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A laboratory-based evaluation of exercise plus contingency management for reducing cigarette smoking

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ABSTRACT

Background: Both contingency management (CM) and exercise have shown promise as smoking cessation treatments, but their combined effects have not been evaluated. The present study evaluated whether CM (in which motivational incentives are provided for abstinence) plus exercise reduced smoking more than either component alone.
Method: In a within-subjects design, 20 smokers were exposed to exercise plus CM, exercise plus CM-control (non-contingent incentives), inactivity plus CM, and inactivity plus CM-control.
Results: CM increased latencies to smoke and decreased total puffs (*Mdn*s = 39.6 min and .8 puffs, respectively) relative to CM-control (*Mdn*s = 2.5 min and 12.8 puffs). Exercise decreased craving relative to baseline for craving based on both the pleasurable consequences of smoking ($D = -10.7$ on a 100-point visual analog scale) and anticipated relief from withdrawal ($D = -5.9$), whereas inactivity increased both components of craving (*D*s = 7.6 and 3.5). Exercise had no effect on smoking or a measure of temporal discounting.
Conclusions: Although exercise decreased craving, it did not affect smoking behavior. Exercise plus CM was not more effective than CM alone.

1. Introduction

Although major strides have been made in tobacco control efforts in the past 50 years (Fiore, 2008), the national prevalence of cigarette smoking has stabilized over the past seven years at approximately 19% (Centers for Disease Control and Prevention (CDC), 2012). For these remaining smokers, of whom 70% report a desire to quit, new approaches to cessation are needed. One way to accomplish these goals is to conceptualize smoking in terms of modern theories of choice and decision making. For example, by conceptualizing cigarette smoking in terms of temporal discounting, new interventions to promote cessation – or methods to enhance the efficacy of existing interventions – can be derived and then subjected to empirical investigations.

Temporal discounting refers to the loss in subjective value of a reward as the delay to receiving that reward increases (Ainslie, 1974; Green and Fisher, 2000; Mazur, 1987). With respect to cigarette smoking, smokers devalue the rewards associated with abstinence (improved health, saving money) because these rewards are usually preceded by long delays. The rate at which rewards decline in value as a function of delay is described by (Mazur, 1987):

$$V = \frac{A}{(1 + kD)}, \quad (1)$$

where *V* refers to the discounted value of the delayed reward, *A* refers to the amount or magnitude of the reward, *D* refers to the delay, and *k* indexes the rate of discounting. Higher *k* values reflect steeper discounting or greater impulsive choice. Cross-sectional research has shown that smokers discount delayed rewards more steeply than non-smokers (Bickel et al., 1999), and longitudinal research has shown that discounting rates predict smoking uptake among adolescents (Audrain-McGovern et al., 2009), as well as treatment outcome among smokers who attempt to quit (MacKillop and Kahler, 2009). These data support the validity of temporal discounting as a framework for indexing impulsive choice. More importantly, the framework directly suggests several approaches to reducing the impulsive choice to smoke that can be readily assessed in controlled, laboratory experiments.

Prior to discussing these approaches, however, note that the discounting equation applies to the value of both smoking and

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abstinence, and the amount of behavior allocated to each alternative is described by:

$$\frac{B_s}{B_a} = \frac{V_s}{V_a} \quad (2)$$

In this equation, the B's reflect the amount of responding allocated to each alternative, the subscripts s and a represent choice for smoking and abstinence, and the value (V) of each alternative is determined by Eq. (1). Thus, treatment strategies implied by this framework include (a) increasing the value of abstinence (e.g., decreasing D in Eq. (1) for abstinence would increase V_a and therefore B_a), (b) decreasing the value of smoking (e.g., decreasing A in Eq. (1) for smoking would decrease V_s and therefore B_s), and/or (c) decreasing smokers' k values (e.g., see Koffarnus et al., 2013, for a review).

One treatment that attempts to increase the value of abstinence is contingency management (CM), in which smokers earn motivational incentives (e.g., vouchers exchangeable for goods and services), contingent on objective verification of abstinence (Higgins et al., 2002; Lussier et al., 2006). By providing alternative commodities at delays that are shorter than those associated with the delayed rewards that typically accompany abstinence, CM can be conceptualized as a treatment that decreases D. However, despite its effectiveness in both laboratory (Dallery and Raiff, 2007; Higgins et al., 2004; Packer et al., 2012) and naturalistic settings (Dallery et al., 2007; Roll et al., 1996; Sigmon et al., 2008), some smokers are not responsive to CM. Interpreted in terms of temporal discounting, this may be because CM increases V_a without decreasing V_s, therefore V_s continues to outweigh V_a, and B_s continues to exceed B_a. Thus, a treatment to decrease V_s and/or decrease smokers' discounting rates (k) could be an ideal complement to CM.

One promising approach to reducing V_s and/or k is physical exercise. A single, brief bout of exercise has been shown to decrease craving (Kurti and Dallery, 2014; Scerbo et al., 2010; Taylor et al., 2005) and withdrawal (Daniel et al., 2007; Everson et al., 2008; Ussher et al., 2009), and increase the delay to ad libitum smoking relative to non-physical activities (Kurti and Dallery, 2014; Reeser, 1983; Taylor and Katomeri, 2007; Thayer et al., 1993). Exercise has also been shown to decrease brain activity in reward and motivation areas in response to smoking cues (Janse Van Rensburg et al., 2009). These data suggest that exercise may decrease the amount or magnitude of reward derived from smoking (i.e., A in Eq. (1) for smoking), and therefore decrease V_s. In addition to decreasing responsiveness to smoking stimuli, exercise has also been shown to decrease activity in brain reward regions in response to stimuli signaling monetary gains (Bothe et al., 2013). Importantly, these same regions haven been identified as potential neural correlates of impulsive choice (e.g., choosing smaller, immediate sums of money rather than larger, delayed sums; Koffarnus et al., 2013; McClure et al., 2004). The capacity for exercise to diminish reactivity to stimuli that promote impulsive choice may suggest that exercise could decrease smokers' rates of temporal discounting (k).

By targeting both V_s and/or k, as well as V_a, the combination of exercise plus CM (respectively) may reduce smoking more effectively than either exercise or CM alone. Thus, the primary purpose of this research was to evaluate the effectiveness of a combined, exercise plus CM approach to smoking relative to its independent components. A secondary purpose was to explore the potential effects of exercise on smokers' rates of temporal discounting.

2. Methods

2.1. Participant recruiting and selection

Participants were recruited via advertisements and flyers posted throughout the community. The inclusion criteria were (a) 18–60 years of age, (b) self-reported smoking of ≥10 cigarettes per day, (c) self-reported desire to quit smoking (to enhance the clinical validity of laboratory-based assessments; Perkins et al., 2006), (d) drug-free urine (e) blood-alcohol concentration (BAC) of 0.0%, and (f) breath carbon monoxide (CO) of ≥10 parts per million (ppm). Exclusion criteria were (a) current drug abuse or dependence (excluding nicotine and caffeine), (b) medication use that would interfere with the study (bupropion, SSRI's), (c) being pregnant or lactating, (d) evidence of a major psychiatric illness (taking psychotropic medication) within the past 6 months, (e) evidence of any condition that might contraindicate physical activity (exercise-induced asthma), (f) answering "Yes" to any questions on the Physical Activity Readiness Questionnaire (PAR-Q, see Section 2.2), and (g) classifying as high-risk for cardiovascular disease according to the Health Status Questionnaire (HSQ, see Section 2.2). Inclusion/exclusion criteria and all experimental procedures were approved by the University of Florida Institutional Review Board.

2.2. Screening

Applicants who responded to advertisements underwent a brief telephone screening. They were asked (a) their age, (b) how many cigarettes they smoked each day, (c) whether they had any medical conditions that prohibited exercise, and (d) whether they wanted to quit smoking. Applicants who met the inclusion criteria were invited to the lab for a 30 min screening session.

At the screening, participants provided urine samples for drug-testing (CupOne Kits; Varian; Lake Forest, CA) and pregnancy-testing (Calhoun Industries; Fort Smith, AZ), as well as breath samples to detect recent drinking (Alco-Sensor IV, Intoximeters, Inc.; Saint Louis, MO) and smoking (Bedfont Scientific Ltd.; Kent, England). Participants' resting heart rates were measured after at least 5 min of sitting, typically while they completed questionnaires. The questionnaires included a psychosocial history, the Physical Activity Readiness Questionnaire (PAR-Q; Hafen and Hoeger, 1994), the Health Status Questionnaire (HSQ; Radosevich et al., 1994), and the Fagerstrom Test for Nicotine Dependence (FTND; Heatherton et al., 1991). The psychosocial history assesses demographics, general health, and medication use; the PAR-Q identifies individuals for whom exercise is not recommended; and the HSQ identifies participants for whom exercise poses a high risk. All high-risk participants were excluded.

2.3. Apparatus and materials

Experimental sessions occurred in small, windowless, well-ventilated smoking rooms that were equipped with a chair, PC with monitor, television with a DVD player, health-related magazines (Running, Men's Health, Women's Health), and a laptop computer with Internet access. Plowshare topography and software (Baltimore, MD) were installed on desktop computers in all smoking rooms. A cigarette mouthpiece was connected to the Plowshare equipment via a hose, and cigarettes were smoked using this mouthpiece to permit passive collection of participants' smoking topography data (time of puffs, puff volume) during CM or CM-control (see Section 2.5). The CM or CM-control task were run using Microsoft Visual Studio® 10.0.