, 2008). That is, determining the amount one must decrease his or her smoking in order to receive monetary payment or vouchers. The most common approach in CMSC has been to set the reinforcement criterion from the outset, typically providing

reinforcement only for those able to demonstrate complete smoking abstinence (e.g., Correia & Benson, 2006; Roll et al., 1996). However, this approach poses problems to a large subset of individuals who, for a variety of reasons (e.g., low motivation to quit, high nicotine dependency), are not able to abstain from smoking, even for relatively short durations (Lamb, Kirby, Morral, Galbicka, & Iguchi, 2004). The result is that the main goals of CM – that participants experience the rewards associated with smoking abstinence and initiate and maintain that abstinence long-term– are never realized. An additional concern of setting unrealistic reinforcement contingencies is that individuals failing to meet these contingencies may withdraw from the treatment entirely and/or become discouraged and be reluctant to initiate future quit attempts.

One viable alternative to using abstinence criterion determined from the outset is to use percentile schedules of reinforcement[1] (Galbicka, 1994; Lamb, Kirby, Morral et al., 2004; Lamb, Morral, Kirby, Iguchi, Galbicka, 2004; Lamb, Morral, Kirby, Galbicka, & Iguchi, 2005). In percentile schedules, reinforcement is delivered contingent on some level of the target behavior (e.g., 50% of normal smoking) that is closer to the desired behavior level (i.e., 0% of normal smoking) than some proportion of recently emitted occurrences (e.g., last week's smoking levels), and thus can be used to shape behavior. For example, individuals may receive reinforcers contingent upon providing biological verification of smoking levels that are lower than 8 of the 9 most recent samples or 16 of the 19 most recent samples (both are examples of an 80^{th} percentile schedule). Lamb, Kirby et al. first implemented percentile schedules in a CMSC intervention among a small sample of healthy adults who had no intentions to quit smoking. All participants received reinforcement based on a percentile schedule, such that only carbon monoxide

(CO) samples indicative of smoking below the median of the previous five samples resulted in reinforcer delivery. In addition, participants were assigned randomly to a constant or escalating magnitude payment arrangement (see Roll et al., 1996). Lamb, Kirby et al. found that participants in both groups achieved significant reductions in smoking as measured by CO levels and self report. Furthermore, participants in the escalating magnitude condition achieved higher rates of overall abstinence. These results replicated previous findings (e.g., Roll & Higgins, 2000) that showed escalating-magnitude payments arrangements are more effective than constant magnitude payments, but more importantly, demonstrated that percentile schedules of reinforcement are feasible for use in CM.

In two follow-up studies, Lamb and colleagues (2004, 2005) investigated two parameters of percentile schedules for CMSC. To determine the optimal percentile schedule, Lamb et al. (2004) compared 10^{th}, 30^{th}, 50^{th}, and 70^{th} percentile schedules among healthy adult smokers interested in quitting smoking. They found that over 90% of participants in the 30^{th}, 50^{th}, and 70^{th} percentile schedules were able to abstain completely (i.e., CO $\leq$ 4 ppm) compared to 67% of participants in the 10^{th} percentile condition. These results indicate that percentile schedules of 30% or greater are most effective for CMSC. In a second study, Lamb et al. (2005) compared the effects of the number of samples used to set the percentile schedule criterion between two groups of healthy adult smokers seeking smoking cessation treatment. Previous studies (Lamb, Kirby et al., 2004; Lamb, Morral et al., 2004) used a nine-sample criterion, and so Lamb et al. compared this to a novel four-sample criterion. They found no significant differences in CO levels or percent meeting abstinence criterion between the nine- and

four-sample windows. However, there was a trend towards lower CO and higher percent meeting abstinence criterion for participants in the four-sample condition. Although not conclusive, this study suggests that smaller sample windows for calculating percentile schedules may be most effective.

CMSC: Behavioral Requirements

Another barrier to successful CMSC treatments is the relatively high behavioral costs for participants that many interventions require (Sigmon et al., 2008). A crucial characteristic of CM is the use of reliable and valid measures of smoking; however, due to the short half-life of CO -- the most commonly used biochemical marker of smoking used in CM studies -- measurements must occur frequently in order to obtain accurate descriptions of smoking. In the past, the majority of CMSC studies have required that participants make daily visits to a clinic or hospital in order to collect smoking measurements (e.g., Lamb, Kirby et al., 2004). These demands can place large burdens on participants for various reasons, such as the time and money lost during transportation to and from the clinic. For example, Correia and Benson (2006) conducted a CMSC study among a college student sample, which required two visits to a campus laboratory per day, for 5 days per week, throughout the entire 3-week study (30 total visits). Although the researchers found that the intervention was effective in reducing smoking among college student smokers, only 39 participants (44%) completed the entire study. Procedures that place high behavioral costs on participants increase the likelihood of participant attrition, which is undesirable clinically and experimentally. Recently, researchers have investigated and developed two areas that may have the potential to reduce behavioral costs for individuals in CMSC treatments: (a) by using more accurate

and precise biochemical measures of smoking and (b) by utilizing new technologies to deliver CM treatments.

By employing more accurate and precise biochemical measures with longer half lives than CO, researchers still would be able to validly detect smoking but would require less frequent measurement from participants. One biochemical marker of smoking that meets these specifications is cotinine, a nicotine metabolite found in plasma, saliva, and urine (SRNT Subcommittee on Biochemical Verification [SBV], 2002). To investigate the impact of reduced behavioral requirements on participant attrition by using cotinine measures, Irons and Correia (2008a) conducted a 3-week brief abstinence test using a college sample. By adding cotinine as the primary measure of smoking, Irons and Correia limited measurements to once weekly, compared to the 10 weekly visits required in Correia and Benson (2006). Furthermore, 100% of participants in Irons and Correia attended all weekly sessions (i.e., no participant attrition). These results suggest that improving biochemical measures of smoking may reduce participant visits and increase participant retention, which may have positive impacts on treatment outcomes and costs.

Although using cotinine rather than CO measures is an effective method of reducing behavioral costs incurred by the participant, there are several limitations associated with its use. First, arranging abstinence contingencies early in treatment solely using cotinine measures is inappropriate. Because of cotinine's long half life relative to CO, cotinine measures are unable to detect initial abstinence (SBV, 2002; i.e., measures provided by a participant who abstains initially will still indicate smoking for several days). To address this problem, researchers use multiple biochemical measures, either in combination (Irons & Correia, 2008a) or at separate times during treatment when most

appropriate (Higgins et al., 2004; e.g., initially using CO and later cotinine). Second, cotinine measures do not provide valid measurements of smoking for participants using nicotine replacement therapies (NRTs), whether planned as a treatment component or otherwise. Finally, particular methods of analyzing cotinine (e.g., gas chromatography) can be overly expensive and impractical outside of the laboratory setting.

Rather than targeting biochemical markers to reduce behavioral costs in CMSC, some researchers have targeted the way in which biochemical samples are collected and verified (Sigmon et al., 2008). Specifically, Dallery and colleagues (2005, 2007) developed an internet-based data collection system that does not require visits to clinics or hospitals to measure participants' smoking levels. In this system, participants receive a laptop computer, web camera, and a CO monitor to use and install in their homes. From their homes, participants email CO video samples twice daily (separated by 8 hours or more) via a web camera to the researchers, who view and confirm the readings and deliver reinforcers electronically (e.g., online vouchers). Using this internet-based system, Dallery and colleagues obtained perfect participant retention (i.e., no participants left the 4-week studies), high sample submission rates (> 93%), and produced abstinence rates similar to other CMSC studies. Others have replicated these findings (e.g., Glenn & Dallery, 2007; Reynolds, Dallery, Shroff, Patak, & Leraas, 2008), suggesting that an internet-based method of CMSC is feasible and effective.

Despite the success of an internet-based model, significant barriers to its more widespread adoption exist, mainly concerning additional treatment costs (i.e., above and beyond a non-internet-based approach) for large numbers of CO monitors, laptop computers, and web cameras, which may be impractical. However, these costs may be

more easily justified among individuals in particular subpopulations for whom behavioral costs (e.g., money, transportation) pose greater challenges to successful smoking cessation treatment, such as rural smokers (Stoops et al., 2009).

An additional method to reduce behavioral requirements for participating in CMSC is to incorporate treatment in settings in which frequent smoking measurements would be minimally invasive and easily accessible. Given that the average American spends 30 or more hours each week working and that the vast majority of Americans work outside of the home, the workplace may be an ideal location in which to study further and potentially disseminate CMSC treatments (Donatelle et al., 2004; United States Bureau of Labor Statistics, 2008, 2010). Furthermore, there are several benefits to implementing CMSC within the workplace that may facilitate its adoption and its efficacy: (a) CM approaches may appeal to employers interested in improving their employees' health, which in turn may increase productivity and reduce health insurance premiums, (b) employees may be more likely to enroll in workplace programs that offer incentives, such as CM, (c) delivery of vouchers or payments may be made easier through already existing payroll systems, and (d) a workplace may encourage new social support systems or the strengthening of current social support systems with coworkers. Even with these numerous potential advantages, few studies have investigated the effects of CMSC within the workplace.

Rand, Stitzer, Bigelow, and Mead (1989) were among the first to study directly the effects of CMSC within the workplace. Using a between-groups design, hospital employees were assigned to one of three conditions: CM with frequent monitoring of smoking (FS), FS, and infrequent monitoring of smoking (IS). Rand et al. found that

participants in the CM with FS group maintained smoking abstinence significantly longer than those in the FS and IS group; there were no differences in smoking abstinence outcomes between the FS and IS group. Although 11 of the total 51 participants (78%) dropped out of the study within 6 months, exit interviews confirmed that these decisions were due to health problems or job relocations, not to the treatment itself. These findings show that regardless of smoking monitoring frequency, participants receiving payments contingent on smoking abstinence have significantly better smoking cessation outcomes. Moreover, these results demonstrate the feasibility of CMSC treatments within the workplace. Other researchers have found similar results (Stitzer & Bigelow, 1983, 1985), but were not concerned particularly with the impact of study setting on smoking outcomes.

Since Rand et al. (1989), no researchers have published any studies focusing specifically on the implementation of CMSC within the workplace, but extensive research has been conducted on incentive-based smoking cessation workplace programs (Donatelle et al., 2004; see Matson, Lee, & Hopp, 1993 for review). This broader category of smoking cessation treatments differs from CM approaches in several important aspects in that most: (a) do not employ advanced methods (e.g., shaping, complex payment arrangements), (b) generally have less experimental control, (c) are not based on psychological learning theory (i.e., operant conditioning), and (d) are included typically only as a small part of more comprehensive smoking treatments (e.g., incentives, counseling, and education as one treatment package). These differences, along with variations across studies regarding definitions of smoking abstinence (e.g., self report vs. biochemical measures), treatment intensity and duration, and others preclude

any definitive conclusions on the effects that contingent reinforcement may have on smoking levels within the workplace.

CHAPTER 3

The Current Study

Although the current study included only smoking as its target behavior, the issues addressed were not necessarily specific to smoking and may generalize to applications of CM for other substances and behaviors. In the current study, I addressed two barriers to the widespread adoption and implementation of CMSC. First, I assessed the efficacy of a novel payment schedule designed to ameliorate past problems involving response requirements. Typical payment arrangements in CMSC require individuals to abstain completely to earn payment; however, large numbers of individuals are not able to meet this criterion and as a result, fail or leave treatment. An alternative to abstinence-contingent payment schedules is to reinforce gradual reductions in smoking (i.e., shaping) over extended periods of time. Although shaping addresses problems involving unrealistic response requirements, not all individuals are incapable of abstaining from smoking early in treatment and these individuals may actually benefit from abstinence-contingent payment arrangements. Additionally, requiring individuals to reduce smoking gradually may involve higher monetary and behavioral costs, for researchers and participants. A potential solution to these problems may be to combine abstinence- and reduction-contingencies in one payment schedule. Providing payments for smoking reduction and abstinence will allow for more individualized treatment and may be more efficient than abstinence or shaping payment arrangements alone.

Consistent with previous research on effective payment arrangements, the novel payment arrangement for the current study provided abstinence payments that escalated in magnitude across weeks. Payments for smoking reduction decreased in magnitude

across weeks, with the intention that the relative reinforcing value of abstinence to reduction would become greater throughout treatment. These payment schedule arrangements may facilitate complete smoking abstinence in later weeks among participants who were first able to reduce but not abstain from smoking.

I expected that when the novel payment contingencies were present, smoking levels would significantly decrease, relative to periods in which the novel payment contingencies were absent.

Second, I implemented the current study within a workplace setting with the goal of reducing behavioral costs incurred by participants. The majority of previous CMSC studies required participants to meet frequently with the research team, often at inconvenient locations (e.g., clinics). As a result of such impractical designs, many participants miss treatment sessions or remove themselves from the treatment completely. By employing CM for smoking cessation in the workplace, where occasional smoking measurement would be relatively noninvasive and accessible, behavioral costs may decrease. Such an outcome may improve participant retention and increase CM's effectiveness. Furthermore, because so few studies have examined CM within the workplace, the current study provided important information on its feasibility and acceptance in non-research settings.

I expected that because implementing CMSC within a workplace would reduce the behavioral costs incurred by the participants, participant attrition would not occur.

Method

Participants

Sample size considerations were made based on an a priori power analysis using GPOWER software (Erdfelder, Faul, & Buchner, 1996). Using a medium effect size based on a meta-analysis of CM for nicotine use (*d* = .31; Prendergast et al., 2006), an ANOVA repeated measures a priori power analysis indicated that 16 participants would be necessary for adequate power (.80) at an alpha level of .05.

Participants were 9 nonstudent staff members at James Madison University (JMU). They were recruited through bulk email announcements sent to all JMU staff, indicating that individuals over the age of 18 might be eligible to enroll in a smoking cessation program during which they would have the opportunity to earn monetary compensation. Interested staff completed an online screener, which was used to collect demographic information, information related to characteristics of smoking behavior, current or planned involvement in structured smoking cessation programs, and willingness to provide biological samples to verify smoking status. Staff who self reported smoking at least eight cigarettes per day, who were not involved in a structured smoking cessation program, and who were willing to provide biological samples to verify smoking status were eligible for this study. Eligible staff received a follow-up email, which included a basic description and timeline of the study, time required for participation, maximum amount of monetary compensation available, and an invitation to attend one of multiple intake sessions.

Measures

Self-report measures. All self-report data were collected via online surveys.

Demographics questionnaire. This questionnaire was used to assess participant characteristics, such as age, gender, and ethnicity (see Appendix A).

Smoking Behavior Questionnaire (SBQ). This questionnaire was used to assess information on smoking history; motivation to quit smoking; previous attempts to quit smoking; and past, current, and future plans to engage in an active smoking cessation program (see Appendix B).

Hooked on Nicotine Checklist (HONC; O'Loughlin, Kishchuk, DiFranza, Tremblay, & Paradis, 2002). This checklist was used to assess level of tobacco dependence based on 10 "yes" or "no" items that measure loss of autonomy (see Appendix C). Loss of autonomy is a symptom characterized by decreased self-control and compulsion, both of which are consistent with clinical descriptions of substance dependence (Wellman et al., 2006). Scores are computed by adding the number of items marked "yes" with higher scores corresponding to higher dependence. The HONC's psychometric properties and correlates with other smoking variables have been evaluated among adults and adolescents (Wellman et al.; DiFranza et al., 2002). The HONC has a one-factor structure with all items loading above .70, high internal consistency (α = .83 - .94), and correlates significantly with a variety of smoking characteristics (e.g., smoking frequency, level, duration, age of onset).

Fagerstrom Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991). This 6-item questionnaire was modified from two earlier versions of the Fagerstrom Tolerance Questionnaire (Fagerstrom & Schneider, 1989; Prokhorov, Pallonen, Fava, Ding, & Niaura, 1996; see Appendix D) and is designed to assess nicotine dependence of tobacco smoking. Specifically, the FTND assesses dependence as measured by an individual's compulsive smoking behavior, defined in terms of nicotine withdrawal and craving. Items are dichotomous and are scored on a 10-

point scale, with higher scores corresponding to higher dependence. Despite its use in most smoking cessation research and clinical settings, studies on the psychometric properties of the FTND have produced inconsistent identification of its factor structure (one-factor vs. two-factor; Wellmen et al. 2006; Radzius et al., 2003, respectively) and poor internal consistency (α = .57 - .72). Furthermore, some researchers criticize its lack of sensitivity and unclear interpretation; however, the FTND does correlate with smoking characteristics (e.g., smoking levels) and may be predictive of long-term abstinence (Breslau & Johnson, 2000). Because of its psychometric limitations, the FTND was included primarily to allow for comparison with previous studies, which frequently report this measure.

Wisconsin Smoking Withdrawal Scale (WSWS; Welsh et al., 1999). This 28-item questionnaire was developed to assess severity and type of smoking withdrawal symptoms (see Appendix E). Items consist of statements related to clinical symptoms of smoking withdrawal (e.g., "I have felt impatient") and are rated on a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*). The WSWS provides an overall withdrawal score (range = 0 [no withdrawal] – 140 [extreme withdrawal] and scores for each of its 7 subscales, which reflect clinical symptoms of nicotine withdrawal: anger, anxiety, sadness, concentration, craving, sleep, and hunger (APA, 1994). Internal consistency for measuring overall withdrawal is high (α = .90 - .91), whereas subscale internal consistencies are slightly lower (α = .75 - .93). Additionally, overall measures on the WSWS are predictive of smoking cessation outcomes (Welsch et al.)

Contemplation Ladder (CL; Biener & Abrams, 1991). Based on the transtheoretical model of health behavior change, the CL was used to assess readiness to

consider smoking cessation (see Appendix F). The CL consists of 10 “rungs”, which are anchored with statements indicating gradually increasing levels of motivation to quit smoking (e.g., “No thought of quitting” to “Taking action to quit”), with higher scores representing greater motivation. Although this measure is not predictive of biochemically verified smoking abstinence, it is predictive of future attempts to begin smoking cessation and correlates significantly with the frequency of previous quit attempts and other smoking change measures (Amodei & Lamb, 2004).

Daily Tobacco Report (DTR). This questionnaire was used to assess average number of cigarettes smoked since last session, tobacco use over the last 24 hours, and time since most recent use (see Appendix G). The DTR includes cigar and chewing tobacco products in addition to cigarettes.

Biological measures.

Expired breath carbon monoxide (CO). BreathCO (Vitalograph Inc., Quivira, KS), a portable breath CO reader, was used to verify smoking behavior (see Appendix H). Expired breath CO in parts per million (ppm) has been established repeatedly as a valid and reliable index of cigarette smoking, and correlates highly with other biological markers indicative of recent smoking including nicotine and cotinine found in plasma, saliva, and urine (Jarvis, Tunstall-Pedoe, Feyerabend, Vesey, & Saloojee, 1987), and in plasma carboxyhemoglobin levels (Jarvis, Belcher, Vesey, & Hutchison, 1986). Self-report measures such as number of cigarettes smoked per day (Abueg, Colletti, & Kopel, 1985), duration of smoking (Deveci, Deveci, Azik, & Ozan, 2004), time since smoking last cigarette (Schmitz, Rhoades, & Grabowski, 1995), and depth of inhalation (Rea, Tyrer, Kasap, & Beresford, 1973) also correlate highly with expired breath CO. Measures

of expired breath CO have been used to distinguish self-identified nonsmokers and smokers with high sensitivity (90%) and specificity (83% - 89%); however, the optimal cut-off levels have varied across studies (range = 6ppm – 10.5ppm; Jarvis, Tunstall-Pedoe et al.; Deveci et al.). Rough estimates of expired breath CO levels across differing types of smokers indicate that, in general, light to moderate smokers have levels between 8 and 15 ppm and heavy smokers have levels between 15 and 40 ppm (Jarvis, Belcher et al.,). Although expired breath CO is a relatively accurate measure (± 3ppm) of recent smoking (6-8 hours), it is not as sensitive as other methods (e.g., urine and salivary cotinine) but is the most common biochemical measure in CMSC. Unlike other methods, obtaining expired breath CO is noninvasive, cost-effective, provides immediate results, and its use is not constrained to a laboratory environment.

Urine cotinine. As a secondary measure, urine samples were analyzed to detect nicotine and its principle metabolite, cotinine (see Appendix I). Unlike nicotine, which has an elimination half-life of approximately 2 hours, cotinine has an elimination half-life of 20 hours (Gilbert, 1993), allowing for more extended detection. Moreover, cotinine levels are reliable and constant throughout most of a smoking day. Numerous studies have demonstrated that urinalysis of cotinine is a valid and acceptable indicator of smoking behavior (e.g., Murray, Connett, Lauger, & Voelker, 1993; Parker et al., 2002), and correlates with other biological measure of recent smoking such as cotinine found in plasma and saliva; nicotine found in plasma, saliva, and urine; expired breath CO and plasma carboxyhemoglobin (Jarvis, Tunstall-Pedoe et al., 1987); and self-reported number of cigarettes smoked per day (Perez-Stable, Benowitz, & Marin, 1995). Of all biological measures of smoking, urine cotinine is the most sensitive (99%) and specific

(97%) in discriminating smokers and nonsmokers (Gilbert). Immunoassay test strips (ITS; NicCheck™ I; Mossman Associates, Blackstone, MA) were used, which provided semiquantitative analyses of cotinine levels over the last 5-7 days. Studies on NicCheck™ I strips have validated their utility and ease of use in measuring smoking (Bernaards, Twisk, van Mechelen, Snel, & Kemper, 2004; Lesichow, Merikle, Cook, Newman, & Muramoto, 1999). ITS scores and strip colors range from 0 (white) to 14 (dark pink), with 0 representing no smoking over the last 5 -7 days and 14 representing very heavy smoking. When possible, ITS strip colors were independently reported by at least two members of the research team. In instances when there was rater disagreement in strip color scores, an average of the scores was recorded.

Procedure

I implemented a 6-week ABAB withdrawal design, including 1 week of intake/baseline, 3 weeks of CM, 1 week of return to baseline, and 1 week of return to CM. All monetary payments (attendance- and smoking-contingent) made available throughout the study were added to participants' bimonthly university paychecks. Over the 6-week period, participants had the opportunity to earn $72 contingent on attending all sessions and providing the required measures and $157 contingent on complete abstinence from smoking for all sessions, for a total of $229. Raffle tickets were entered into a drawing for a $75 VISA® check card, which occurred following completion of the study; participants had the opportunity to earn 16 raffle tickets throughout the study. At each session, participants were shown a progress report, which included information about their recent smoking behavior and money earned. If participants failed to attend more than one session, they were removed from the study.

Intake/Baseline (Week 1). Staff who fulfilled the intake inclusion criteria met with a member of the research team on campus in a psychology laboratory room at an agreed upon time. At this session, a member of the research team verified that potential participants smoked more than eight cigarettes per day, were not engaged in a structured smoking cessation program or taking medication to quit smoking, and were willing to provide biological samples. Participants were reminded that the biological measurements detect only nicotine and CO. If participants met self-report inclusion criteria, they provided informed consent and an expired breath CO sample, which must have been > 10 ppm to be eligible for enrollment. This inclusion CO level represents moderate smoking levels and was selected as a cut-off to approximate the highest value used to distinguish smokers and nonsmokers (Jarvis, Belcher et al., 1986). Next, the researcher gave an overview of the study and answered any questions before obtaining informed consent for full enrollment. Participants subsequently completed the following self-report measures: demographics questionnaire, SBQ, HONC, FTND, WSWS, CL, and DTR. Before leaving, participants were told that they earned $10 and that if they returned in 2 days (Baseline) and provided self-report and biological measures, they would earn $20, regardless of their smoking levels.

During the baseline session, participants completed the DTR and provided expired breath CO and urine samples. Before the end of the session, the researcher described in detail the contingencies for the next 3 weeks (CM) and answered any questions.

Contingency Management (CM; Weeks 2-4). During the 3 CM weeks, participants met with a member of the research team twice weekly (Monday – Friday).

The time and location of these meetings were individualized for each participant. That is, participants had the option of meeting at the on-campus psychology laboratory, their workplace, or some other agreed upon site. One of the two weekly meetings was held at a constant date and time (planned), whereas the other meeting was not (surprise). At surprise sessions, participants were notified of a session by phone 15 minutes prior, and met a researcher at a prearranged location or the researcher came to the participant's workplace. Surprise sessions were included to discourage participants from smoking irregularly in order to maximize payments (i.e., if all sessions were planned, a participant could shift smoking patterns in ways that make smoking undetectable in order to earn money without actually decreasing smoking).

Planned session. During planned sessions, participants provided expired breath CO and urine samples and completed the DTR and WSWS. After the urinalysis was complete, participants were told whether or not they met reduction or abstention criteria and the accompanying payment (see below). Participants were reminded of the upcoming contingencies, and regardless of smoking levels, all participants who completed the required measures received $2 for their time. Planned sessions lasted no longer than 20 minutes.

Payments and reduction/abstention criteria. Reduction criteria for planned sessions required that all of the following were met: (a) 30% reduction in expired breath CO levels (taken from average of previous two sessions), (b) maintenance or decrease in urine cotinine levels from previous session, and (c) decrease in self-reported number of cigarettes smoked. Payments contingent on meeting reduction criteria across the 3 CM weeks were held constant at $5 and one raffle ticket. Abstention criteria for planned

sessions required that all of the following were met: (a) expired breath CO levels < 4 ppm, (b) maintenance or decrease in urine cotinine levels, and (c) self-reported number of cigarettes smoked was 0. Payments contingent on meeting abstention criteria across the 3 CM weeks were held constant at $18 and two raffle tickets.

Surprise sessions. During surprise sessions, participants provided expired breath CO samples and completed the DTR. After completing these measures, participants were told whether they met reduction or abstention criteria for the sessions and the accompanying payment (see below). Participants were reminded of the upcoming contingencies, and regardless of smoking levels, all participants received $1 for their time. Surprise sessions lasted no longer than 5 minutes.

Payments and reduction/abstention criteria. Reduction criteria for surprise sessions required that the following were met: (a) 30% reduction in expired breath CO levels (taken from average of previous two sessions) and (b) decrease in self-reported number of cigarettes smoked. Payments contingent on meeting reduction criteria decreased across the 3 CM weeks as follows: $8 during the first week, $4 during the second week, and $2 during the third week. Each reduction payment included a raffle ticket across all 3 CM weeks. Abstention criteria for surprise sessions required that the following were met: (a) expired breath CO levels < 4 ppm and (b) self-reported number of cigarettes was 0. Payments contingent on abstention criteria increased across the 3 CM weeks as follows: $15 the first week, $20 the second week, and $25 the third week.

Return to Baseline (Week 5). During the return to baseline week, participants met twice with the researcher. At the first session, participants provided expired breath CO and urine samples and completed the SBQ, HONC, FTND, WSWS, CL, and DTR.

At the second session, participants provided expired breath CO and urine samples and completed the DTR, and the researcher explained the contingencies for the final study week. Participants earned $10 and $20 for completing all required measures at the first and second sessions, respectively.

Return to Contingency Management (CM; Week 6). The return to CM week was identical in procedure to Weeks 2-4, but payments reflected the contingencies of Week 4. At the planned session, participants earned $5 for reduction, $18 for abstention, and $2 for completing the measures. At the surprise session, participants earned $2 for reduction, $25 for abstention, and $1 for completing the measures. At the participants' final session, researchers answered any questions about their involvement in the study and made available additional resources for smoking cessation (see Appendix J). Participants were told that an email would be sent to the winner of the raffle within the next 2 weeks.

Results

Consistent with theoretical and clinical behavior analytic approaches, I analyzed all data at the individual level (see Barlow, Nock, & Hersen, 2009 for a full discussion of the advantages and disadvantages of this approach). Visual analysis (Cooper et al., 2007) was used to determine the extent to which behavior changed as a result of the experimental manipulation (i.e., CM) for the primary dependent smoking measures – expired breath CO, urine cotinine, self-reported number of daily cigarettes smoked since the previous session, and self-reported time since last smoking. Specifically, variability, level, and trend were assessed within and across conditions when possible to detect any meaningful changes in individuals' smoking. In instances in which multiple responses

were given for self-report items (e.g., number of cigarettes smoked since previous session = 15-17), an average of the values was used. Although originally planned, inferential statistical tests of significance as supplemental evidence were not used due to the small sample size and associated low statistical power.

In total, 61 individuals responded and completed the initial smoking behavior screener, and approximately 40 individuals met the study eligibility criteria. Of these individuals, who were provided a brief description of the study and were invited to participate, 12 scheduled and attended the intake session. Ultimately, 9 participants qualified and enrolled in the study. For the 3 individuals who attended the intake session but did not qualify for enrollment, 2 did not provide sufficiently high expired breath CO readings, and 1 reported current use of nicotine replacement therapy. Of the 9 participants, six (67%) completed the entire study. Only data for those participants who completed the entire 6-week study are reported.

General Description of Sample

All participants were Caucasian middle-aged women 42 – 59 years old (*M* = 48.4), with the exception of Participant 15, who was 28 years old, and Participant 8 who was male. All participants reported smoking 7 days per week, began smoking as adolescents, and expressed at least some desire to quit smoking. Four of the six participants (Participants 3 and 15 being the exceptions) had attempted to quit smoking at least once in their lifetime (*M* = 5.7 attempts, range = 1 - 15), and reported various cessation methods including joining a support group, gradually reducing smoking levels, referring to educational materials, enrolling in self-help programs, quitting with a friend, and taking medications. All participants who had made previous attempts had tried

quitting cold turkey. Five of the six participants showed symptoms of moderate to severe nicotine dependence as demonstrated on the HONC (M = 8.6, range = 7 – 10) and FTND (M = 5.6, range = 3 – 7). Participant 15 provided little evidence of significant nicotine dependence (HONC = 4, FTND = 0).

Participant 3

Biological measures. Figure 1 shows the expired breath CO levels across all condition weeks. During baseline, her CO levels dropped substantially at Session 2 following intake. Her CO levels throughout CM Weeks 2 – 4 were consistently lower than the baseline mean but were still similar or slightly less than Session 2's CO levels. During the CM condition, her CO levels showed a minor downward trend and were relatively stable. Following removal of the contingencies, her CO levels increased slightly then dropped to nearly 0 at the next session. Upon reinstating CM for the final week, her CO increased, similar to levels during CM Weeks 2 – 4. Of the 8 sessions for which monetary compensation could be earned, Participant 3 met reduction CO criterion for 1 (12.5%) and abstention CO criterion for 3 (37.5%).

Figure 2 shows the urinalysis scores across all condition weeks. Her urinalysis scores at intake indicated high levels of smoking; however, her urinalysis score for Session 2 decreased roughly 20%. On the first session of CM Weeks 2 – 4, her urinalysis score was substantially lower than both urinalysis scores during baseline, but urinalysis scores at Sessions 6 and 8 returned to baseline levels. During the first return to baseline session, her urinalysis score changed little from Sessions 6 and 8, but decreased to its lowest level at Session 10. Following reinstatement of CM, her urinalysis score increased to levels similar to those of Sessions 6 and 8, but slightly lower than those for her first

baseline week. Of the 4 sessions for which monetary compensation could be earned contingent on urinalysis scores, she met reduction/abstention criterion on 2 (50%).

Self-report measures. Figure 3 shows the self-reported daily number of cigarettes smoked since the previous session across all condition weeks. Following intake, her daily number of cigarettes smoked decreased 50.0% at Session 2. During CM Weeks 2 – 4, her mean daily number of cigarettes smoked was substantially less than that during the baseline session; however, CM Weeks 2 – 4's values were similar to those reported at Session 2.Throughout CM Weeks 2 – 4, her daily number of cigarettes fluctuated slightly with no apparent trend. Upon removal of the contingencies, her daily number of cigarettes decreased slightly from those of CM Weeks 2 -4. When CM was reintroduced in Week 6, her daily number of cigarettes smoked increased slightly to values within the range of those reported during CM Weeks 2 – 4. Of the 8 sessions for which monetary compensation could be earned, Participant 3 met self-report reduction criterion for 5 (62.5%) and abstention CO criterion for 0 (0.0%).

Figure 4 shows the self-reported time in minutes since last smoking a cigarette across all condition weeks. Time since last smoking increased to a large degree from intake to Session 2 during the initial baseline. When CM was introduced during Weeks 2 – 4, time since last smoking changed little from Session 2 but remained within ranges reported during baseline. Across CM Weeks 2 – 4's sessions, time since last smoking varied slightly with an observable small upward trend during Weeks 3 and 4. When the contingencies were removed for Week 5 and reinstated for Week 6, her time since last smoking varied significantly, with two sessions (Sessions 10 and 12) well above

previously reported times, whereas Sessions 9 and 11 were consistent with those reported during the initial baseline and CM Weeks 2 – 4.

Attendance and earnings. Participant 3 attended all 12 sessions of the study. Of the 8 sessions for which she could earn monetary compensation contingent on smoking, she met all reduction criteria twice (25.0%) and did not meet all abstention criteria for any session (0.0%). In total, she earned $10/2 raffle tickets for decreasing her smoking and $72 for attending sessions and completing all required measures.

Participant 8

Biological measures. Figure 5 shows the expired breath CO levels across all condition weeks. During the baseline week, his CO levels fell significantly (75% decrease) during Session 2 relative to intake. Following implementation of CM, his CO level increased above Session 2's value, but much lower than intake. Sessions 3 – 5 showed a declining trend with little variability, eventually reaching a CO level less than that of Session 2. His CO for Sessions 6 – 8 increased to levels slightly less than his average baseline and was stable. When contingencies were subsequently withdrawn, his CO levels increased slightly above CM Week's 2 – 4's levels. For Week 6, when CM was reinstated, his CO levels increased relative to the previous baseline, at levels higher than all previous sessions excluding intake. Of the 8 sessions for which monetary compensation could be earned, Participant 8 met CO reduction criterion for 1 (12.5%) and abstention CO criterion for 1 (12.5%).

Figure 6 shows the urinalysis scores across all condition weeks. Urinalysis scores during baseline were stable and indicative of light smoking levels. When contingencies were implemented, urinalysis scores increased significantly at Session 3, but stabilized at

Sessions 5 and 8 at levels below those of baseline. The sudden increase in his urinalysis scores at Session 3 was likely a result of chewing tobacco use, which he self reported using at times in place of smoking at Sessions 2 and 3. The use of chewing tobacco in place of smoking may also account for the sharp decline in CO levels from Session 1 to 2 (see Figure 5). During the return to baseline, his urinalysis scores increased to levels above the initial baseline week and to levels much higher than those of Sessions 5 and 8. When CM was reintroduced during Week 6, his urinalysis score remained at levels consistent with those of the previous baseline condition. Of the 4 sessions for which monetary compensation could be earned contingent on urinalysis scores, he met reduction/abstention criterion on 2 (50.0%).

Self-report measures. Figure 7 shows the self-reported daily number of cigarettes smoked since the previous session across all condition weeks. During baseline, there was a small decrease in daily number of cigarettes smoked from intake to Session 2. Upon introduction of CM, the daily number of cigarettes smoked decreased sharply, nearly to zero, for Sessions 3 and 4, but increased and stabilized during the remaining sessions of CM Weeks 2 – 4. Despite this increase, the daily number of cigarettes smoked was still significantly less than baseline levels. When CM was withdrawn during Week 5, the daily number of cigarettes smoked did not change notably. During the final CM week, the daily number of cigarettes smoked increased slightly than decreased to levels similar to CM Weeks 2 – 4 for the final session. Of the 8 sessions for which monetary compensation could be earned, Participant 8 met self-report reduction criterion for 4 (50.0 %) and abstention CO criterion for 0 (0.0%).

Figure 8 shows the self-reported time in minutes since last smoking a cigarette across all condition weeks. During the baseline week, time since last smoking increased drastically from intake to Session 2. Again, this increase is likely attributable to his use of chewing tobacco between Sessions 1 and 2. During CM Weeks 2 – 4, time since last smoking remained relatively stable, with the exception of Session 7, and increased relative to baseline (omitting Session 2 as a comparison). Time since last smoking changed little when the contingencies were removed during Week 5 and when they were last reimplemented at Week 6.

Attendance and earnings. Participant 8 attended all 12 sessions of the study. Of the 8 sessions for which he could earn monetary compensation contingent on smoking, he met all reduction criteria once (12.5%) and did not meet all abstention criteria for any session (0.0%). In total, he earned $8/1 raffle tickets for decreasing his smoking and $72 for attending sessions and completing all required measures.

Participant 11

Biological measures. Figure 9 shows expired breath CO levels across all condition weeks. During baseline, her CO levels were relatively stable and indicative of moderate smoking. Upon introduction of CM, her CO levels reduced significantly for all sessions relative to baseline. For Weeks 3 and 4, her CO levels increased relative to Week 2 and showed an upward trend. When the contingencies were removed at Week 5, her CO increased to a level similar to baseline, but decreased at Session 10 to levels provided during CM Weeks 2 – 4. At Week 6, when the contingencies were reinstated, her CO levels decreased from the previous session and finally increased slightly. CO

levels for Week 6 were substantially lower than both baseline weeks and similar to CM Weeks 2 – 4.

Figure 10 shows the urinalysis scores across all condition weeks. Her urinalysis score decreased significantly at Session 2, following intake. During CM Weeks 2 – 4, her urinalysis scores were slightly lower than that of intake, but consistent with Session 2. When the contingencies were removed at Week 5, urinalysis scores did not change notably. At Week 6, when the contingencies were replaced, her urinalysis score remained at levels similar to all previous sessions, except intake.

Self-report measures. Figure 11 shows the self-reported daily number of cigarettes smoked since the previous session across all condition weeks. Her daily number or cigarettes smoked decreased substantially during baseline at Session 2 relative to intake. Upon implementation of CM, her daily number of cigarettes increased slightly but remained at a level lower than that of intake. At the following session, (Session 4) her daily number of cigarettes decreased to levels below both baseline sessions. During Weeks 3 and 4, her daily number of cigarettes smoked increased slightly but stayed at levels equal or lower than baseline. When the contingencies were withdrawn at Week 5, her daily number of cigarettes did not change. At Week 6, when the contingencies were reinstated, her daily number of cigarettes decreased to levels lower than all previous sessions.

Figure 12 shows the self-reported time in minutes since last smoking a cigarette across all condition weeks. During baseline, her time since last smoking at intake and baseline was low and consistent for both sessions. When CM was introduced, her time since last smoking increased substantially and remained stable for Sessions 3 – 5. During

Sessions 5 – 7, her time since last smoking showed a declining trend, and at Session 8 her time since last smoking increased but did not reach the higher levels reported during Sessions 3 – 5. When the contingencies were removed, her time since last smoking decreased but remained at levels similar to those of CM Weeks 2 – 4. Her time since last smoking during Week 5 was significantly greater than that reported during the first baseline condition. At Week 6, when the contingencies were reimplemented, her time since last smoking increased initially to levels greater than all previous sessions but decreased at her last session to a level lower than Week 5.

Attendance and earnings. Participant 11 attended all 12 sessions of the study. Of the 8 sessions for which she could earn monetary compensation contingent on smoking, she met all reduction criteria three times (37.5%) and did not meet all abstention criteria for any session (0%). In total, she earned $16/2 raffle tickets for decreasing her smoking and $72 for attending sessions and completing all required measures.

Participant 12

Biological measures. Figure 13 shows the expired breath CO levels across all condition weeks. During baseline, her CO level decreased significantly at Session 2 relative to intake. During CM Weeks 2 – 4, her CO levels were considerably lower than intake, but similar to Session 2's level, with the exception of Session 8, during which her CO level increased. At Week 5, when the contingencies were withdrawn, her CO level decreased substantially from the previous session, but throughout the return to baseline her CO levels were at levels comparable to CM Weeks 2 – 4. Upon reinstatement of the CM condition, her CO levels did not change notably.

Figure 14 shows the urinalysis scores across all condition weeks. During baseline, her urinalysis score decreased significantly at Session 2 relative to intake. During CM Weeks 2 – 4, her urinalysis scores fluctuated little at levels lower than intake but slightly greater than Session 2. When the contingencies were subsequently removed, her urinalysis score decreased minimally to a level similar to Sessions 3 and 6. There was no change in urinalysis score relative to Week 5 when CM was reimplemented at Week 6.

Self-report measures. Figure 15 shows the self-reported daily number of cigarettes smoked since the previous session across all condition weeks. During baseline, her daily number of cigarettes smoked decreased substantially from intake to Session 2. Upon introduction of the CM intervention, her daily number of cigarettes smoked did not change from the previous session. At Session 5, her daily number of cigarettes smoked decreased below that reported at Session 2, and at Session 8 increased above. When the contingencies were withdrawn at Week 5, there was no change in her daily number of cigarettes smoked at either session. Initially, at Session 11 when CM was reintroduced there was no change in daily number of cigarettes smoked, but at her final session there was a decrease in level within the range of CM Weeks 2 – 4.

Figure 16 shows the self-reported time in minutes since last smoking a cigarette across all condition weeks. During the baseline week, her time since last smoking increased considerably from intake to Session 2. When the contingencies were introduced at Session 3, her time since last smoking increased above both baseline levels. During Session 4 – 6, her time since last smoking decreased relative to Session 3 but was similar or slightly greater than that reported at Session 2. At Sessions 7 and 8, her time since last smoking rose sharply above all previous levels and declined to a level comparable to

Session 2. Upon withdrawal of CM, her time since last smoking increased to a small degree and remained at levels reported during CM Weeks 2 – 4 and above the initial baseline. At Week 6, when the contingencies were reinstated, her time since last smoking increased to levels within the range of those during CM Weeks 2 – 4.

Attendance and earnings. Participant 12 attended all 12 sessions of the study. Of the 8 sessions for which she could earn monetary compensation contingent on smoking, she met all reduction criteria once (12.5%) and did not meet all abstention criteria for any session (0%). In total, she earned $8/1 raffle tickets for decreasing her smoking and $72 for attending sessions and completing all required measures.

Participant 13

Biological measures. Figure 17 shows expired breath CO levels across all condition weeks. During baseline, her CO level decreased substantially from intake to Session 2 (nearly 50%). Following the start of CM, her CO level increased slightly relative to Session 2 but still was considerably lower than that of intake. During Sessions 3 – 5, her CO levels decreased continually, reaching a level lower than that of Session 2. At Session 6, her CO level rose sharply to levels above those seen in previous CM weeks but subsequently decreased to levels lower than Week 2 for Session 7 and 8. When the contingencies were removed at Week 5, her CO level increased minimally. Her CO levels during Week 5 were similar to those provided at Session 2 and significantly lower than that of intake. During Week 6, when CM was reintroduced, her CO level decreased slightly from the previous session and at Session 12 increased to levels consistent with Week 5. Her CO levels during Week 6 were similar to those during CM Weeks 2 – 4.

Figure 18 shows the urinalysis scores across all condition weeks. During Week 1, her urinalysis scores increased from intake to Session 2. When CM was implemented, her urinalysis score decreased to a level below both baseline sessions. At Session 5, her urinalysis score increased above baseline levels and at Session 7 decreased to a level similar to Session 3. When the contingencies were removed at Week 5, her urinalysis score rose sharply to its highest level of the study and decreased to a level similar to Week 4 at the following session. During Week 6, when CM was reintroduced, her urinalysis score did not change and was at a level similar to those provided in CM Weeks 2 – 4.

Self-report measures. Figure 19 shows the self-reported daily number of cigarettes smoked since the previous session across all condition weeks. During baseline, her daily number of cigarettes smoked decreased significantly from intake to Session 2. When the CM intervention began, her daily number of cigarettes smoked increased slightly relative to the previous session but was considerably lower than intake. At Session 5, her daily number of cigarettes smoked increased above those reported at Week 2 and gradually declined through Session 7. At Session 8, her number of cigarettes smoked increased to a near-intake level and represented the highest self-report during CM Weeks 2 – 4. At Week 5, when the contingencies were withdrawn, her daily number of cigarettes did not change. When CM was next reinstated at Week 6, her daily number of cigarettes decreased relative to previous baseline to levels consistent with CM Weeks 2 – 4.

Figure 20 shows the self-reported time in minutes since last smoking a cigarette across all condition weeks. During baseline, her time since last smoking did not change

notably. During CM Weeks 2 – 4, her time since last smoking was highly variable. At Session 3, when CM was first implemented, her time since last smoking increased substantially relative to baseline; however, at Session 4, her level dropped to nearly 0. During Sessions 5 – 8, her time since last smoking showed an increasing trend, reaching levels above those reported at baseline for Sessions 6 – 8. When the contingencies were subsequently removed, her time since last smoking decreased considerably. Following reimplementation of the CM intervention, her time since last smoking increased relative to the previous baseline at levels similar to those during CM Weeks 2 – 4 and above initial baseline levels.

Attendance and earnings. Participant 13 attended all 12 sessions of the study. Of the 8 sessions for which she could earn monetary compensation contingent on smoking, she never met all reduction criteria (0.0%) or all abstention criteria (0.0%). In total, she earned $0 and 0 raffle tickets contingent on smoking and $72 for attending sessions and completing all required measures.

Participant 15

Biological measures. Figure 21 shows the expired breath CO levels across all condition weeks. During baseline, her CO levels decreased drastically from intake to Session 2 (92.3%). When the CM intervention was initiated, her CO level did not change from Session 2 but was significantly lower than that of intake. At Session 4, her CO level increased from Session 3 but was still indicative of smoking abstinence. Sessions 6 – 8 showed a gradual reduction in CO levels, eventually reaching 0. When the contingencies were withdrawn in Week 5, her CO levels increased slightly to levels consistent with

those of CM Weeks 2 – 4. During Week 6, when CM was reimplemented, her CO levels decreased to small degree from Session 10 and increased 1 ppm at her final session.

Figure 22 shows the urinalysis scores across all condition weeks. During baseline, her urinalysis score rose slightly from intake to Session 2 and both scores were indicative of light smoking. Upon introduction of CM at Session 3, her urine score increased relative to Sessions 1 and 2. At Session 6, her urinalysis score decreased to 0, but at the following session increased to a level higher than baseline scores and lower than Session 3. When the contingencies were removed, urinalysis scores decreased to 0 for both baseline sessions and remained at this level when CM was reintroduced at Session 11.

Self-report measures. Figure 23 shows the self-reported daily number of cigarettes smoked since the previous session across all condition weeks. During baseline, her daily number of cigarettes smoked was relatively stable; however, within CM Weeks 2 – 4, her daily number of cigarettes smoked fluctuated considerably. When the CM condition was implemented at Session 3, her daily number of cigarettes smoked increased above baseline levels but quickly decreased below baseline levels at the following session. At Sessions 6 and 7, her daily number of cigarettes smoked increased from Session 4 and dropped significantly on Session 8. During the return to baseline week, her daily number of cigarettes smoked increased substantially, above levels reported during CM Weeks 2 – 4 and the initial baseline. When CM was reintroduced at Week 6, her daily number of cigarettes decreased to levels similar to those of CM Weeks 2 – 4 and continued decreasing to Session 12.

Figure 24 shows the self-reported time in minutes since last smoking a cigarette across all condition weeks. During baseline, her time since last smoking increased greatly

from intake to Session 2. When CM was implemented at Session 3, her time since last smoking increased slightly, showing a small declining trend through Session 7. At Session 8, her time since last smoking increased above all previous levels. When the contingencies were removed, her time since last smoking rose at Session 9 then decreased to levels consistent with CM Weeks 2 – 4. At Week 6, when CM was reimplemented, her time since last smoking increased from Session 10 and continued increasing until the end of the study.

Attendance and earnings. Participant 15 attended 11 of the 12 (87.5%) sessions. Of the 7 sessions for which she could earn monetary compensation contingent on smoking, she met all reduction criteria five times (71.4%) and did not meet all abstention criteria for any session (0.0%). In total, she earned $20/4 raffle tickets for decreasing smoking and $72 for attending sessions and completing all required measures.

CHAPTER 4

Discussion

The present study evaluated the efficacy and feasibility of a CMSC intervention using a novel payment schedule implemented within a workplace setting to address issues related to response requirements and behavioral costs, respectively. This study was the first to employ a payment schedule in which abstention and reduction payments operated concurrently. Furthermore, the current study was the first of its type to consider the effects of a schedule in which payment magnitudes for particular smoking contingencies decreased throughout the treatment weeks. Also, although not the first study to implement CMSC within a workplace setting, it was the first to do so with the intention of reducing behavioral costs for both participants and researchers. These arrangements represent unique approaches toward an improved methodological understanding and practical implementation of CMSC.

Although clear in its aims and objectives, the current study's results provide inconclusive evidence about the extent to which it did or potentially could ameliorate the challenges associated with inadequate response requirements and high behavioral costs. Contrary to my prediction, participants' biological and self-reported evidence of smoking did not systematically reduce when the novel payment schedule was present relative to periods in which it was absent. This finding is inconsistent with the vast majority of previously published studies on CMSC. For example, Dallery, Glenn, and Raiff (2007) found that over 60% of participant samples met abstinence criterion during CM compared to less than 5% during an initial baseline period. Stitzer and Bigelow (1983) obtained similar results in a reduction-based intervention in which 42 – 72% met criterion (i.e.,

50% reduction relative to baseline) during CM. Within a workplace setting, Rand et al. (1989) found that participants paid contingent on smoking abstinence delayed time to relapse significantly longer than those paid independent of smoking levels. Noteworthy differences between these studies and the current study (e.g., CO cutoff levels, method of data collection) do limit the extent to which their results can be compared directly; however, despite these differences, these and other studies (see Sigmon et al., 2008) did demonstrate that smoking levels decreased significantly as a result of CM whereas the present study did not. Also contradictory to my hypothesis, the current design did not retain all participants throughout the 6-week study period. This finding is contradictory to previous CMSC studies. Although the present study required fewer visits and more convenient locations than previous studies, the attrition rates were similar or greater than those requiring 5 or more weekly visits (e.g., Correia & Benson, 2006) over longer periods of time (e.g., 3 months; Lamb, et al., 2005). Furthermore, the attrition rates in the current study were much higher than similar studies also conducted within a workplace setting (e.g., Rand et al.; Stitzer & Bigelow). There are several limitations and concerns that may explain partially the current study's failure to demonstrate (a) systematic smoking reductions during CM weeks relative to baselines and (b) high participant retention. These limitations and concerns raise important empirical questions as to the most optimal and practical methods of implementing CMSC.

Limitations of the Current Study and Future Directions

Failure to establish stable baseline smoking levels. Perhaps the greatest shortcoming of the current study was the failure to establish stable baseline smoking levels (This problem is most relevant to the initial baseline. See "Weaknesses of reversal

designs using CM"). The establishment of a baseline in which a behavioral dimension shows stability is essential to any single-subject analysis and serves two primary functions (Barlow et al., 2009; Cooper et al., 2007). First, a stable baseline provides a description of the target behavior at its natural levels (i.e., in the absence of an independent variable); and second, a stable baseline serves as a predictor of future behavior. For example, if a participant submits CO samples that are stable during baseline, one can predict that subsequent levels will be similar, assuming relevant environmental events remain unchanged. Any changes in CO levels following a systematic manipulation (e.g., addition or withdrawal of CM) provide support that any increase(s) or decrease(s) in level or variability are a function of the manipulation. Such conclusions can be drawn only from reversal or multiple-baseline designs (e.g., baseline, CM, return to baseline; see "Weaknesses of reversal designs using CM" for more on multiple-baseline designs).

In the present study, biological and self-report data were collected just twice during baseline. Collecting baseline data on such few occasions did not allow for a proper assessment of trends. Furthermore, the limited number of sessions during baseline increased the likelihood that extraneous variables (e.g., stress, access to cigarettes) accounted for the variability relative to a design using more repeated measurements. Most importantly, because an insufficient sample size precluded the use of statistical methods, collecting data only twice during baseline did not allow for an experimentally rigorous analysis of the effect CM may have had on participant's smoking levels. In order to address the goals of the current study more sufficiently, future researchers should implement designs in which baseline stability is required prior to introducing CM. Doing

so would increase the extent to which a functional relationship between CM and smoking levels could be identified clearly.

Although experimentally ideal, to the best of my knowledge, no published CMSC study to date has required a stable baseline period prior to introducing CM. Instead, a consistent trend in the literature has been to specify the lengths of baseline from the outset, typically using a timeframe of 1 – 2 weeks (e.g., Correia & Benson, 2006; Lamb et al., 2005). There are numerous practical explanations for this approach. First, for some participants, establishing a stable baseline may take considerably longer than 1 – 2 weeks, which would lead to more costly treatments. Second, obtaining stable smoking levels requires frequent measurements, which would drastically increase the behavioral costs of the participants and researchers and could increase attrition rates compared to studies using shorter baselines. Third, daily smoking patterns are highly variable, and stability or cyclical patterns may not emerge with many current smoking measures (Griffith, Shiffman, & Heitjan, 2009). Given these concerns, designs requiring stable baselines may be best suited for methodological investigations or component analyses, whereas less stringent designs may be ample for clinical applications of CMSC.

Despite the limited amount of smoking data collected during baseline, a consistent pattern of smoking emerged from participants' intake sessions to their second baseline sessions. All participants appeared to reduce their recent smoking at the second baseline session relative to intake, as observed in all 6 participants' CO levels and 4 participants' urinalysis scores. This limited even further the extent to which any potential causal relationships could be drawn. Any decreases in CO or urinalysis observed when CM was introduced could simply represent a continuation of the decreasing levels seen during

baseline. It is unclear what factor(s) may have influenced participant's sharp decreases in smoking during baseline. It is possible that participation in a smoking cessation study increased participants' self-monitoring of smoking, and they may have initiated smoking reduction on their own during this time; however, previous studies suggest that self-monitoring has little effect (Rand et al., 1989) or can actually increase smoking (McFall, 1970).

Weaknesses of reversal designs using CM. The current study used an ABAB design consisting of baseline, CM, return to baseline, and return to CM. This design was chosen because it offers two advantages over simpler ABA designs, which most previous CMSC studies have used (e.g., Irons & Correia, 2008a). First, ABAB designs are preferred from a clinical standpoint because they end on a treatment phase, which may facilitate a participant's transition to an alternative treatment option following the study. Second, ABAB designs are preferred from an experimental perspective because by including a second B phase, they are capable of demonstrating an additional change in behavior as a function of the treatment. Although useful for the study of many clinical problems, withdrawal designs may be inappropriate for studying CM.

Withdrawal designs operate under the assumption that a treatment can be completely removed and reinstated. In previous studies and the present, contingencies for smoking reduction or abstention technically were completely removed and reinstated; however, if CM is successful, smoking levels should not return to baseline levels. The goal of any CM treatment is to arrange artificial reinforcement contingencies to help initiate a previously difficult or unattainable level of a target behavior. Once this level is reached, the individual should begin to contact natural reinforcers associated with that

target behavior level. Ideally, these natural reinforcement contingencies should be sufficiently strong enough to maintain the desired target behavior level long-term; therefore, when CM is removed, behavior should remain stable.

The incompatibility of a withdrawal design for CM has been documented in several previous CMSC studies (e.g., Correia & Benson, 2006; Dallery & Glenn, 2005; Stitzer & Bigelow, 1982). In these studies, smoking levels decreased significantly during CM relative to an initial baseline period; however, smoking levels did not return to these levels during a second baseline period. An experimental interpretation of these findings suggests that variables other than CM may have been responsible for the smoking reductions. A more plausible, clinical interpretation would suggest that CM was responsible for the smoking reductions, and that the failure to return to baseline levels was due to natural reinforcers that participants had begun to contact during CM, which maintained lower smoking levels. To circumvent issues related to internal validity and to make experimental and clinical interpretations more aligned, a nonwithdrawal design, such as the multiple-baseline design, is necessary.

Essentially, multiple-baseline designs can be conceptualized as a series of AB designs in which treatment is introduced in staggered intervals across individuals (Barlow et al., 2009). Once steady-state responding is achieved during baseline, treatment is introduced for one participant until steady-state responding is achieved during treatment. Treatment is introduced in this fashion across all participants and is never withdrawn during the study. The extent to which behavior changes when and only when treatment is introduced is used as an indicator of experimental control. Multiple baselines have been used very little in CMSC studies (e.g., Dallery & Glenn, 2005), but they may offer a

viable approach, addressing issues related to CM's carryover effects while maintaining ethical standards by ending with treatment. Future research is necessary to determine the utility of multiple-baseline designs for use with CMSC.

Practical drawbacks of smoking measurement. Objective verification of the target behavior is an essential component of CM; however, smoking is particularly difficult to measure. The current study used a combination of (a) expired breath CO, to capture recent smoking (6 – 8 hours); (b) urine cotinine, to capture prolonged smoking (5 – 7 days), and (c) self-report, to capture smoking since the previous session. In using these three measures, there was very little chance that participants could earn compensation if they did not truly reduce or abstain from smoking. Likewise, there was very little chance that participants were not compensated, if in fact they did reduce or abstain. Yet, there were several factors that may have influenced participant's smoking measures that deserve consideration. First, all surprise sessions were intended to be chosen randomly by day and time, but due to practical issues (e.g., some participants could not meet certain days), certain participants had a limited number of days and times during which surprise sessions could occur. Although unlikely, it is possible that participants shifted their smoking patterns to attempt to meet reduction criteria for surprise sessions. Researchers for future studies may wish to enroll only participants with certain days and times of availability to reduce any effect this may have had.

Second, meeting times for constant sessions occurred on different days and at different times across participants. For example, participants met with researchers on Tuesday, Wednesday, or Thursday, with some meeting in the late morning and other meeting in the early evening. Any day- or time-related environmental events relevant to

smoking could have influenced smoking levels throughout the study. For example, participants meeting earlier in the week may have provided different urine cotinine scores compared to those meeting later in the week due to increased smoking that may have occurred over the weekend when smoking was not monitored. From the current study, these conclusions are difficult to reach, but future studies should consider these factors, possibly by scheduling participants at the same time and day.

Third, implementing CMSC within the workplace has numerous advantages, but with more employers banning smoking among employees (Fichtenberg & Glanz, 2002), the use of CO and other measures of recent smoking may not provide a valid index suitable for CM interventions. The workplaces included in the present study allowed smoking outdoors but prohibited smoking within public buildings. I did not assess smoking levels during working versus nonworking hours, and it is possible that differences existed that affected treatment outcomes. Other researchers implementing CM within the workplace should consider these factors and may need to adjust their methods of verifying smoking accordingly.

Fourth, the time intervals between sessions were not held constant during weeks in which CM was in place. Time intervals between sessions varied from 0 – 2 days during weekdays and up to 6 days including the weekend, which may have created situations in which participants reduced or abstained from smoking, but did not earn compensation (e.g., a participant with sessions on a Monday and Thursday may have reduced or abstained on Wednesday). Future studies may need to require more frequent measurements to determine the extent to which this occurs. Also, future researchers may

want to explore the effects of different time intervals between sessions on treatment outcomes.

Payment magnitudes and cost-effectiveness. In the current study, participants could earn an average of $6 contingent on smoking reduction and an average of $19.63 contingent on smoking abstention at each session. Compared to most previous CMSC studies, payment magnitudes for the present study were considerably higher, which presumably should have led to lower smoking levels and higher abstention rates than lower payment magnitudes (Correia & Benson, 2006; Stitzer & Bigelow, 1983). One explanation for the current study's failure to show reduced smoking levels may be that payment magnitudes were insufficient. Low payment magnitudes may have contributed also to participant attrition, although these payments were exceptionally high (i.e., average of $15 per session during baselines and $1.50 during CM weeks) compared to other CMSC studies. The selection of the average monetary payments per session was informed from a previous study (Irons & Correia, 2008b), in which college student smokers indicated monetary amounts for which they would completely abstain from smoking for various periods of time (e.g., 1 day, 1 week). The current study used a sample of middle-aged adults holding full-time jobs who likely had higher personal incomes than participants in Irons' study. It is possible that individuals with greater personal incomes require higher payment magnitudes to initiate smoking reduction or abstinence. Some researchers (e.g., Dallery & Glenn, 2005) have begun to publish demographic information related to personal income, but no empirical methods exist on how to use this information. Determining whether and the extent to which personal

income affects smoking outcomes is a necessary step toward creating more efficient CMSC interventions.

Other differences in sample characteristics between Irons and Correia (2008b) and the present study, such as the number of years smoked (i.e., older smokers are more likely to have smoked longer), also could moderate the relationship between payment magnitude and smoking outcomes. Moreover, the reduction payments were established based on data for smoking abstinence. At present, there are no studies that have investigated the relationship between payments for smoking reduction and abstention. In the current study, reduction payments were significantly lower than those for abstention. However, it is still unclear whether payment magnitudes for reduction and abstention would be most beneficially arranged in a linear (e.g., 50% [25%] reduction criterion would result in 50% [50%] of the abstinence payment magnitude) or nonlinear fashion (e.g., payment magnitudes for reduction would change relative to abstinence magnitudes over the course of treatment). Further understanding of the relationship between response requirements and payment magnitudes is essential for creating CMSC interventions that are cost-effective, an aim that is arguably the greatest barrier to its wide-spread adoption.

Recently, more strategies to decrease CM costs have been explored. Petry and colleagues (2002, 2000) employed variable value (i.e., lottery-based) contingencies using CM for the treatment of substances other than nicotine and obtained results consistent with those employing standard monetary payments, while keeping treatment costs low. A similar approach was used in the present study, in which participants could earn one raffle ticket contingent on smoking reduction and two raffle tickets contingent on smoking abstention at each session, which were entered into a lottery for a $75 VISA®

check card. Other methods for increasing the cost-effectiveness of CMSC include (a) funding treatments through community donations (e.g., Donatelle, Prows, Champeau, & Hudson, 2000), (b) deposit contracting (e.g., Dallery, Meredith, & Glenn, 2008) , and (c) treatment fee rebates (see Amass and Kamien, 2008, who discuss this approach and the others at length). Future researchers also may want to search for reinforcers that have additional health benefits or address other societal problems related to smoking, especially among at-risk populations and/or those in underserved areas. For example, individuals with little formal education or deficient English skills who successfully reduce or abstain from smoking could enroll in classes taught by volunteers or receive donated educational technology software/hardware. These individuals could experience a number of benefits above and beyond smoking cessation (e.g., education could lead to a better-paying job, language skills could allow parents to finally help their children with schoolwork). Indeed, CM arrangements that address societal problems that co-occur with substance abuse have been extremely successful (e.g., unemployment and heroin/cocaine use; Silverman, Svikis, Robles, Stitzer, & Bigelow, 2002) and have the potential to be highly cost-effective.

Delayed payments. One potential strength of implementing CMSC within the workplace is that payments can be incorporated easily into the existing payroll system, reducing many administrative burdens that might deter employers from enrolling. However, typical payroll systems in the United States distribute paychecks at varying delays, with most ranging from weekly to monthly. In the current study, participants were told that payments would be added to their bi-monthly paychecks, and that they could expect their first payment within 1 to 3 weeks from their first session. During Week 3,

several participants reported that they had not received their study payments. Due to a payroll processing error, study payments were not distributed as planned, and participants received their payments as one lump sum roughly 7 to 8 weeks following their intake session. A failure to provide more immediate payments contingent on smoking and attendance may explain the current study's inability to reduce smoking levels and to retain participants.

A large body of basic nonhuman animal and human research has shown unequivocally that reinforcers delivered immediately following a target behavior increase that behavior substantially more than reinforcers delivered following some delay (Chung & Herrnstein, 1967; Cooper et al., 2007; Madden, 2000; Vuchinich & Heather, 2003). Said differently, individuals value immediately available reinforcers more so than those that are available at a delay (e.g., $1 available now is more valuable than $1 tomorrow). This phenomenon, generally referred to as temporal or delay discounting, is especially pertinent to the study of substance abusers, including smokers, who tend to discount delayed reinforcers significantly higher than non- or ex-smokers (Bickel, Odum, & Madden, 1999). Roll, Reilly, and Johanson (2000) examined the effects of delayed payment in a laboratory model of CM, during which participants could choose to take puffs from a cigarette or receive money delivered immediately or at a delay. They showed that when the cigarette and monetary consequences were available immediately, participants abstained from smoking significantly more than when both were delivered at a delay. This finding suggests that when possible, researchers and clinicians should provide payments immediately following verification of smoking reduction or abstention to maximize CM's efficacy. Lussier et al. (2006) corroborated Roll et al.'s results and

showed that the effect size for CM studies providing immediate reinforcer delivery was roughly twice that of those providing delayed reinforcement.

Given these findings, the results of the current study are not surprising. Payments delayed 7 to 8 weeks following attendance and verification of a behavior are not likely to have a significant impact. The long delay for payments was unplanned, but nevertheless it does raise important questions about the feasibility of CMSC within the workplace. The current study processed just nine individuals' payments. Larger studies within a workplace might demand updated payroll systems or additional staff, which some employers may not be able to afford. Another potential challenge for future studies relates to the delay to payment itself. The current study was unable to determine if payments delivered bi-monthly could initiate and maintain smoking reduction and abstinence. Future researchers should examine differing delays within the workplace to consider the clinical and practical advantages and disadvantages of each.

Payment arrangements. Many of the issues described above limit the extent to which any conclusions can be drawn regarding the novel payment arrangements used in the present study, but several aspects of the arrangements deserve consideration. The payment arrangements of the present study provided abstention and reduction payments concurrently in an attempt to accommodate smokers who were not able to abstain immediately and those who were. Abstention payments escalated in magnitude across treatment weeks, whereas reduction payments decreased in magnitude. This arrangement increased the reinforcing value of abstention relative to reduction over time, with the intention of facilitating a transition to complete abstention later in the study for those gradually reducing in the early treatment weeks.

A major limitation of these payment arrangements was that magnitudes changed across weeks, regardless of whether participants were able to initiate smoking reduction. For example, during the first week of CM, 2 of the 6 participants were unable to meet reduction criteria for both sessions. During the following week (Week 3), payment magnitudes for reduction decreased by 50% for all participants. Although the abstention payment increased 33% during this week, the participants who were unable to initiate reduction the week prior would be less likely to do so during Week 3, based on previous studies on payment magnitudes (e.g., Stitzer & Bigelow, 1983). Furthermore, these participants would not be expected to completely abstain during Week 3. An additional weakness of these arrangements was that despite obtaining initial reductions, no participants transitioned to smoking abstinence. This suggests that (a) absolute abstinence payment magnitudes were insufficient or too delayed or (b) the relative difference between abstention and reductions payments was too small. There are several options that future studies might investigate to improve upon the present study's payment arrangements. Payment magnitudes for smoking reduction could decrease on an individual rather than weekly basis. This would increase the likelihood that participants earn smoking-contingent reinforcement, but this method would provide no guarantee. A potential solution would be to use an arrangement in which reduction payments escalate in magnitude based on individual smoking levels. In this way, participants who fail to contact reduction contingencies early in treatment could have another opportunity to reduce at a higher magnitude, which should increase the likelihood of earning payment. For example, if a participant failed to reduce during the first week of treatment for a payment magnitude of $10, his or her next payment would increase in magnitude the

following week. Another approach to ensure contact with reinforcement could be to lower reduction criteria on an individual basis. For example, if a participant failed to reduce during the first week of treatment when reduction criterion was a 30% reduction, the following week could become less stringent (e.g., 20%). Both components (i.e., magnitude and criteria) also could be modified simultaneously; however, reducing criteria may be limited by the types of measures used to verify smoking. A traditional escalating magnitude payment arrangement, in which successive reductions or abstentions result in subsequent magnitude increases, also could be incorporated (Roll et al., 1996). Escalating magnitude payment arrangements are now a standard practice in CMSC and may lead to better treatment outcomes. Finally, the present schedule might be improved by adding a reset contingency (e.g., Roll & Higgins, 2000), which has been shown to increase sustained smoking abstinence.

Conclusion

The results of the present study pose more questions than they provide answers. The methodological and practical limitations discussed above highlight an ongoing struggle within the CM literature. There is no question that CM can initiate and maintain smoking reduction and abstinence; however the extent to which these findings, many of which were discovered in highly controlled settings, can generalize to real-world environments and applications remains a challenge. Researchers are well-aware of this challenge, and many have begun to develop innovative approaches to improve CM's effectiveness. Nevertheless, some fundamental areas of CM (e.g., payment schedules) have received little attention in recent years, perhaps due to greater funding opportunities for randomized controlled trials. These seldom investigated research areas may prove to

be equally important to further development of CM interventions, and a return to the human operant and basic nonhuman animal research laboratories where CM's core principles were discovered may be necessary. Given the clear clinical potential of CM, research into its application will continue to increase, but the results of the current study demonstrate the dearth of basic knowledge that needs addressing in order to harness this powerful technology to its fullest potential.

Footnote

[1]Although often referred to as shaping, technically this is incorrect. Shaping involves providing reinforcers contingent upon successive changes in response typographies that more closely approximate some ultimate goal. In a changing criterion design, the target response typography remains constant and reinforcers are provided contingent upon successive changes in some quantifiable dimension of that target. Thus, changing criterion design is a more accurate way of describing the implementation of percentile schedules of reinforcement in CM. See Cooper et al. (2007) for more on this distinction.

Appendix A

Demographics Questionnaire

1) What is your participant ID?

2) Gender

   Male
   Female

3) What is your age?

4) Race

   Asian
   Black or African American
   White
   Hispanic or Latino
   American Indian or Alaska Native
   Native Hawaiian or other Pacific Islander
   Multi-ethnic
   Other

Appendix B

Smoking Behavior Questionnaire

1) On how many days of the week do you smoke cigarettes?

2) How old were you when you began to smoke cigarettes regularly?

3) For how many hours, on average each day, are you closely subjected to other people's tobacco smoke?

   NOTE: "*closely subjected*" means that you see, smell, or inhale tobacco smoke

4) How many times have you tried to quit smoking?

5) How interested are you in stopping smoking?

   Strongly
   Very
   Somewhat
   A little
   Not at all

6) Have you ever tried to stop smoking before using the following methods?

   Clinical or group
   Gradual reduction
   Written materials
   Hypnosis
   Special filters
   Self-help program
   Cold turkey
   Stop with a friend
   Medication
   Other

7) Are you currently using any of the following methods to stop smoking?

   Clinical or group
   Gradual reduction
   Written materials
   Hypnosis
   Special filters
   Self-help program

Cold turkey
Stop with a friend
Medication
Other

8) Do you plan to use any of the following methods to quit smoking in the next 6 weeks?

Clinical or group
Gradual reduction
Written materials
Hypnosis
Special filters
Self-help program
Cold turkey
Stop with a friend
Medication
Other

Appendix C

Hooked on Nicotine Checklist

Indicate your answer, “yes” or “no”, for the following 10 questions:

Have you ever tried to quit using tobacco products, but couldn't?

Do you smoke now because it really hard to quit?

Have you ever felt like you were addicted to tobacco?

Do you ever have strong cravings to smoke?

Have you ever felt like you really needed a cigarette?

Is it hard to keep from smoking at times or in places where others are not?

When you haven't smoked for a while
OR
when you tried to stop smoking...

...did you find it hard to concentrate because you couldn't smoke?

...did you feel more irritable because you couldn't smoke?

...did you feel a strong need or urge to smoke?

...did you feel nervous, restless or anxious because you couldn't smoke?

Appendix D

Fagerstrom Test for Nicotine Dependence

How soon after you wake up in the morning do you smoke your first cigarette?

After 60 minutes
31-60 minutes
6-30 minutes
Within 5 minutes

Do you find it difficult to refrain from smoking in places where it is forbidden?

Yes
No

Which cigarette would you hate most to give up?

First in the morning
Any other

How many cigarettes do you smoke per day?

10 or less
11-20
21-30
31 or more

Do you smoke more frequently during the first part of the day after awakening than during the rest of the day?

Yes
No

Do you smoke when you are so ill that you are in bed most of the day?

Yes
No

Appendix E

Wisconsin Smoking Withdrawal Scale

All items are rated on a 5-point scale (0 = *strongly disagree*, 4 = *strongly agree*)

Food is not particularly appealing to me.
I am getting restful sleep.
I have been tense or anxious.
My level of concentration is excellent.
I awaken from sleep frequently during the night.
I have felt impatient.
I have felt upbeat and optimistic.
I have found myself worrying about my problems
I have had frequent urges to smoke.
I have felt calm lately.
I have been bothered by the desire to smoke a cigarette.
I have felt sad or depressed.
I have been irritable, easily angered.
I want to nibble on snacks or sweets.
I have been bothered by negative moods such as anger, frustration, and irritability.
I have been eating a lot.
I am satisfied with my sleep.
I have felt frustrated.
I have felt hopeless or discouraged.
I have thought about smoking a lot.
I have felt hungry.
I feel that I am getting enough sleep.
It is hard to pay attention to things.
I have felt happy and content.
My sleep has been troubled.
I have trouble getting cigarettes off my mind.
It has been difficult to think clearly.
I think about food a lot.

Appendix F

Contemplation Ladder

Each rung on this ladder represents where various smokers are in their thinking about quitting. Check the number that indicates where **you** are now. PLEASE CHECK ONLY ONE.

Rung 0
No thought about quitting
Rung 1
Rung 2
Think I need to consider quitting some day
Rung 3
Rung 4
Rung 5
Think I should quit but not quite ready
Rung 6
Rung 7
Starting to think about how to change my smoking patterns
Rung 8
Rung 9
Rung 10
Taking action to quit

Appendix G

Daily Tobacco Report

On average, how many cigarettes per day have you smoked since your last session?

Have you smoked cigarettes over the last 24 hours?

Yes
No

If YES, how many cigarettes have you smoked over the last 24 hours?
If YES, how long ago did you smoke your last cigarette? (Hrs or min)
Have you smoked any cigars over the last 24 hours?

Yes
No

If YES, how many cigars have you smoked over the last 24 hours?
IF YES, how long ago did you smoke your last cigar? (Hrs or min)
Have you smoked any pipe tobacco over the last 24 hours?

Yes
No

If YES, how many times did you smoke pipe tobacco over the last 24 hours?
IF YES, how long ago did you smoke your last pipe tobacco? (Hrs or min)
Have you had any chewing tobacco over the last 24 hours?

Yes
No

If YES, how many times did you use chewing tobacco over the last 24 hours?
IF YES, how long ago you last use chewing tobacco? (Hrs or min)

Appendix H

Vitalograph® BreathCO

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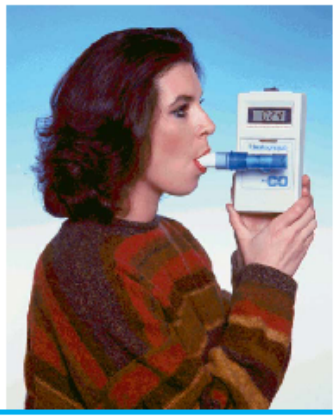
the motivational tool ...
in smoking cessation

BreathCO, the simple non-invasive way to measure breath carbon monoxide levels.

- Hand-held, battery operated unit is quick and easy to use
- Disposable mouthpieces ensure hygienic and inexpensive operation
- Easy-to-read, large display
- Unique, accurate zero adjuster slide
- Reliable calibration



help smokers kick the habit

Smoking Cessation can be a success with the motivation provided by the BreathCO monitor. The BreathCO provides visual proof to the smoker of the dangerous CO levels in their lungs.

Showing smokers the poison they are carrying in their blood and the damage they are doing to their bodies as a result of their habit is an excellent motivator.

Let Vitalograph's BreathCO be a part of your successful smokingcessation program. It is never too late to stop smoking; even at 65 life expectancy increases by 10 years.

Vitalograph® ... the spirometry people

Appendix I

NicCheck™ I Test Strips
For Use in the Detection of Nicotine and/or its Metabolites in Urine

Background

In recent years, the knowledge and awareness of health hazards associated with tobacco consumption (especially from smoking cigarettes) has increased. Surgeon Generals' Reports of the U.S. Public Health Service (PHS) have identified cigarette smoking as one of the most significant causes of death and disease in the U.S. This awareness has also increased all over the world. Smoking is cited as one of the major causes of cancer (1, 2); it is responsible for an estimated 30% of all cancer deaths including 87% of lung cancer, the leading cause of cancer mortality. It is also responsible for 21% of deaths from coronary heart disease, 18% of stroke deaths, and 82% of deaths from chronic obstructive pulmonary disease (3). Other forms of tobacco use, including pipe and cigar smoking and the use of smokeless tobacco, are also associated with significantly elevated risks of disease and death (4, 5).

Self-reports of smoking behavior have been shown to be unreliable (6, 7, 8, 9). The availability of sensitive and reproducible analytical methods has led to the increased use of biochemical markers for the measurement of tobacco consumption (10). Measurement of carbon monoxide, carboxyhemoglobin or thiocyanate in the blood, or of nicotine/cotinine in plasma, saliva or urine have been used to validate self-reported smoking habits. However, none of these methods are satisfactory for routine use. Measurement of expired carbon monoxide or carboxyhemoglobin levels and thiocyanate levels may vary due to exposures unrelated to smoking, such as traffic emissions and diet (11). Nicotine is a tobacco-specific alkaloid with a half-life of 2 hours in blood. Its principal metabolite cotinine (12), has an average half-life of 20 hours in urine (13, 14), making it a reasonable candidate for use as a biochemical marker for tobacco consumption.

The NicCheck I test is a simple test that detects nicotine and/or its metabolites in urine as a means to identify habitual consumers of tobacco. It can also differentiate nicotine consumers into “low” versus “high” categories. For the classification of smokers by the NicCheck I test as positive or negative based on comparison to GC urine cotinine values, individuals with cotinine values of 200 ng/mL and above were classified as smokers and those with cotinine values of less than 200 ng/mL were considered nonsmokers. The NicCheck I test is suited for routine use since it is technically simple to perform, and requires no instrumentation. Test results are available within 15 minutes.

There appears to be an increasing need to not only verify an individual's smoking status, but also to be able to know the level of nicotine consumption. The number of cigarettes smoked is not a true reflection of the nicotine consumed since the kinds of cigarettes smoked are different, the intensity with which cigarette smoke is inhaled can vary considerably from individual to individual, and the metabolism of nicotine in individuals can also vary. Thus, two individuals smoking the same number of cigarettes may have vastly different nicotine levels in their system. Determining the level of nicotine consumption, for example, can be important to aid individuals to quit their smoking habit. There is increasing evidence that a person with low nicotine dependence

may require lower nicotine replacement therapy when compared to an individual who is more highly nicotine dependent. Additionally, monitoring the decrease in the color intensity on the NicCheck test strip may serve as an indicator of decreasing nicotine consumption during smoking cessation efforts and may provide the patient with positive reinforcement. The test may also be used to verify cessation. A test such as the NicCheck I test would provide a simple, inexpensive and rapid method for determining the smoking status of the individual and in identifying the smoker as a low or high nicotine consumer.

Test Description

The NicCheck test strip has four chemicals spotted along the length of the strip at definite intervals. In testing for the presence of nicotine and its metabolites in urine, the NicCheck I test strip is placed (diethylthiobarbituric acid end first) into approximately 0.5 mL of urine contained in a suitable test tube. When urine diffuses up the test strip, the potassium thiocyanate mixes with chloramine-T on the strip, releasing cyanogen chloride. The cyanogen chloride then reacts with the nicotine (and/or its metabolites), if present, in the urine. Diethylthiobarbituric acid reacts with the resulting glutaconaldehyde to produce a pale pink to dark pink color along the length of the test strip and in the liquid remaining at the bottom of the tube.

Handling Procedures

Each test strip should be carefully removed from the canister by only handling the strip at the arrow end. Handling other parts of the test strip must be avoided. Alternatively, a pair of clean forceps may be used to remove the strips from the canister. The test strip must be placed in the urine sample (approximately 0.5 mL) with the indicator arrow pointing downward in order for the urine sample to diffuse past the reagents in the proper sequence. The test sample container (a 13 x 100 mm glass tube is recommended) must be long enough to enclose the length of the entire test strip. The canister must be closed tightly after removal of the required number of strips.

Storage Instructions

NicCheck I test strips do not require refrigerated shipping. Upon receipt, the canister should be kept at 2-8 ^{o}C. The test strips should be protected from unnecessary light and humidity to prevent light-induced and moisture-induced deterioration of the reagents on the test strip.

In general, when stored in the tightly closed canister at 2-8 ^{o}C, the test strips can be used for at least two years from the date of manufacture. Since the test strips are susceptible to conditions of high humidity, the canister must be kept tightly closed after removal of the required number of strips.

Indications of Instability

While a pale brown color may be observed at the lower end of an unused test strip, this does not indicate a degradation of the test strip and does not interfere with the reaction. However, a bright yellow or dark brown color observed elsewhere on the test strip may indicate instability. Quality control checks using NicCheck I Human Urine Positive and Negative Test Controls (sold separately) should be performed whenever instability is suspected.

Specimen Collection and Preparation

NicCheck I test strips may be used with any freshly voided, stored (refrigerated or frozen) urine specimens or with urine collected under special conditions, such as first-

morning specimens and post-prandial urine specimens. The urine specimen must be collected in a clean container. Preservatives must not be added to the urine specimen. If testing cannot be performed within 4 hours after collection of the urine, the specimen must be stored at 2-8 ^{o}C. If stored at 2-8 ^{o}C, testing must be performed within 48 hours. The specimens must be brought to room temperature prior to testing, and mixed thoroughly before use. The test may also be performed on specimens stored frozen at -20 ^{o}C. The frozen specimens may not be frozen and thawed more than three times. Studies beyond three freeze-thaw cycles have not been conducted. If stored frozen, the specimens must be thawed and brought to room temperature prior to testing.

It should be noted that the NicCheck I test strips function appropriately in the pH range of 4.5-8.5. The NicCheck I test may react as false negative if the pH of the urine is outside of this range. Normal urine has a pH of 4.5-8.0 with an average pH of 6.0.

Test Description

1. Obtain a urine specimen and transfer 0.5-1.0 mL of urine to a 13 x 100 mm test tube or equivalent.
2. Remove a NicCheck I test strip from the canister, handling the strips only at the arrow end. Do not touch any other part of the test strip. Alternatively, a clean pair of forceps may be used to remove the test strip from the canister.
3. Place the test strip directly into the urine specimen with the arrow pointing downward into the specimen.
4. After introduction of the test strip into the specimen, observe results at 15 minutes. For differentiation into “low” versus “high” consumption of nicotine, comparison of the test results to the color chart provided must also be performed at 15 minutes.

Materials Provided

Fifty (50) NicCheck I test strips are provided with each kit. A color chart for the differentiation of smokers into “low” versus “high” consumers of nicotine is also provided with each kit.

Materials Required But Not Provided

13 x 100 mm test tubes (or equivalent), Forceps (optional), and a test tube rack

Interpretation of Results

The appearance of a pale pink to dark pink color on the strips is a positive reaction and indicates the presence of nicotine and/or its metabolites in the specimen. Occasionally, colors in the spectrum of orange to reddish pink may be observed. These are also to be considered as true positive reactions. Color development must occur along the length of the test strip. The intensity of color on the strip at the end of 15 minutes may be compared to those on the color chart, to differentiate between “low” versus “high” nicotine consumption.

If the color along the length of the test strip is less in intensity than the pink color on the color chart, the result is read as a “low” positive. If the color on the test strip matches in intensity or is darker in intensity than the pink color on the color chart, the result is interpreted as a “high” positive. Absence of a color in the pink to red spectrum is considered a negative result.

Note: As the NicCheck I test reaction occurs (positive or negative), it is normal for a bright yellow color to develop at the top end of the strip (near the arrows).

Limitations of the Procedure

If reactions with positive and negative test controls are not as expected, unused test strips should not be used, and the distributor and/or manufacturer should be notified. Consumption of therapeutic levels (daily dose of 500 mg or greater) of niacin may result in a false-positive reaction by the NicCheck I test.

Reliable results and proper interpretation of results are dependent on performing the procedure as described in the package insert.

For the correct result to be obtained with the NicCheck I test, it is important to note the following conditions under which proper color development on the test strip may be impeded.

Delivering more than 1 mL of urine into the test tube for the NicCheck I test may result in improper color development due to inability of the sequential reaction to occur. Delivering less than 0.5 mL of urine will be insufficient to wet the full length of the test strip.

Using a beaker or urine collection container for performing the NicCheck® I test is unacceptable. Since the color development depends upon the sequential reaction of reagents along the entire length of the test strip, it is important to use a narrow test tube which is long enough to enclose the entire length of the strip.

For color development, the test strip must be placed with the arrow pointing downward into the tube.

Urine must be delivered directly to the bottom of the test tube in order to avoid sticking of the test strip to the inner wall of the tube. If the test strip sticks to the inner wall of the test tube, it does not allow for proper color development along the length of the test strip. The test must be repeated if this occurs.

Under conditions of high humidity, the test tube containing the NicCheck I test strip must be kept covered.

The NicCheck I result must be read 15 minutes after introduction of the test strip into the urine. Reading the reaction after 25 minutes may result in a decrease in the color intensity on the NicCheck test strip.

Appendix J

Debriefing Statement

The purpose of this study was to examine an intervention designed to help individuals reduce their smoking. If participation in this study caused you any discomfort or distress, you should visit one of the following:

- Counseling and Student Development Center located in Varner House, immediately adjacent to the statue of James Madison and the Hoffman Hall bus stop in the Bluestone area of campus (540.568.6552; http://www.jmu.edu/counselingctr/)
- University Health Center located next to Burruss Hall, at the corner of Mason and Grace St, adjacent to Rockingham Memorial Hospital, (540.568.6178; http://www.jmu.edu/healthctr/)

For more information on how you can quit smoking, visit the US Department of Health and Human Services Centers for Disease Control and Prevention Smoking and Tobacco Use web page at http://www.cdc.gov/tobacco/quit_smoking/index.htm or one of these other reputable web sites that address smoking cessation.

http://www.smokefree.gov/

http://www.nlm.nih.gov/medlineplus/smokingcessation.html

http://www.cancer.gov/cancertopics/factsheet/Tobacco/cessation

http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=22931

http://www.surgeongeneral.gov/tobacco/

References

Abueg, F. R., Colletti, G., & Kopel, S. A. (1985). A study of reactivity: The effects of increased relevance and saliency of self-monitored smoking through enhanced carbon monoxide feedback. *Cognitive Therapy and Research, 9*, 321-333.

Amass, L., & Kamien, J. B. (2008). Funding contingency management in community treatment clinics. In S. Higgins, K. Silverman, & S. Heil (Eds.), *Contingency management in substance abuse treatment* (pp. 280 - 297). New York: The Guilford Press.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders, (4th ed.)*. Washington, DC: American Psychiatric Association.

Amodei, N., & Lamb, R. J. (2004). Convergent and concurrent validity of the Contemplation Ladder and URICA scales. *Drug and Alcohol Dependence, 73*, 301-306.

Barlow, D. H., Nock, M. K., & Hersen, M. (2009). *Single case experimental designs: Strategies for studying behavior change*. Boston: Pearson Education, Inc.

Baum, W. M. (1979). Matching, undermatching, and undermatching in studies of choice. *Journal of the Experimental Analysis of Behavior, 32*, 269-281.

Baum, W. M., & Rachlin, H. C. (1969). Choice as time allocation. *Journal of the Experimental Analysis of Behavior, 12*, 861-874.

Bernaards, C. M., Twisk, J. W. R., van Mechelen, W., Snel, J., & Kemper, H. C. G. (2004). Comparison between self-report and a dipstick method (NicCheck1) to assess nicotine intake. *European Addiction Research, 1*, 163-167.

Bickel, W. K., Odum, A. L., & Madden, G. J. (1999). Impulsivity and cigarette smoking: Delay discounting in current, never, and ex-smokers. *Psychopharmacology, 146*, 447 – 454. doi: 10.1007/PL00005490

Biener, L., & Abrams, D. (1991). The Contemplation Ladder: Validation of a measure of readiness to consider smoking cessation. *Health Psychology*, *10*, 360-365. doi: 10.1037/0278-6133.10.5.360

Bigelow, G. E., & Silverman, K. (1999). Theoretical and empirical foundations of contingency management treatments for drug abuse. In S. Higgins & K. Silverman (Eds.), *Motivating behavior change among illicit-drug abusers: Research on contingency management interventions* (pp. 15-31). Washington, D. C.: American Psychological Association.

Bisaga, A., Padilla, M., Garawi, F., Sullivan, M. A., & Haney, M. (2006). Effects of alternative reinforcer and craving on the choice to smoke cigarettes in the laboratory. *Human Psychopharmacology: Clinical and Experimental*, *22*, 41-47.

Breslau, N., & Johnson, E. O. (2000). Predicting smoking cessation and major depression in nicotine-dependent smokers. *American Journal of Public Health*, *90*, 1122–1127.

Budney, A. J., Moore, B. A., Higgins, S. T., & Rocha, H. L. (2006). Clinical trial of abstinence-based vouchers and cognitive behavioral therapy for cannabis dependence. *Journal of Consulting and Clinical Psychology*, *74*, 307-316.

Carey, K. B., & Carey, M. P. (1990). Enhancing the treatment attendance of mentally ill chemical abusers. *Journal of Behavioral Therapy and Experimental Psychiatry*, *21*, 205-209.

Carroll, M. E., Bickel, W. K., & Higgins, S. T. (2001). Nondrug incentives to treat drug abuse: Laboratory and clinical developments. In M. Carroll & B. Overmier (Eds.), *Animal research and human health: Advancing human welfare through behavioral science* (pp. 139-154). Washington, D. C.: American Psychological Association.

Catania, A. C. (1963). Concurrent performances: A baseline for the study of reinforcement magnitude. *Journal of the Experimental Analysis of Behavior, 6,* 299-300.

Center for Disease Control and Prevention (1990). *The health benefits of smoking cessation* (DHHS Publication No. [CDC] 90-8416, 1990). Retrieved from http://profiles.nlm.nih.go v/NN/B/B/C/T/_/nnbbct.pdf

Center for Disease Control and Prevention. (2002). Annual smoking-attributable mortality, years of potential life lost, and economic costs: United States 1995-1999. *Morbidity and Mortality Weekly Report, 51(14),* 300-303. Retrieved from http://www.cdc.gov/mmwr/P DF/wk/mm5114.pdf

Center for Disease Control and Prevention. (2004). *The health consequences of smoking: A report of the Surgeon General*. Retrieved from http://www.cdc.gov/tobacco/data_statistic s/sgr/2004/pdfs/

Center for Disease Control and Prevention. (2008). Smoking-attributable mortality, years of potential life lost, and productivity losses: United States 2000-2004. *Morbidity and Mortality Weekly Report, 57(45),* 1226-1228. Retrieved from http://www.cdc.gov/mmwr/ PDF/wk/mm5745.pdf

Center for Disease Control and Prevention. (2009). Cigarette smoking among adults and trends in smoking cessation: United States, 2008. *Morbidity and Mortality Weekly Report*, *58(44)*, 1227 – 1232. Retrieved from http://www.cdc.gov/mmwr/PDF/wk/mm5845.pdf

Chung, S-H., & Herrnstein, R. J. (1967). Choice and delay of reinforcement. *The Journal of the Experimental Analysis of Behavior, 10*, 67-74.

Conger, R. & Killeen, P. (1964). Use of concurrent operants in small group research. *Pacific Sociological Review*, *17*, 399-416.

Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied Behavior Analysis*. Upper Saddle River, New Jersey: Pearson Education.

Correia, C. J., & Benson, T. A. (2006). The use of contingency management to reduce cigarette smoking among college students. *Experimental and Clinical Psychopharmacology*, *14*, 171 – 179.

Dallery, J., & Glenn, I. M. (2005). Effects of an internet voucher-based reinforcement program for smoking abstinence: A feasibility study. *Journal of Applied Behavior Analysis*, *38*, 349-357.

Dallery, J., Glenn, I. M., & Raiff, B. R. (2007). An internet-based abstinence reinforcement treatment for cigarette smoking. *Drug and Alcohol Dependence*, *86*, 230-238.

Dallery, J., & Meredith, S., & Glenn, I. M. (2008). A deposit contract method to deliver abstinence reinforcement for cigarette smoking. *Journal of Applied Behavior Analysis*, *41*, 609 – 615. doi: 10.1901/jaba.2008.41-609

Danaei, G., Ding, E. L., Mazaffarian, D., Taylor, B., Rehm, J., Murray, C. J. L., & Ezzati, M. (2009). The preventable causes of death in the United States: Comparative risk assessment of dietary, lifestyle, and metabolic risk factors. *Plos Medicine, 6*. doi: 10.1371/journal.pmed.1000058

Day, J. M. (2008). Pharmacological approaches to treatment. In G. L. Fisher & N. A. Roget (Eds.), *Encyclopedia of substance abuse: Prevention, treatment, and recovery*. SAGE Publishers.

Deveci, S. E., Deveci, F., Acik, Y., & Ozan, A. T. (2004). The measurements of exhaled carbon monoxide in health smokers and nonsmokers. *Respiratory Medicine, 98*, 551-556.

DiFranza, J. R., Savageau, J. A., Fletcher, K., Ockene, J. K., Rigotti, N.A., McNeil, A. D., … Wood, C. (2002). Measuring the loss of autonomy over nicotine use in adolescents: The DANDY (Development and Assessment of Nicotine Dependence in Youths) study. *Archives of Pediatric & Adolescent Medicine, 156*, 397-403. Retrieved from www.archpediatrics.com

Donatelle, R. J., Hudson, D., Dobie, S., Goodall, A., Hunsberger, M., & Oswald, K. (2004). Incentives in smoking cessation: Status of the field and implications for research and practice with pregnant smokers. *Nicotine & Tobacco Research, 6*, 163-179.

Donatelle, R. J., Prows, S. L., Champeau, D., & Hudson, D. (2000). Randomised controlled trial using social support and financial incentives for high risk pregnant smokers: Significant Other Supporter (SOS) program. *Tobacco Control, 9(Suppl:III)*, iii67 – iii69. doi: 10.1136/tc.9.suppl_3.iii67

Dutra, L., Stathopoulou, G., Basden, S. L., Leyro, T. M., Powers, M. B., & Otto, M. W. (2008). A meta-analytic review of psychosocial interventions for substance use disorders. *American Journal of Psychiatry*, *165*, 179-187.

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments, & Computers*, *28*, 1-11.

Fagerstrom, K. –O., & Schneider, N. G. (1989). Measuring nicotine dependence: A review of the Fagerstrom Tolerance Questionnaire. *Journal of Behavioral Medicine*, *12*, 159 – 182.

Fichtenberg, C. M., & Glantz, S. A. (2002). Effects of smoke-free workplaces on smoking behaviour: A systematic review. *British Medical Journal*, *325*, 188 – 194.

Foll, B., & Goldberg, S. R. (2006). Nicotine as a typical drug of abuse in experimental animals and humans. *Psychopharmacology*, *184*, 367-381. doi: 10.1007/s00213-005-0155-8

Galbicka, G. (1994). Shaping in the 21st century: Moving percentile schedules into applied settings. *Journal of Applied Behavior Analysis*, *27*, 739-760.

Gilbert, D. D. (1993). Chemical analyses as validators in smoking cessation programs. *Journal of Behavioral Medicine*, *16*, 295-308.

Glenn, I. M., & Dallery, J. (2007). Effects of internet-based voucher reinforcement and a transdermal nicotine patch on cigarette smoking. *Journal of Applied Behavior Analysis*, *40*, 1-13.

Griffith, S. D., Shiffman, S., & Heitjan, D. F.(2009). A method comparison study of timeline followback and ecological assessment of daily cigarette consumption. *Nicotine & Tobacco Research, 11*, 1368 – 1373.

Griffiths, R. R., Bigelow, G. E., & Henningfield, J. E. (1980). Similarities in animal and human drug-taking behavior. *Advances in Substance Abuse, 1,* 1-90.

Heatherton, T. F., Kozlowski, L. T., Frecker, R. C., & Fagerstrom, K.-O. (1991). The Fagerstrom Test for Nicotine Dependence: A revision of the Fagerstrom Tolerance Questionnaire. *British Journal of Addiction, 86,* 1119-1127.

Henningfield, J. E., & Goldberg, S. R. (1983). Nicotine as a reinforcer in human subjects and laboratory animals. *Pharmacology, Biochemistry, and Behavior, 19,* 989-992.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior, 4,* 267-272.

Higgins, S. T. (1997). The influence of alternative reinforcers on cocaine use and abuse: A brief review. *Pharmacology, Biochemistry, and Behavior, 57,* 419-427.

Higgins, S. T., Budney, A. J., Bickel, W. K., Hughes, J. R., Foerg, F., & Badger, G. (1994). Achieving cocaine abstinence with a behavioral approach. *American Journal of Psychiatry, 150,* 763-769.

Higgins, S. T., Heil, S. H., & Lussier, J. P. (2004). Clinical implications of reinforcement as a determinant of substance use disorders. *Annual Review of Psychology, 55,* 15.1-15.31. doi: 10.1146/annuarev.psych.55.090902.142033

Higgins, S. T., Heil, S. H., Solomon, L. J., Bernstein, I. M., Lussier, J. P., Abel, R. L., …. Badger, G. J. (2004). A pilot study on voucher-based incentives to promote

abstinence from cigarette smoking during pregnancy and postpartum. *Nicotine & Tobacco Research, 6,* 1015-1020.

Higgins, S. T., & Silverman, K. (2008). Introduction. In S. Higgins, K. Silverman, & S. Heil (Eds.), *Contingency management in substance abuse treatment* (pp. 1-15). New York: The Guilford Press.

Hollard, V., & Davison, M. C. (1971). Preference for qualitatively different reinforcers. *Journal of the Experimental Analysis of Behavior, 16,* 375-380.

Hughes, J. R., Gust, S. W., Skoog, K., Keenan, R. M., & Fenwick, J. W. (1991). Symptoms of tobacco withdrawal. *Archives of General Psychiatry, 48,* 52-59.

Hughes, J. R., Higgins, S. T., & Bickel, W. K. (1994). Nicotine withdrawal versus other drug withdrawal syndromes: Similarities and dissimilarities. *Addiction, 89,* 1461-1470.

Iguchi, M. Y., Belding, M. A., Morral, A. R., Lamb, R. J., & Husband, S. D. (1997). Reinforcing operants other than abstinence in drug abuse treatment: An effective alternative for reducing drug use. *Journal of Consulting and Clinical Psychology, 65,* 421-428.

Irons, J. G. & Correia, C. J. (2008a). A brief abstinence test for college student smokers. *Experimental and Clinical Psychopharmacology,* 16, 223-229.

Irons, J. G., & Correia, C. J. (2008b, May). *The value of abstinence from smoking test: A novel choice procedure for assessment of incentive adequacy.* A paper presented at the annual meeting of the Association for Behavior Analysis: International, Chicago, IL.

Jarvis, M. J., Belcher, M., Vesey, C., & Hutchison, D. C. (1986). Low cost carbon monoxide monitors in smoking assessment. *Thorax, 41,* 886-887. doi: 10.1136/thx.41.11.886

Jarvis, M. J., Tunstall-Pedoe, H., Feyerabend, C., Vesey, C., & Saloojee, Y. (1987). Comparison of tests used to distinguish smokers from nonsmokers. *American Journal of Public Health, 77,* 1435-1438.

Jorenby, D. E., Hays, T., Rigotti, N. A., Azoulay, S., Watsky, E. J., Williams, K. E., . . .Reeves, K. R. (2006). Efficacy of varenicline, an alpha-4-beta-2 nicotinic acetylcholine receptor partial agonist, versus placebo or sustained-release bupropion for smoking cessation: A randomized controlled trial. *Journal of the American Medical Association, 296,* 56-63.

Jorenby, D. E., Leischow, S. J., Nides, M. A., Rennard, S. I., Johnston, J. A., Hughes, A. R., . . . Baker, T. B. (1999). A controlled trial of sustained-release bupropion, a nicotine patch, or both for smoking cessation. *The New England Journal of Medicine, 340,* 685-691.

Julien, R. M., Advokat, C. D., & Comaty, J. E. (2008). Caffeine and nicotine. In *A primer of drug action* (pp. 479-511). New York, NR: Worth Publishers.

Krishnan-Sarin, S., Duhig, A. M., McKee, S. A., McMahon, T. J., Liss, T., McFetridge, A., & Cavallo, D. A. (2006). Contingency management for smoking cessation in adolescent smokers. *Experimental and Clinical Psychopharmacology, 14,* 306-310.

Lamb, R. J., Kirby, K. C., Morral, A. R., Galbicka, G., & Iguchi, M. Y. (2004). Improving contingency management programs for addiction. *Addictive Behaviors, 29*, 507-523.

Lamb, R. J., Morral, A. R., Kirby, K. C., Iguchi, M. Y., & Galbicka, G. (2004). Shaping smoking cessation using percentile schedules. *Drug and Alcohol Dependence, 76*, 247-259.

Lamb, R. J., Morral, A. R., Kirby, K. C., Galbicka, G., & Iguchi, M. Y. (2005). Shaping reduced smoking in smokers without cessation plans. *Experimental and Clinical Psychopharmacology, 13*, 83-92.

LeSage, M. G. (2009). Toward a nonhuman animal model of contingency management: Effects of reinforcing abstinence from nicotine self-administration in rats with an alternative nondrug reinforcer. *Psychopharmacology*, *203*, 13-22. doi: 10.1007/s00213-008-1362-x

Lesichow, S. J., Merikle, E. P., Cook, G., Newman, R., & Muramoto, M. (1999). An evaluation of NicCheck®1: A dipstick method for analyzing nicotine and its metabolites. *Addictive Behaviors, 24*, 145-148.

Lussier, J. P., Heil, S. H., Mongeon, J. A., Badger, G. J., & Higgins, S. T. (2006). A meta-analysis of voucher-based reinforcement therapy for substance use disorders. *Addiction*, *101*, 192-203.

Madden, G. J. (2000). A behavioral economics primer. In W. Bickel & R. Vuchinich (Eds.), *Reframing health behavior change with behavioral economics* (pp. 1 - 26). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Matson, D. M., Lee., J. W., & Hopp, J. W. (1993). The impact of incentives and competitions on participants quit rates in worksite smoking cessation programs. *American Journal of Health Promotion, 7*, 295 – 306.

McGinnis, J. M.,& Fogue, W. H. (1993). Actual causes of death in the United States. *Journal of the American Medical Association, 270*, 2207-2212.

McDowell, J. J. (1988). Matching theory in natural human environments. *The Behavior Analyst, 11*, 95-109.

McFall, R. M. (1970). Effects of self-monitoring on normal smoking behavior. *Journal of Consulting and Clinical Psychology, 2*, 135 – 142.

Murray, R. P., Connett, J. E., & Zapawa, L. M. (2009). Does nicotine replacement therapy cause cancer? Evidence from the Lung Health Study. *Nicotine & Tobacco Research, 11*, 1076-1082. doi:10.1093/ntr/ntp104

Murray, R. P., Connett, J. E., Lauger, G. G., & Voelker, H. T. (1993). Error in smoking measures: Effects of intervention on relations of cotinine and carbon monoxide to self-reported smoking. *American Journal of Public Health, 83*, 1251-1257.

National Institutes of Health. National Institute on Drug Abuse. (2008). *Treatment approaches for drug addiction*. Retrieved from http://www.nida.nih.gov/pdf/infofacts/treatment08.pdf

New Jersey Department of Health and Human Services. (2003). Then and now in New Jersey: Health profiles for 1900 and 2000. Retrieved from http://www.state.nj.us/health/chs/190 02000.pdf

Newsam, C., Favell, J. E., & Rincover, A. (1983). The side-effects of punishment. In S. Axelrod & J. Apsche (Eds.), *The effects of punishment on human behavior* (pp. 285-316). New York: Academic Press.

O'Loughlin, J., Kishchuk, N., Difranza, J., Tremblay, M., & Paradis, G. (2002). The hardest thing is the habit: A qualitative investigation of adolescent smokers' experience of nicotine dependence. *Nicotine & Tobacco Research, 4,* 201-209. doi: *10.1080/14622200210123000*

Parker, D. R., Lasater, T. M., Windsor, R., Wilkins, J., Upegui, D. I., & Heimdal, J. (2002). The accuracy of self-reported smoking status assessed by cotinine test strips. *Nicotine & Tobacco Research, 4,* 305 -309.

Perez-Stable, E. J., Benowitz, N. L., & Marin, G. M. (1995). Is serum cotinine a better measure of cigarette smoking than self-report? *Preventative Medicine, 24,* 171-179.

Perkins, K. A., Grobe, J. E., Fonte, C., Goettler, J., Caggiula, A. R., Reynolds, W. A., . . . Jacob, R. G. (1994). Chronic and acute tolerance to subjective, behavioral, and cardiovascular effects of nicotine in humans.

Perkins, K. A., Hickcox, M. E., & Grobe, J. E. (2000). Behavioral economics of tobacco smoking. In W. Bickel & R. Vuchinich (Eds.), *Reframing health behavior change with behavioral economics* (pp. 265-312). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Petry, N. M. (2000). A comprehensive guide to the application of contingency management procedures in clinical settings. *Drug and Alcohol Dependence, 58,* 9–25.

Petry, N. M., & Martin, B. (2002). Low-cost contingency management for treating cocaine- and opioid-abusing methadone patients. *Journal of Consulting and Clinical Psychology, 70*, 398-405.

Petry, N. M., Martin, B., Cooney, J. L., & Kranzler, H. R. (2000). Give them prizes, and they will come: Contingency management for treatment of alcohol dependence. *Journal of Consulting and Clinical Psychology, 68*, 250-257.

Pierce, W. D., & Cheney, C. D. (2004). *Behavior Analysis and Learning*. Mahwan, New Jersey: Lawrence Erlbaum Associates.

Powell, J., & Azrin, N. (1968). The effects of shock as a punisher for cigarette smoking. *Journal of Applied Behavior Analysis, 1*, 63-71.

Prendergast, M., Podus, D., Finney, J., Greenwell, L., & Roll, J. (2006). Contingency management for treatment of substance use disorders: A meta-analysis. *Addiction, 101*, 1546-1560. doi:10.1111/j.1360-0443.2006.01581.x

Prokhorov, A. V., Pallonen, U. E., Fava, J. L., Ding, L., & Niaura, R. (1996). Measuring nicotine dependence among high-risk adolescent smokers. *Addictive Behaviors, 21*, 117–127.

Radzius, A., Gallo, J. J., Epstein, D. H., Gorelick, D. A., Cadet, J. L., Uhl, G. E., & Moolchan, E. T. (2003). A factor analysis of the Fagerstrom Test for Nicotine Dependence (FTND). *Nicotine & Tobacco Research, 5*, 255 – 260. doi: 10.1080/1462220031000073289

Rand, C. S., Stitzer, M. L., Bigelow, G. E., & Mead, A. M. (1989). The effects of contingent payment and frequent workplace monitoring on smoking abstinence. *Addictive Behaviors, 14*, 121 – 128.

Rawson, R. A., McCann, M. J., Flammino, F., Shoptaw, S., Miotto, K., Reiber, C., …. Ling, W. (2006). A comparison of contingency management and cognitive-behavioral approaches for stimulant-dependent individuals. *Addiction, 101*, 267-274.

Rea, J. N., Tyrer, P. J., Kasap, H. S., & Beresford, S. A. A. (1973). Expired air carbon monoxide, smoking, and other variables: A community study. *British Journal of Preventive and Social Medicine, 27*, 114-120.

Reynolds, B., Dallery, J., Shroff, P., Patak, M., & Leraas, K. (2008). A web-based contingency management program with adolescent smokers. *Journal of Applied Behavior Analysis, 41*, 597-601.

Roddy, E. (2004). ABC of smoking cessation: Bupropion and other non-nicotine pharmacotherapies. *British Medical Journal, 328*, 509-511. doi: 10.1136/bmj.328.7438.509.

Roll, J. M., & Higgins, S. T. (2000). A within-subject comparison of three different schedules of reinforcement of drug abstinence using cigarette smoking as an exemplar. *Drug and Alcohol Dependence, 58*, 103-109.

Roll, J. M., Higgins, S. T., & Badger, G. J. (1996). An experimental comparison of three different schedules of reinforcement of drug abstinence using cigarette smoking as an exemplar. *Journal of Applied Behavior Analysis, 29*, 495-205.

Roll, J. M., Reilly, M. P., & Johanson, C. (2000). The influence of exchange delays on cigarette versus money choice: A laboratory analog model of voucher-based reinforcement therapy. *Experimental and Clinical Psychopharmacology, 8*, 366 – 370. doi: 10.I037//I064-1297.8.3.366

Roll, J. M., & Shoptaw, S. (2006). Contingency management: Schedule effects. *Psychiatry Research, 144*, 91-93.

Rose, J. E., & Corrigall, W. A. (1997). Nicotine self-administration in animals and humans: Similarities and differences. *Psychopharmacology*, *130*, 28-40.

Salin-Pascual,, R. J., Rosas, M., Jimenez-Genchi, A., Rivera-Meza, B. L., & Delgado-Parra, V. (1996). Antidepressant effect of transdermal nicotine patches in nonsmoking patients with major depression. *Journal of Clinical Psychiatry*, *57*, 387-389.

Schmitz, J. M., Rhoades, H., & Grabowski, J. (1995). Contingent reinforcement for reduced carbon monoxide levels in methadone maintenance patients. *Addictive Behaviors*, *20*, 171-179.

Shoaib, M., Schindler, C. W., & Goldberg, S. R. (1997). Nicotine self-administration in rats: Strain and nicotine pre-exposure effects on acquisition. *Psychopharmacology*, *129*, 35-43.

Shoptaw, S., Reback, C. J., Peck, J. A., Xang, X., Rotheram-Fuller, E., Larkins, S., …. Hucks-Ortiz, C. (2005). Behavioral treatment approaches for methamphetamine dependence and HIV-related sexual risk behaviors among urban gay and bisexual men. *Drug and Alcohol Dependence*, *78*, 125-134.

Shoptaw, S., Rotheram-Fuller, E., Xang, X., Frosch, D., Nahom, D., Jarvick, M. E., …. Ling, W. (2002). Smoking cessation in methadone maintenance. *Addiction*, *97*, 1317-1328.

Sigmon, S. C., Lamb, R. J., & Dallery, J. (2008). Tobacco. In S. Higgins, K. Silverman, & S. Heil (Eds.), *Contingency management in substance abuse treatment* (pp. 99-119). New York: The Guilford Press.

Silverman, K., Svikis, D., Wong, C. J., Hampton, J., Stitzer, M. L., & Bigelow, G. E. (2002). A reinforcement-based therapeutic workplace for the treatment of drug abuse: Three-year abstinence outcomes. *Experimental and Clinical Psychopharmacology*, *10*, 228 – 240. doi: 10.1037/1064-1297.9.1.14

SRNT Subcommittee on Biochemical Verification. (2002). Biochemical verification of tobacco use and cessation. *Nicotine & Tobacco Research, 4*, 149-159.

Stead, L. F., Perera, R., Bullen, C., Mant, D., & Lancaster, T. (2008). Nicotine replacement therapy for smoking cessation. *Cochrane Database of Systematic Reviews*, *4*, CD000146. doi: 10.1002/14651858.CD000146.pub3

Stitzer, M. L., & Bigelow, G. E. (1983). Contingent payment for carbon monoxide reduction: Effects of pay amount. *Behavior Therapy, 14, 647-656.*

Stitzer, M. L., & Bigelow, G. E. (1984). Contingent reinforcement for carbon monoxide reduction: Within-subject effects of pay amount. *Journal of Applied Behavior Analysis, 17*, 477-483.

Stitzer, M. L., Bigelow, G. E., & Liebson, I. (1979). Reducing benzodiazepine self-administration with contingent reinforcement. *Addictive Behaviors*, *4*, 245-252.

Stitzer, M. L., & Petry, N. M. (2006). Contingency management for treatment of substance abuse. *Annual Review of Clinical Psychology, 2*, 411-434.

Stoops, W. W., Dallery, J., Fields, N. M., Nuzzo, P. A., Schoenberg, N. E., Martin, C. A. … Wong, C. J. (2009). An internet-based abstinence reinforcement smoking

cessation intervention in rural smokers. *Drug and Alcohol Dependence*, *105*, 56-62.

Tevyaw, T. O. L., Colby, S. M., Tidey, J. W., Kahler, C. W., Rohsenow, D. J., Barnett, N. P., …. Monti, P. M. (2009). Contingency management and motivation enhancement: A randomized clinical trial for college student smokers. *Nicotine & Tobacco Research, 11*, 739-749.

Tidey, J. W., O'Neil, S. C., & Higgins, S. T. (2002). Contingent monetary reinforcement of smoking reductions with and without transdermal nicotine in outpatients with schizophrenia. *Experimental and Clinical Psychopharmacology*, *10*, 241-147.

United States Bureau of Labor Statistics. (2008). *American time use summary survey*. Retrieved from http://www.bls.gov/news.release/atus.nr0.htm

United States Bureau of Labor Statistics. (2010). *Employment situation summary*. Retrieved from http://www.bls.gov/news.release/empsit.nr0.htm

United States National Office of Vital Statistics. (1976). *Vital statistics rates in the United States, 1900 – 1940*. New York: Arno Press. Retrieved from http://www.cdc.gov/nchs/da ta /dvs/lead1900_98.pdf

van Houten, R. (1983). Punishment: From the animal laboratory to the applied setting. In J. Apsche and S. Axelrod (Eds.), *The effects of punishment on human Behavior* (pp. ??-??). New York: Academic Press.

Vidrine, J. I., Cofta-Woerpel, L., Daza, P., Wright, K. L., & Wetter, D. W. (2006). Smoking cessation 2: Behavioral treatments. *Behavioral Medicine, 32*, 99-109.

Vuchinich, R. E, & Heather, N. (2003). Introduction: Overview of behavioural economic perspectives on substance use and addiction. In R. Vuchinich & N. Heather

(Eds.), *Choice, behavourial economics, and addiction* (pp. 1-34). Oxford: Elsevier.

Wellman, R. J., Savageau, J. A., Godiwala, S., Savageau, N., Friedman, K., Hazelton, J., & DiFranza, J. R. (2006). A comparison of the Hooked on Nicotine Checklist and the Fagerstrom Test for Nicotine Dependence in adult smokers. *Nicotine & Tobacco Research, 8,* 675-580. doi: 10.1080/14622200600789965

Welsh, S. K., Smith, S. S., Wetter, D. W., Jorenby, D. E., Fiore, M. C., & Baker, T. B. (1999). Development and validation of the Wisconsin Smoking Withdrawal Scale. *Experimental and Clinical Psychopharmacology, 7,* 354-361. doi: 10.1037/1064-1297.7.4.35

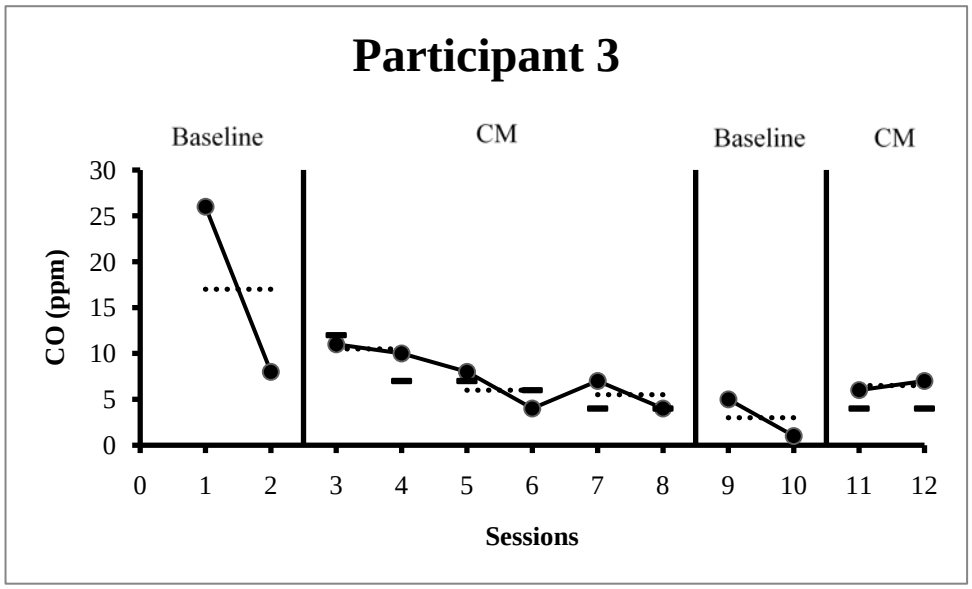


Figure 1. Expired breath CO across all condition weeks for Participant 3. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels.

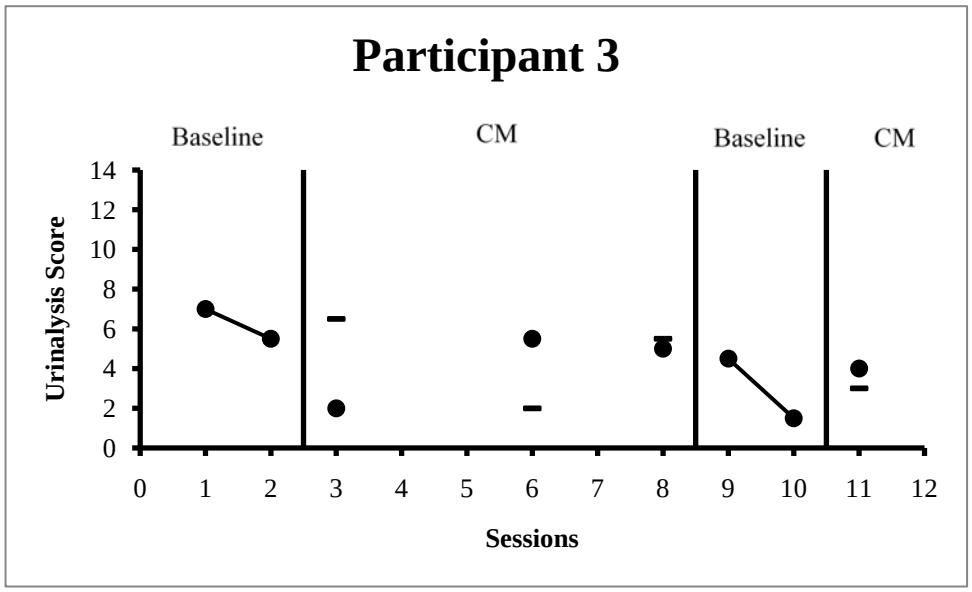


Figure 2. Urinalysis scores across all condition weeks for Participant 3. Short, solid dash marks represent reduction/abstention criterion.

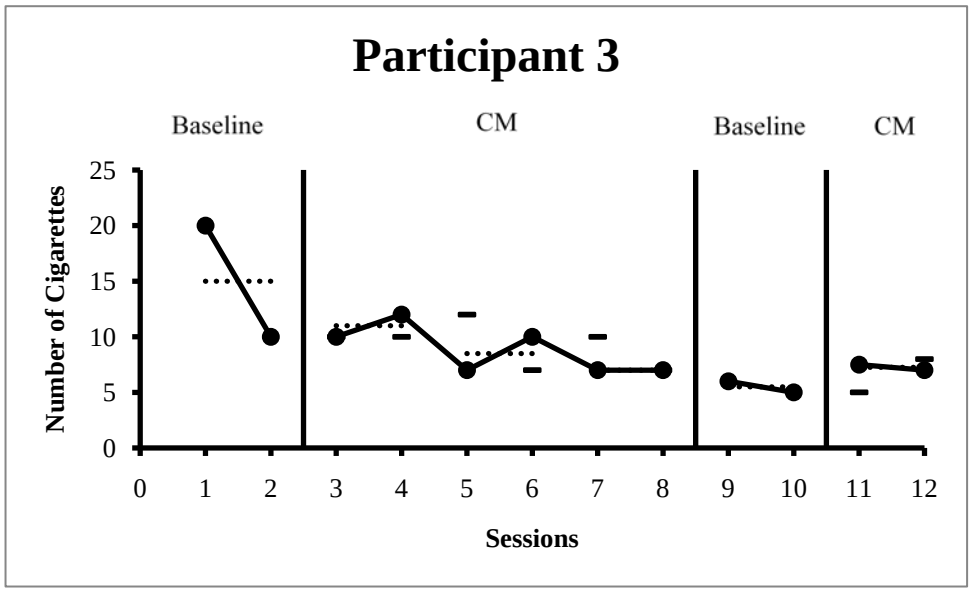


Figure 3. Self-reported daily number of cigarettes smoked since the previous session across all condition weeks for Participant 3. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels. The value for Session 1 represents Participant 3's response to the question, "On average, how many cigarettes do you smoke each day?".

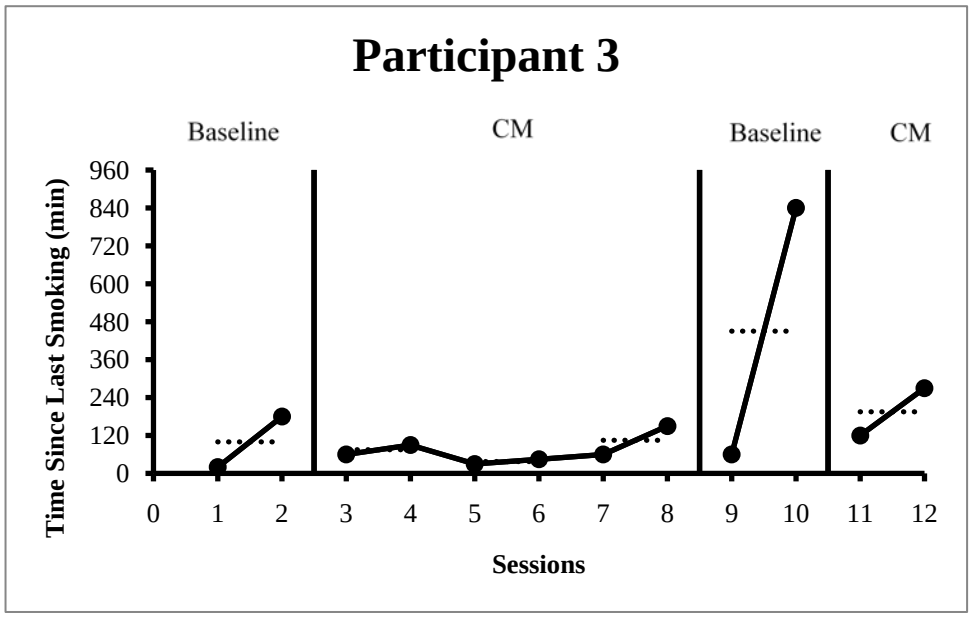


Figure 4. Self-reported time in minutes since last smoking a cigarette across all condition weeks for Participant 3. Longer, dotted lines represent weekly mean levels. Payment was not contingent on time since last smoking, therefore no reduction/abstention criteria are shown.

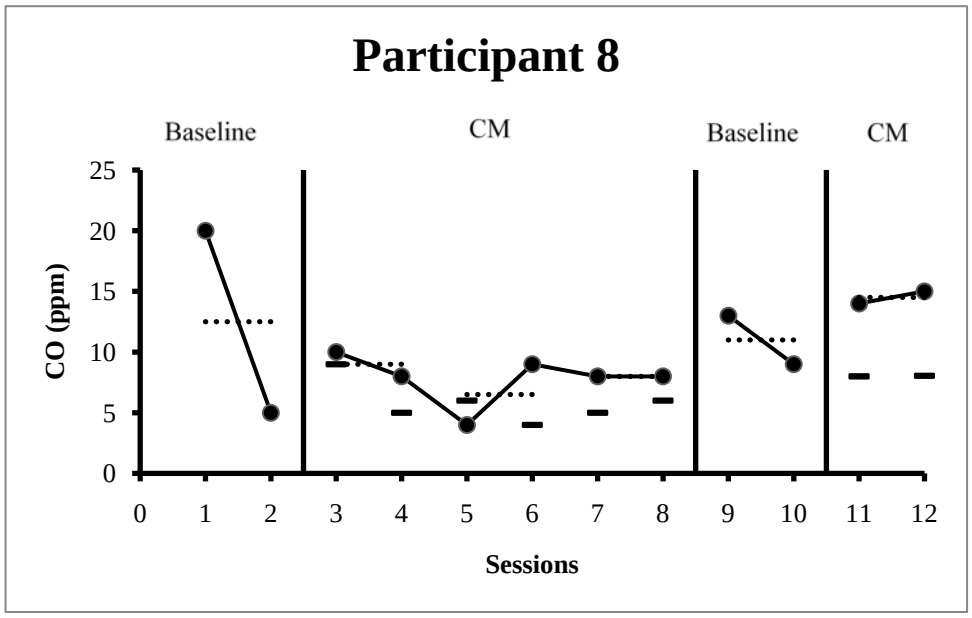


Figure 5. Expired breath CO across all condition weeks for Participant 8. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels.

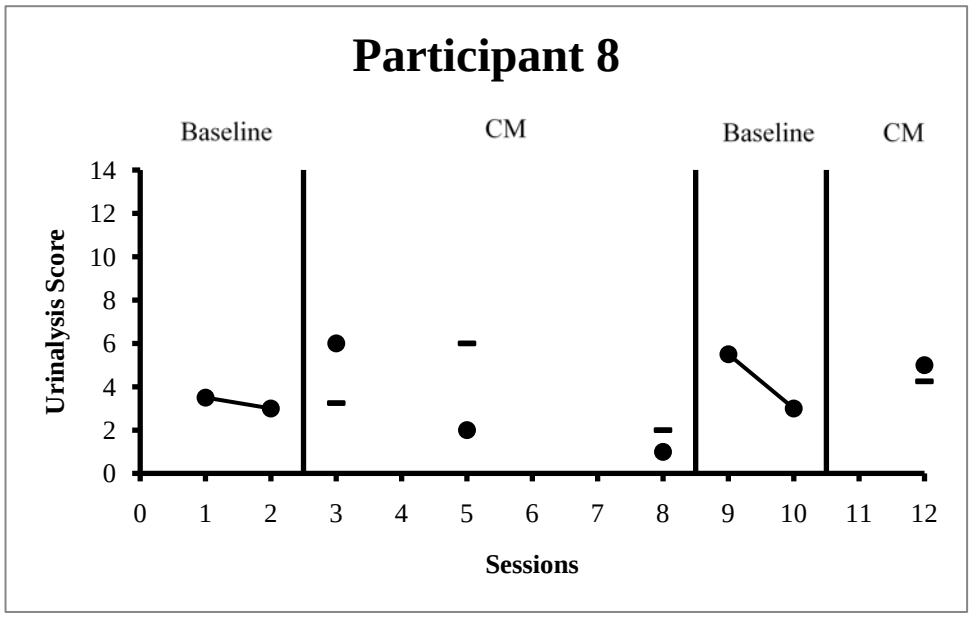


Figure 6. Urinalysis scores across all condition weeks for Participant 8. Short, solid dash marks represent reduction/abstention criterion.

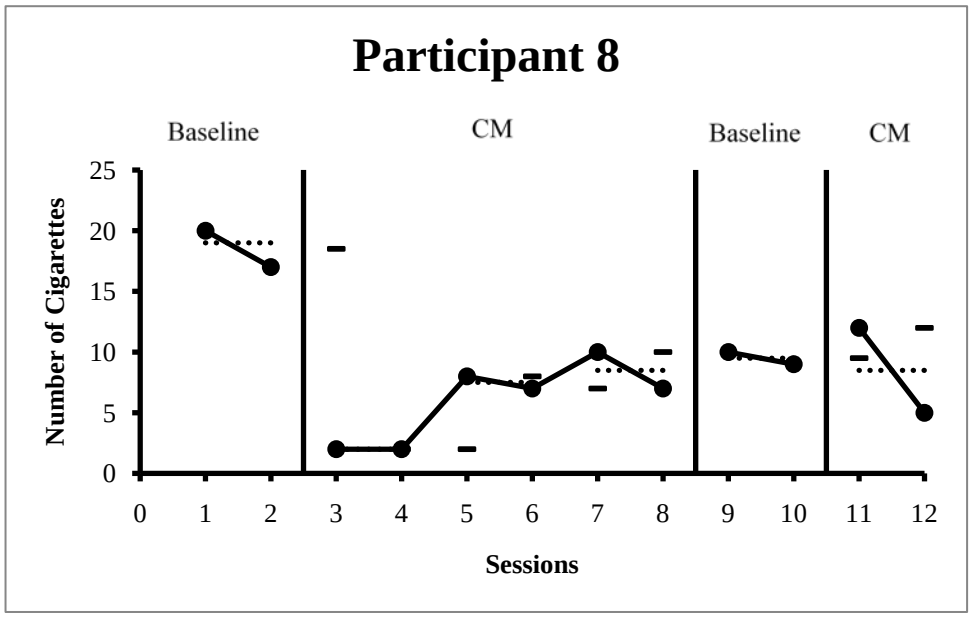


Figure 7. Self-reported daily number of cigarettes smoked since the previous session across all condition weeks for Participant 8. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels. The value for Session 1 represents Participant 8's response to the question, "On average, how many cigarettes do you smoke each day?"

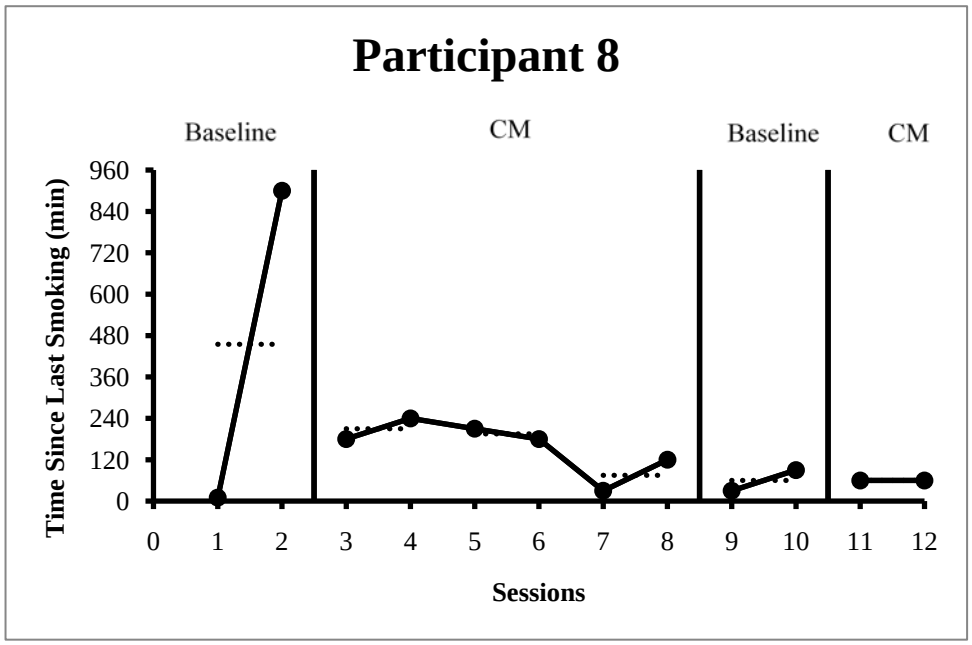


Figure 8. Self-reported time in minutes since last smoking a cigarette across all condition weeks for Participant 8. Longer, dotted lines represent weekly mean levels. Payment was not contingent on time since last smoking, therefore no reduction/abstention criteria are shown.

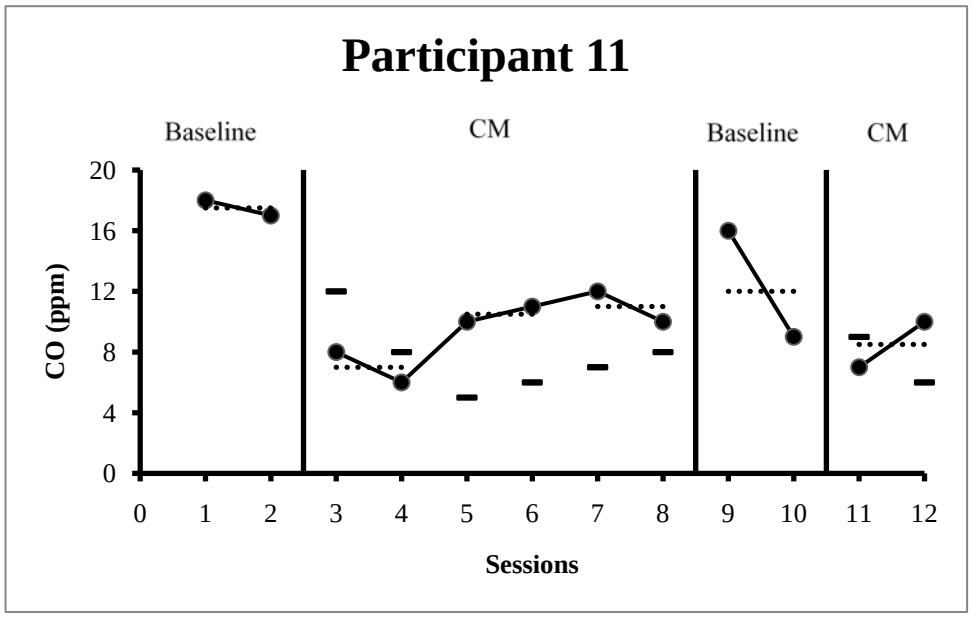


Figure 9. Expired breath CO across all condition weeks for Participant 11. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels.

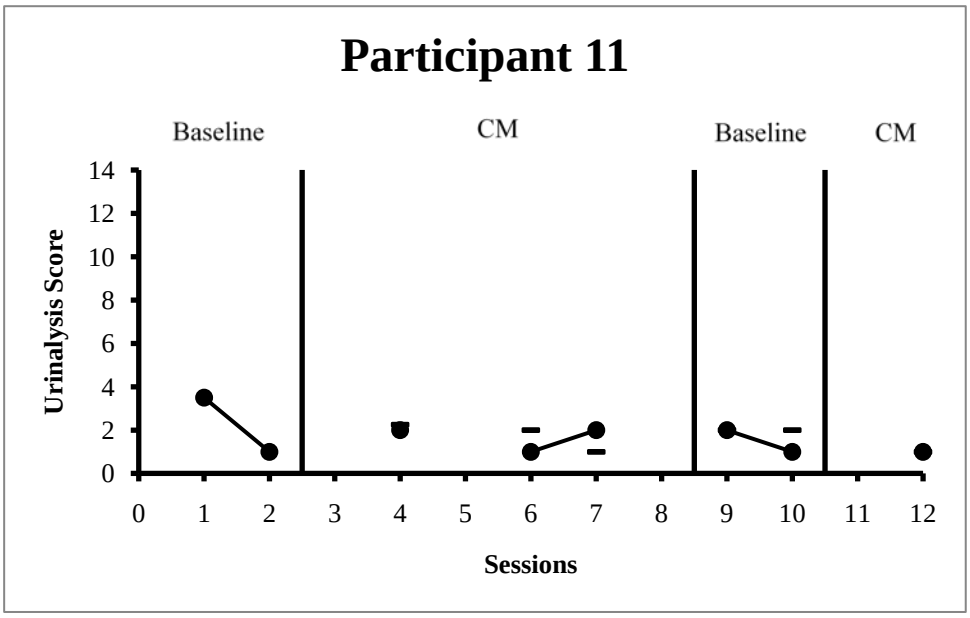


Figure 10. Urinalysis scores across all condition weeks for Participant 11. Short, solid dash marks represent reduction/abstention criterion.

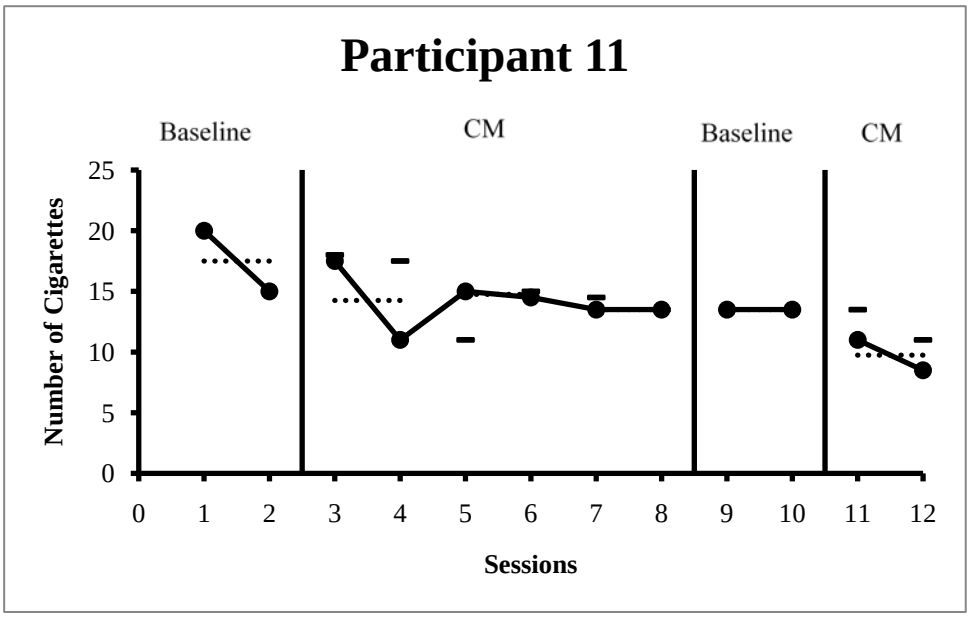


Figure 11. Self-reported daily number of cigarettes smoked since the previous session across all condition weeks for Participant 11. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels. The value for Session 1 represents Participant 11's response to the question, "On average, how many cigarettes do you smoke each day?"

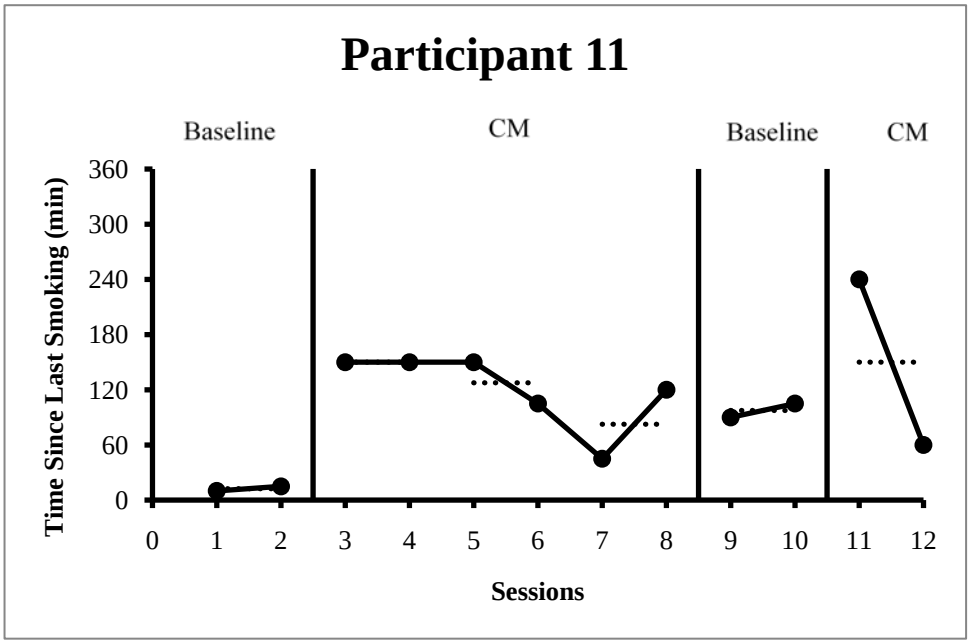


Figure 12. Self-reported time in minutes since last smoking a cigarette across all condition weeks for Participant 11. Longer, dotted lines represent weekly mean levels. Payment was not contingent on time since last smoking, therefore no reduction/abstention criteria are shown.

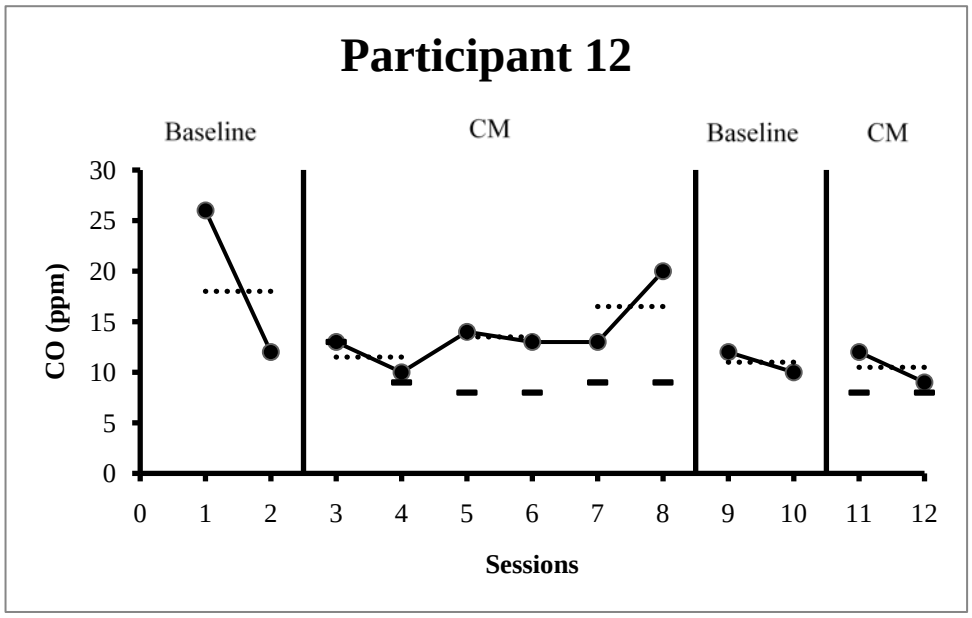


Figure 13. Expired breath CO across all condition weeks for Participant 12. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels.

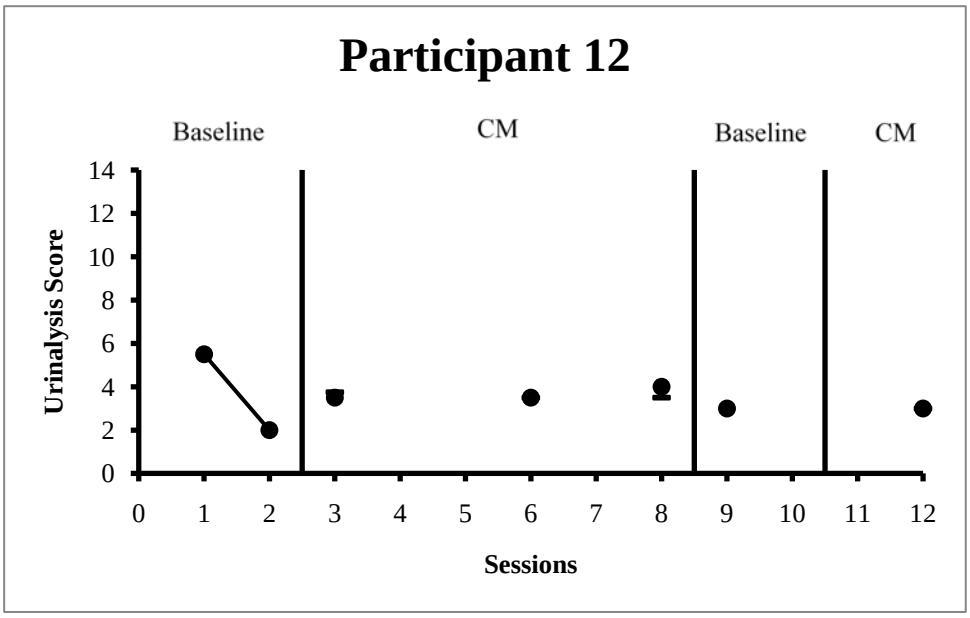


Figure 14. Urinalysis scores across all condition weeks for Participant 12. Short, solid dash marks represent reduction/abstention criterion.

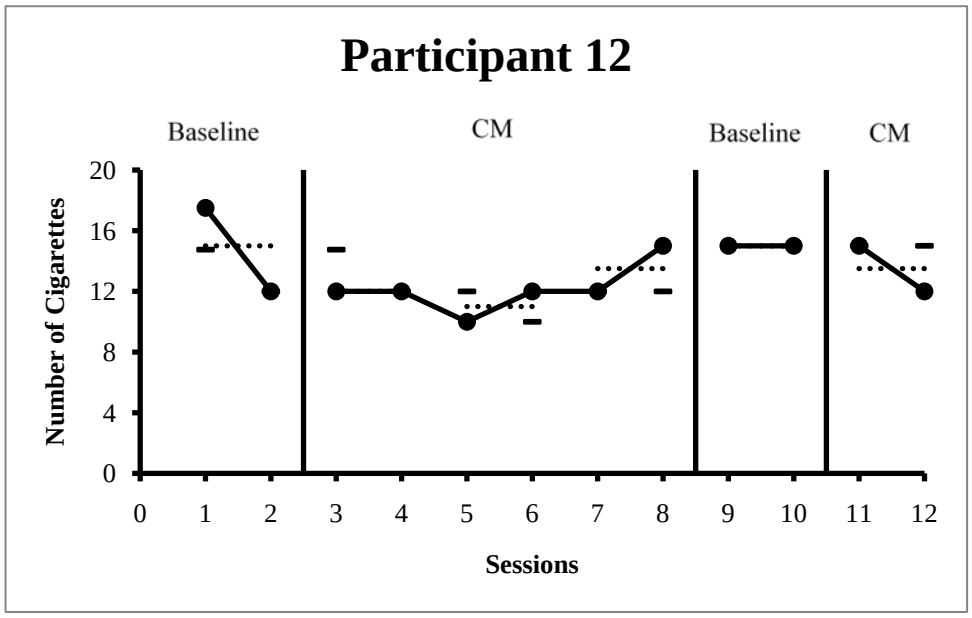


Figure 15. Self-reported daily number of cigarettes smoked since the previous session across all condition weeks for Participant 12. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels. The value for Session 1 represents Participant 12's response to the question, "On average, how many cigarettes do you smoke each day?"

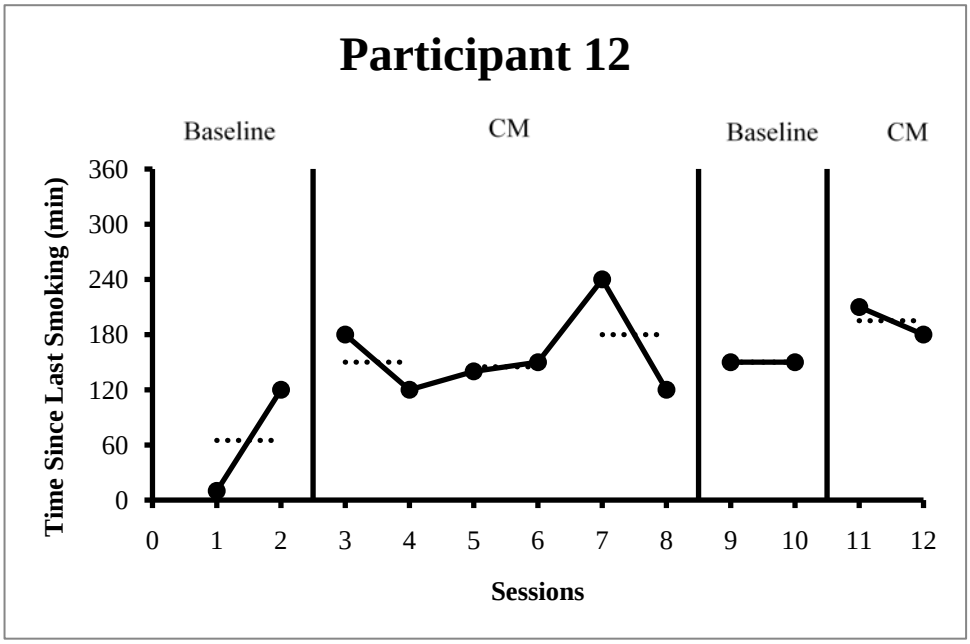


Figure 16. Self-reported time in minutes since last smoking a cigarette across all condition weeks for Participant 12. Longer, dotted lines represent weekly mean levels. Payment was not contingent on time since last smoking, therefore no reduction/abstention criteria are shown.

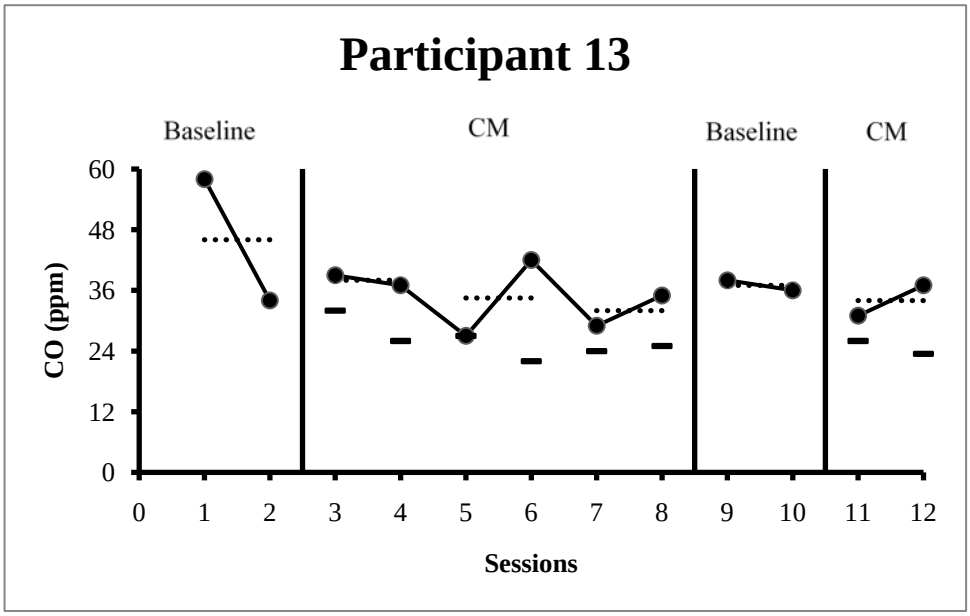


Figure 17. Expired breath CO across all condition weeks for Participant 13. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels.

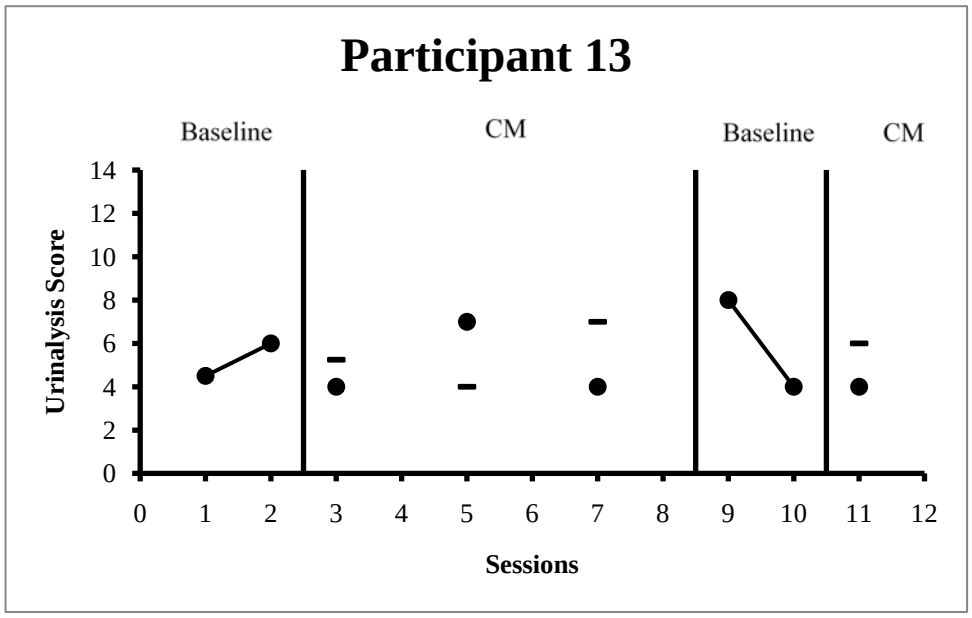


Figure 18. Urinalysis scores across all condition weeks for Participant 13. Short, solid dash marks represent reduction/abstention criterion.

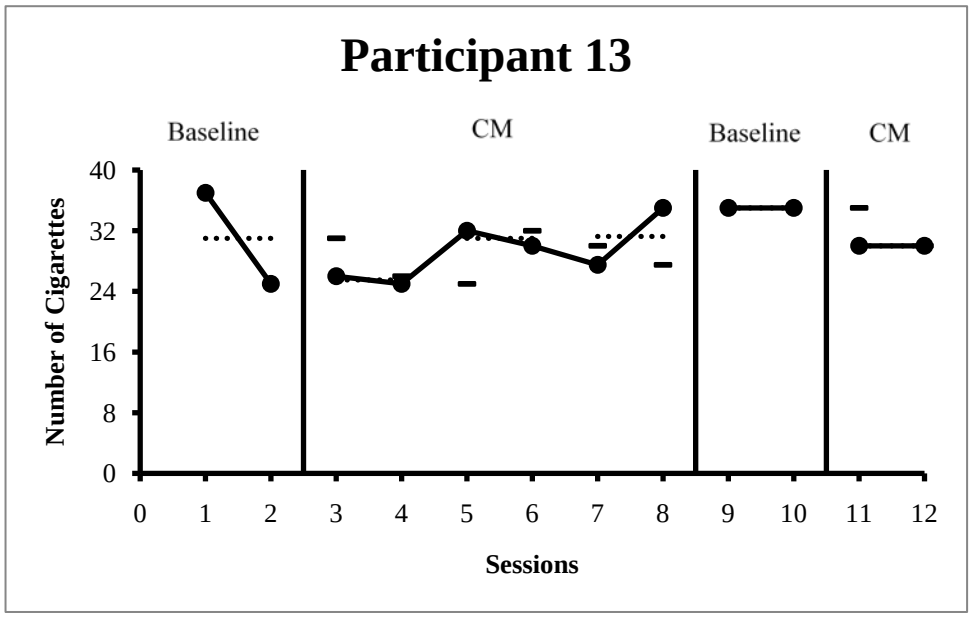


Figure 19. Self-reported daily number of cigarettes smoked since the previous session across all condition weeks for Participant 13. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels. The value for Session 1 represents Participant 13's response to the question, "On average, how many cigarettes do you smoke each day?"

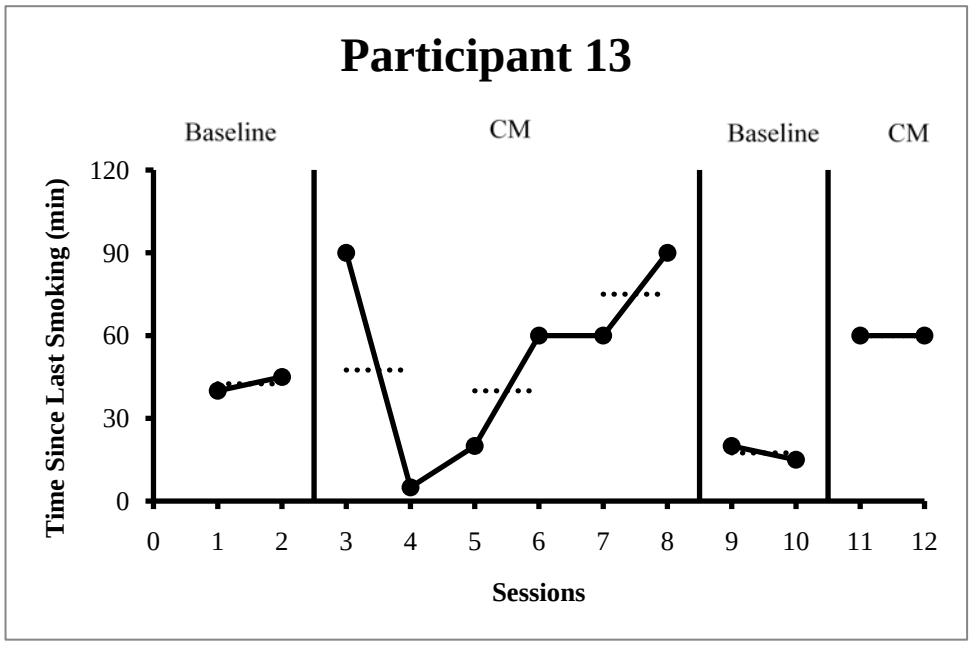


Figure 20. Self-reported time in minutes since last smoking a cigarette across all condition weeks for Participant 13. Longer, dotted lines represent weekly mean levels. Payment was not contingent on time since last smoking, therefore no reduction/abstention criteria are shown.

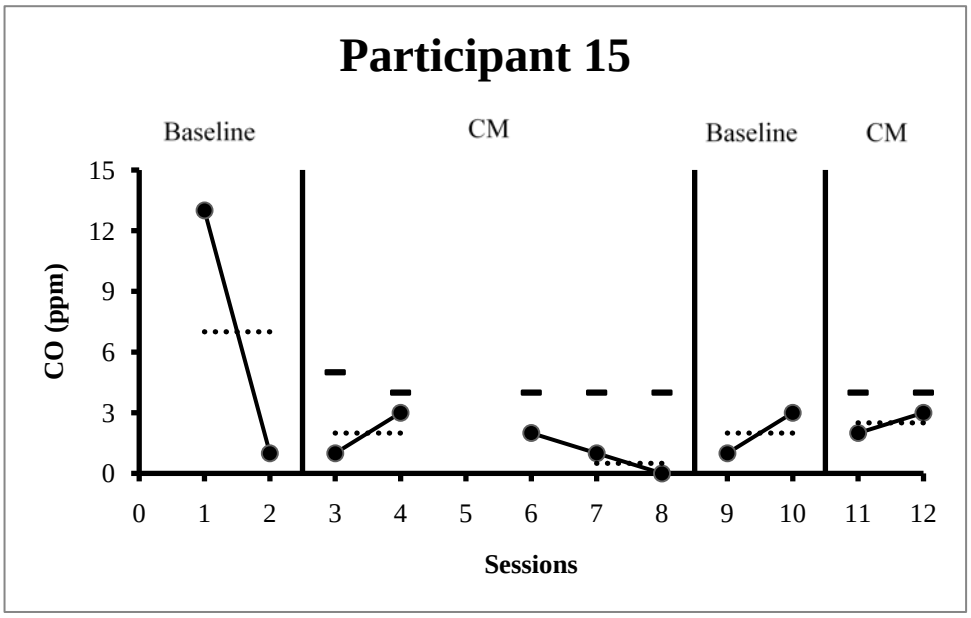


Figure 21. Expired breath CO across all condition weeks for Participant 15. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels. The datum for Session 5 is not shown because Participant 15 missed that session.

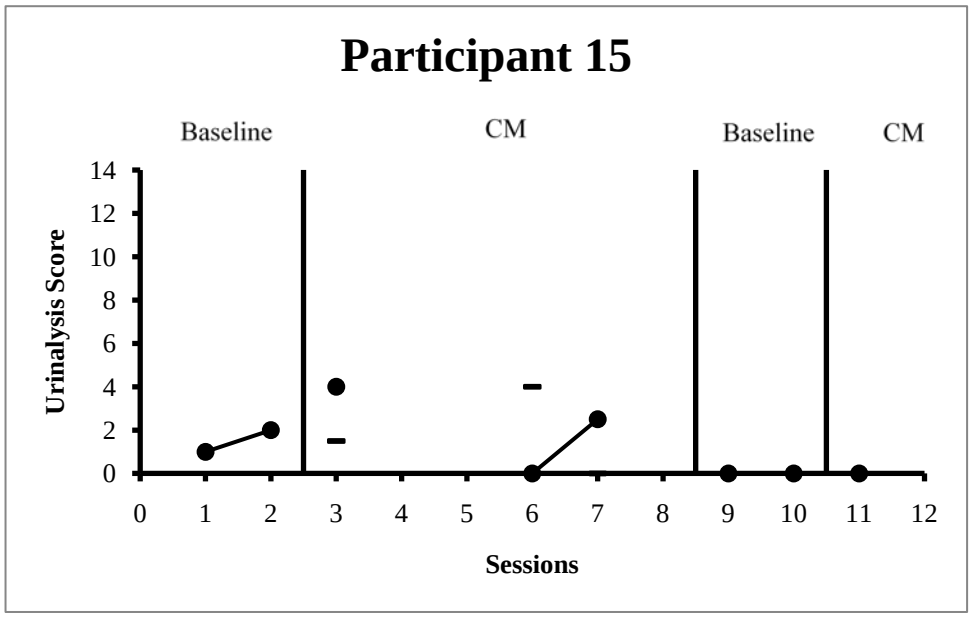


Figure 22. Urinalysis scores across all condition weeks for Participant 15. Short, solid dash marks represent reduction/abstention criterion. The datum for Session 5 is not shown because Participant 15 missed that session.

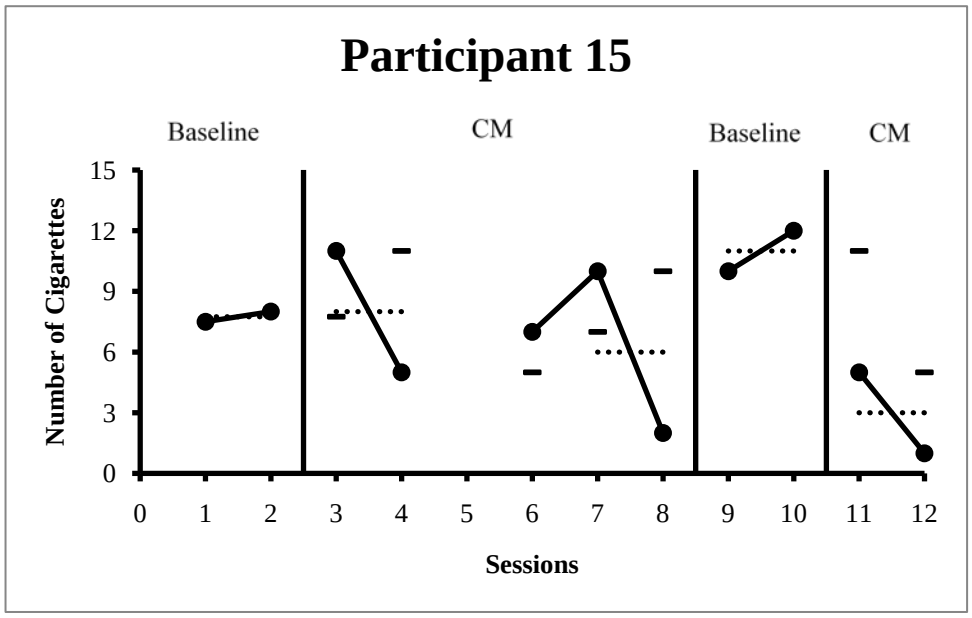


Figure 23. Self-reported daily number of cigarettes smoked since the previous session across all condition weeks for Participant 15. Short, solid dash marks represent reduction criterion. Longer, dotted lines represent weekly mean levels. The value for Session 1 represents Participant 15's response to the question, "On average, how many cigarettes do you smoke each day?" The datum for Session 5 is not shown because Participant 15 missed that session.

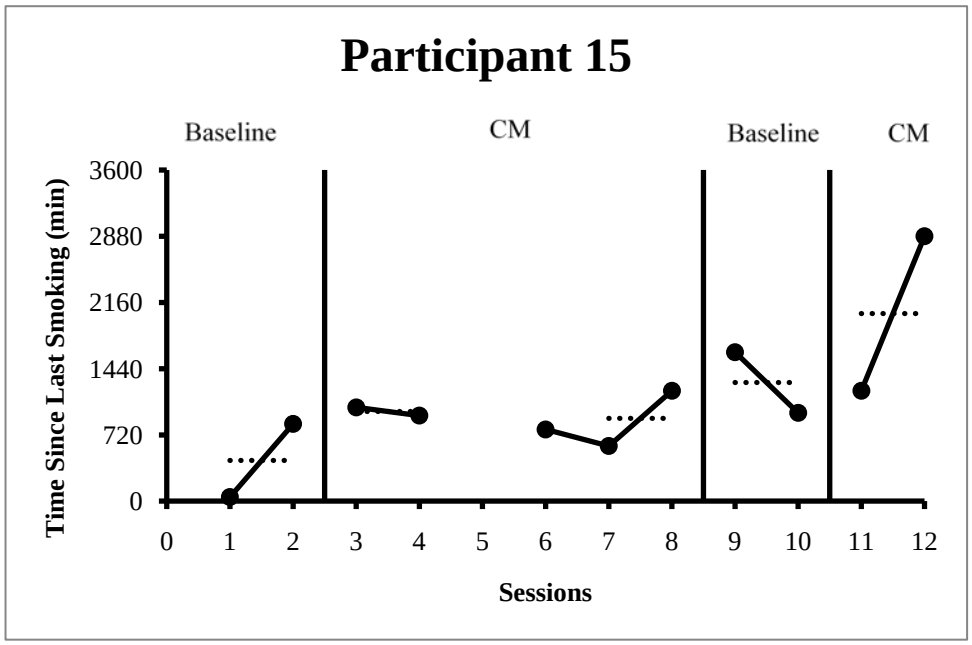


Figure 24. Self-reported time in minutes since last smoking a cigarette across all condition weeks for Participant 15. Longer, dotted lines represent weekly mean levels. Payment was not contingent on time since last smoking, therefore no reduction/abstention criteria are shown. The datum for Session 5 is not shown because Participant 15 missed that session.