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Brief report
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Reduced Influence of Monetary Incentives on Go/NoGo Performance During Smoking Abstinence

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Abstract

Introduction: Smokers may experience decreased sensitivity to nondrug incentives during acute smoking deprivation. This decreased sensitivity may undermine attempts to encourage continued abstinence by enhancing cognitive processes through the use of monetary incentives. This study assessed whether the capacity for monetary incentives to enhance cognitive performance was compromised in nicotine-deprived smokers.

Method: Eighteen smokers performed an incentivized Go/NoGo task on 2 occasions, once after smoking as usual prior to the session, and once after undergoing 12-hr abstinence. Participants could earn up to $5.00 ($2.50 per session) based on their performance on reward blocks of the Go/NoGo task.

Results: Performance was significantly more accurate on incentivized NoGo, frequent-Go, and infrequent-Go trials relative to neutral trials during the smoke as usual session. Participants also produced fewer premature, impulsive responses on rewarded versus neutral blocks during the smoke as usual session. No significant difference between reward and neutral blocks was observed on any of the 4 performance indices during the abstinent session.

Conclusions: The ability for monetary incentives to enhance inhibitory control may be compromised during acute abstinence in smokers. These findings may have implications for contingency management treatment programs which are thought to promote continued abstinence partly by facilitating the allocation of cognitive resources to processes that encourage continued abstinence by increasing the value associated with continued abstinence.

Introduction

Nicotine administration increases extracellular dopamine in the nucleus accumbens,[1] a brain area implicated in incentive processing.[2] Repeated administration of nicotine is theorized to impact the mesolimbic dopamine system such that drug-associated rewards gain increased incentivize salience while the incentive salience of nondrug rewards is reduced.[3,4] These alterations in reward functioning are thought to be masked during smoking satiety due to nicotine's continued ability to increase dopamine transmission in areas of the brain associated with reward.[5] During smoking abstinence, however, the drug-induced changes to reward processes may be "unmasked."

In line with these theories, smokers experience less interference from appetitive words on Stroop tasks following overnight

smoking abstinence,[6,7] suggesting that the salience of nondrug rewards is reduced during abstinence. Recent neuroimaging work has provided evidence for dissociable effects of smoking abstinence on drug and nondrug rewards on incentive processing at the neural level.[8] In abstinent smokers, heightened activation in reward-related regions was observed during the anticipation of smoking rewards. Conversely, these regions demonstrated attenuated activation during the anticipation of monetary rewards.

The phenomenon of abstinent-related reward insensitivity has implications for smoking cessation. Contingency management approaches attempt to encourage continued smoking abstinence by manipulating the contingencies associated with cigarette smoking.[9] These approaches may be effective partly by enhancing the value associated with a target behavior (e.g., continued abstinence) through the provision of an incentive, thus encouraging the allocation of cognitive resources to achieve that behavior.[10] Indeed, enhanced performance on cognitive tasks has been observed in nonsmokers during incentivized trials, relative to trials with no incentive.[11,12] However, incentives fail to improve cognitive performance in populations exhibiting impaired reward processing.[13] The experience of reward insensitivity during smoking abstinence may undermine efforts to use nondrug rewards to promote continued abstinence through the enhancement of cognitive processes.

This study examined the capacity for monetary incentives to modulate performance on a cognitive task in smokers during periods of smoking satiety and abstinence. In line with findings demonstrating abstinence-related reward alterations,[8] we hypothesized that monetary incentives would enhance task performance during smoking satiety but not during smoking abstinence.

Method

Participants

Upon receipt of Institutional Review Board approval, 23 smokers were recruited via community advertisements. Inclusion criteria were (a) ≥18 years old, (b) daily smoking for the past year, (c) inhaling while smoking, and (d) no intention to quit smoking in the next month. Exclusion criteria were (a) current illicit drug abuse; (b) current dependence on drugs of abuse besides cigarettes; (c) current major depression; (d) women who were pregnant or lactating, or who planned to become pregnant or breastfeed during the study; and (e) other tobacco use within the past year. Participants who dropped out before completing the study ($n = 5$) were excluded, leaving a final sample of 18 (5 females). The mean age of these participants was 31.06 ($SD = 13.82$). Participants identified as Caucasian (66.7%), Asian (27.8%), and mixed race (5.6%). Participants reported smoking an average of 11.08 ($SD = 11.27$) cigarettes per day. The sample exhibited very low nicotine dependence according to the Fagerstrom Test of Nicotine Dependence (FTND), with a mean score of 2.61 ($SD = 2.35$).

Procedure

Participants attended a baseline session involving breath carbon monoxide (CO) analysis, psychiatric screening, and other measures detailed in the measures section. Participants then attended two counterbalanced (smoke as usual [SAU] and deprived) sessions. For deprived sessions, participants were instructed not to smoke for at least 12 hr before the session. For SAU sessions, participants were instructed to continue their regular smoking habits.

Participants began the experimental sessions by providing a CO sample. Participants then completed a recent nicotine, alcohol, and substance use measure. Participants reporting the use of alcohol or other substances within 24 hr before experimental sessions were asked to return at a later date when they had refrained from substance use ($n = 1$). Investigators then administered a measure of nicotine withdrawal, followed by two cognitive tasks (not reported here), and an incentivized Go/NoGo task. Each session lasted approximately 2 hr.

Measures

A coVitalBedfont Micro Smokerlyzer® was used to monitor CO levels. The Beck Depression Inventory-II[14] and the Center for Epidemiologic Studies Depression Scale—Revised[15] were used to screen for current depression. A screening for dependence on drugs other than nicotine was also administered. Participants then completed the FTND.[16] During both experimental sessions, participants were administered the Questionnaire of Smoking Urges—Brief (QSU).[17]

Go/NoGo Task

An incentivized version of the Go/NoGo task was administered via computer with a 17-inch monitor. The task consisted of three trial types: frequent-Go (FGO), infrequent-Go (IFGO), and NoGo trials.[18] IFGO stimuli in Go/NoGo tasks are increasingly employed[19] as they allow investigators to dissociate neural activity associated with response inhibition and activity associated with the processing of infrequently presented stimuli. For the FGO and IFGO trials, participants were required to press the space bar on a computer keyboard using the index finger of their dominant hand. On NoGo trials, participants were required not to press the space bar, that is, they were required to withhold from responding. Each trial consisted of the presentation of a colored square for 400 ms followed by the presentation of a fixation cross for 400 ms. Responses were collected during this 800 ms period. Participants were instructed to respond as fast and as accurately as possible. Trials with reactions times <150 ms were excluded from analyses of FGO, IFGO, and NoGO trials to avoid the inclusion of potentially premature responses. IFGO were indicated by gray squares. The relationship between color (blue/purple) and trial type (FGO/NoGo) was counterbalanced across subjects for the FGO and NoGo trial types. The percentage of FGO, IFGO, and NoGo trials was 75%, 12.5%, and 12.5%, respectively. The trial types were presented pseudorandomly. One run consisted of 100 trials. A NoGo trial was never preceded or followed by a NoGo trial. Ten FGO trials were presented at the beginning of each run to encourage the establishment of a prepotent response. Participants completed 10 runs. Five runs were preceded by a ring of dollar signs ($), indicating the availability of monetary reward depending on run performance. Five runs were preceded by a ring of pound signs (#), indicating that no monetary reward was available. The order of runs was randomized. Participants were instructed that they could earn up to $5.00 ($2.50 per session), and that faster and more accurate performance on rewarded blocks would result in a greater reward amount. Participants were instructed that they would receive the earned rewards once they had completed the study and the investigators had time to analyze their data. All participants received the full reward amount after completing their final session.

Analysis

Given the clear hypotheses, that performance would be enhanced on rewarded relative to neutral blocks during the SAU but not the

deprived session, planned comparisons in the form of paired-samples *t* tests were employed to compare the difference between accuracy rates and reaction times on reward and neutral NoGo, FGO, and IFGO trials, as well as the percent of premature responses <150 on the task, across SAU and abstinent sessions. Based on a power analysis conducted using data from an incentivized cognitive task,[20] our sample size was sufficient to obtain statistical power at the recommended .80 level[21] to detect differences between the reward and neutral conditions.

Results

Participant Smoking Abstinence

All participants reported no cigarette use for at least 12 hr preceding their abstinent sessions. Participants' expired CO levels during the SAU session (M = 12.61, SD = 7.84) were significantly greater than levels during the abstinent session (M = 5.67, SD = 4.31), t (17) = 5.62, p < .001. Scores on the QSU during the SAU session (M = 21.39, SD = 10.74) were significantly different to scores during the abstinent session (M = 34.67, SD = 16.51), t (17) = –4.06, p = .001.

The Effects of Smoking Satiety on Go/NoGo Task Indices

Our hypothesis was that the capacity for incentives to enhance Go/NoGo task indices (Table 1) would differ across SAU and abstinent sessions. Planned comparison paired-samples *t* tests revealed a significant difference between neutral and reward NoGo trials during the SAU condition, t (17) = –2.94, p = .01, η^2 = .61, but not during the abstinent condition, t (17) = –2.14, p =.05.

Planned comparison paired-samples *t* tests were conducted on percentage of correct responses on Go-trials trials across incentive conditions and sessions. There was a significant difference between accuracy rates on rewarded FGO trials versus neutral FGO trials during the SAU, t (17) = 3.64, p = .002, η^2 = .76, but not the abstinent, t (17) = 1.87, p = .08, condition. For the IFGO trials, a significant difference was observed between accuracy rates on rewarded IFGO trials versus neutral IFGO trials during the SAU, t (17) = 3.49, p = .003, η^2 =.73, but not the abstinent, t (17) = 1.48, p = .16, conditions.

Paired-samples *t* tests were conducted on reaction times for correct FGO and IFGO trials across incentive conditions and sessions. No significant differences were observed between the latencies for correct neutral and reward FGO trials during the SAU, t (17) = –0.31, p = .76, and abstinent, t (17) = 0.28, p = .78, conditions. No significant differences between the latencies for correct neutral and reward IFGO trials, during the SAU, t (17) = –0.14, p = .89, and abstinent, t (17) = 0.59, p = .57, conditions were observed.

Paired-samples *t* tests were conducted on percent premature responses on the task across incentive conditions and sessions. A significant difference emerged between the percent of premature responses on reward versus neutral blocks during the SAU session, t (17) = –3.95, p = .001, η^2 = .82, but not during the abstinent session, t (17) = –2.07, p = .05.

Discussion

This study aimed to determine if the performance-enhancing effect of monetary incentives on cognitive performance was affected by smoking abstinence. During the SAU session, smokers performed more accurately and less impulsively on trials for which monetary reward was available contingent on performance, relative to trials for which no monetary reward was available. Following smoking abstinence, performance was not significantly affected by the availability of monetary reward.

The finding that monetary reward did not enhance performance during the deprived session may be a result of abstinence-related reward-insensitivity, a phenomenon that has been observed across a range of experimental modalities.[6,8,22] The findings have implications for the incentives used in contingency management programs. If the incentives used in such interventions, often monetary rewards,[23] are not salient to smokers due to abstinent-related reward insensitivity, they may fail to change the value associated with continued smoking abstinence, thus undermining attempts to encourage the allocation of cognitive resources towards self-regulatory processes to support continued abstinence. Notably, this effect was observed in smokers exhibiting low nicotine dependence suggesting that this is a phenomenon that may impact interventions even in low-dependent smokers.

A limitation of the current study is the small sample. However, the consistent pattern of results across four indices of task performance suggests that these findings warrant further investigation. Questions for future research include whether the reduced capacity of monetary rewards to enhance inhibitory control holds when larger monetary rewards are available. Furthermore, investigating the generalizability of this reward insensitivity to other types of incentives (e.g., social praise; food) is crucial to determine if suitable, alternative incentives to enhance cognitive performance in deprived smokers exist in order to inform the development of effective interventions.

Table 1. Results of Paired-Samples *t* tests for Frequent-Go, Infrequent-Go, NoGo, and Percent Premature Responses Across Incentives and Sessions

	Smoke as usual			Abstinent		
	Reward	Neutral	*T*	Reward	Neutral	*t*
Percent correct (*SD*)						
Frequent-GO	94.85 (4.02)	92.19 (5.38)	3.64*	92.14 (7.34)	89.50 (8.66)	1.87
Infrequent-Go	95.08 (4.53)	92.06 (4.50)	3.49*	92.59 (7.53)	89.99 (9.92)	1.48
NoGo	52.72 (14.39)	43.61 (15.29)	2.94*	48.78 (13.68)	44.94 (14.03)	2.14
Percent premature responses (*SD*)						
All trial types	5.92 (4.68)	9.44 (6.67)	–3.95*	8.79 (7.36)	11.72 (8.87)	–2.07
Reaction time in milliseconds (*SD*)						
Frequent-Go	323.48 (58.38)	324.96 (76.13)	–0.28	334.23 (56.93)	332.43 (66.47)	0.31
Infrequent-Go	347.52 (64.81)	346.28 (89.13)	0.14	351.92 (65.22)	357.23 (82.46)	–0.59

Note. *Significant at p < .05.

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Declaration of Interests

None declared.

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