Original investigation

Anhedonia and Abstinence as Predictors of the Subjective Pleasantness of Positive, Negative, and Smoking-Related Pictures

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Abstract

Introduction: Anhedonia—diminished interest or pleasure in response to rewards—is a dimension implicated in several psychiatric disorders linked to smoking. This laboratory study sought to identify motivational mechanisms linking anhedonia and tobacco addiction by testing the hypothesis that anhedonia, abstinence, and their interaction would predict excesses and deficits in the perceived pleasantness of smoking-related and positive pictures, respectively. We assessed the pleasantness of negative pictures as a secondary outcome.

Methods: After a baseline session involving self-report measures of anhedonia and other factors, 125 regular smokers attended two counterbalanced experimental sessions (overnight abstinent and non-abstinent) at which they rated the pleasantness of positive, smoking-related, negative, and neutral (control) pictures presented via computer. The difference in pleasantness ratings of positive, smoking-related, and negative pictures relative to neutral pictures served as the index of participants' appraisal of the motivational salience of nondrug reward, drug reward, and aversive signals, respectively.

Results: With and without adjusting for sex and depressive symptoms, greater anhedonia significantly or marginally predicted greater pleasantness of smoking (vs. neutral), lower pleasantness of positive (vs. neutral), less unpleasantness of negative (vs. neutral) pictures ($|βs| = 0.18$ to 0.35 , $ps = .007$ to $.07$). Anhedonia by abstinence interaction effects on pleasantness ratings of each stimulus category (vs. neutral) were not significant ($|βs| ≤ 0.02$, $ps ≥ .36$).

Conclusions: Anhedonia and abstinence additively increase the salience of smoking-related cues in anhedonic smokers. Smoking cessation efforts that attenuate sensitization to smoking stimuli may benefit anhedonic smokers early in quit attempts.

Implications: Taken together, these findings provide tentative evidence that anhedonia is associated with a relative imbalance in the motivational salience of drug relative to nondrug rewards and may be associated with a generalized hypo-reactivity to both positive and negative stimuli. Though some prior smoking research has evidenced this relative imbalance in anhedonia with self-report or a smoking-choice task, we additionally show that this pattern may extend to hyper-affective reactivity to smoking-related stimuli being coincident with hypo-affective reactivity to nondrug-related positive stimuli (ie, may extend to greater pleasantness ratings of smoking pictures being accompanied by lower pleasantness ratings of positive pictures).

Introduction

Individuals with psychiatric disorders (eg, mood and anxiety disorders) are 2–3 times more likely to be current smokers^{1,2} and tobacco-dependent^{3,4} and display smoking cessation rates that are approximately 20%–40% lower^{2,5} compared to individuals without psychiatric disorders. Furthermore, smokers with comorbid mental disorders constitute nearly half of all deaths attributed to tobacco-related causes in the United States each year.² Given that psychiatric comorbidity in smoking is pervasive and extends across many mental health conditions, identifying transdiagnostic psychopathological factors implicated in numerous conditions comorbid with smoking may provide a parsimonious approach to understanding this devastating pattern of comorbidity.

Anhedonia, or difficulty experiencing interest or pleasure in response to rewards, is one dimensional factor (ie, psychopathological symptom and trait) that has been implicated in a number of psychiatric disorders linked to smoking, including major depressive disorder,^{3,4,6} social anxiety,^{1,2,7} posttraumatic stress disorder,^{1,2,8} and schizophrenia.^{2,9} Anhedonia has also been related to smoking onset and escalation,¹⁰ daily smoking,¹¹ current tobacco dependence,¹² and greater likelihood of smoking relapse following quit attempts.^{13–16} Given such findings, identifying mechanisms linking anhedonia and tobacco addiction may prove useful for understanding and ultimately treating the transdiagnostic underpinnings of smoking-psychiatric comorbidity.

Recent conceptualizations in psychopathological science posit that depressive and substance use disorders originate from pathologies involving excesses and deficits in motivational responses to stimuli that signal opportunities for reinforcement.¹⁷ From this reinforcement-pathology perspective, anhedonia reflects pervasively deficient motivational responses to common rewards that most people find enjoyable. Drug dependence can be conceptualized as the development of a disparity in motivational responsiveness to stimuli that signal drug rewards relative to nondrug rewards, which in turn promotes the prioritization of drug-taking behavior over other important social, occupational, or recreational activities.¹⁸ Though such conceptualizations have provided insight into understanding psychopathology and drug dependence separate from one another, synthesis of such concepts to elucidate motivational mechanisms that underlie anhedonia-smoking comorbidity is lacking.

We propose a model positing that interactions between anhedonia and nicotine withdrawal result in pathological motivational responses to smoking and nonsmoking cues which drive anhedonia-smoking comorbidity. The model proposes that because nicotine acts as a pharmacological reward enhancer,¹⁹ smoking serves to offset inherent deficient motivational responsiveness to nondrug rewards (ie, anhedonia). Then when anhedonic smokers abstain from tobacco, reward process deficits previously suppressed by nicotine become expressed and potentially exacerbated by withdrawal (which increases anhedonia levels^{20,21}). Thus, anhedonic smokers are expected to exhibit deficient responses to stimuli signaling nondrug reward, particularly when nicotine-deprived. In this state, smoking may be one of the few rewards capable of eliciting positive reinforcement in acutely abstinent anhedonic smokers, resulting in a disproportionate increase in the motivational salience of smoking-related stimuli for smokers with high (vs. low) anhedonia during smoking abstinence.

While direct evidence of imbalanced motivational responses to smoking relative to nonsmoking rewards in anhedonia is lacking, extant data provide indirect support that this model is plausible.

Smokers with higher (vs. lower) anhedonia have been shown to report amplified smoking urge and diminished positive affect during tobacco abstinence^{13,22,23} and to choose smoking over an alternative reinforcer in a behavioral economic choice task.²⁴ Methodologies that parse responses to smoking-related and nonsmoking reward stimuli and show discordant motivational response patterns by reward type would provide clearer evidence of the aforementioned model.

Robinson and Berridge²⁵ posited a close relation between the extent to which cues signaling reward command attention and their perceived attractiveness, as both are closely tied to the incentive value (or motivational salience) of the stimuli (eg, drug-related stimuli). One method of addressing this process in human research has been to examine the perceived pleasantness of stimuli.²⁶ In support of the notion that perceived pleasantness may differentiate whether a cue has acquired incentive properties, previous findings have shown that smoking-related pictures are perceived as more pleasant among smokers than nonsmokers.²⁷ Moreover, smoking abstinence has been shown to augment bias for smoking-related stimuli^{28,29} and diminish processing of positive stimuli.^{30,31} Thus, perceived pleasantness may depict the expression of pathological prioritization of the motivational salience of smoking over nonsmoking rewards magnified in drug-deprived states.

This laboratory study of moderate-to-heavy daily smokers sought to identify motivational mechanisms linking anhedonia and tobacco addiction. To this end, we investigated the effects of anhedonia, experimentally-verified overnight abstinence, and their interaction on the perceived pleasantness of positive, negative, and smoking-related pictures (relative to neutral control pictures)—putative markers of motivational salience attribution to each stimulus type. We hypothesized that anhedonia and abstinence would independently and synergistically interact to predict greater pleasantness of smoking-related (vs. neutral) pictures and lower pleasantness of positive (vs. neutral) pictures. We included negatively valenced pictures to examine the specificity of the aforementioned hypotheses, expecting anhedonia and abstinence to particularly impact pleasant or reward-related stimuli (ie, positive and smoking-related pictures) but not impact aversive stimuli (ie, negative pictures).

Methods

Participants

Participants were 125 non-treatment seeking smokers in the Los Angeles area recruited via online and community advertisements. Inclusion criteria were: (1) ≥ 18 years old; (2) regular cigarette smoking for ≥ 2 years; (3) currently smoking ≥ 10 cigs/day; (4) normal or corrected-to-normal vision; and (5) fluency in English. Exclusion criteria were: (1) intention to cut down or quit smoking within the next 30 days; (2) current DSM-IV non-nicotine substance dependence (to prevent alcohol drug withdrawal from washing out tobacco abstinence manipulation); (3) breath carbon monoxide (CO) level < 10 ppm at the start of the baseline session; (4) current DSM-IV bipolar or unipolar major mood disorder, psychotic symptoms, or current use of psychiatric medications (to prevent cognitive or behavioral impairment that might interfere with completing the behavioral tasks or modulation of tobacco abstinence effects by psychiatric medication); (5) current pregnancy; and (6) current use of non-cigarette tobacco or nicotine products. The current study reflects the secondary analysis of data from a larger study on individual differences in tobacco withdrawal. Participants were compensated approximately \$200 for completing the overall study. The study was approved by the University of Southern California Institutional Review Board.

Procedure

Following a telephone screen, participants attended a baseline session during which they provided informed consent, were assessed for eligibility (eg, via breath CO measurement and brief psychiatric interview), and completed self-report measures of demographics, smoking-related characteristics, anhedonia, depression, and cigarette dependence (see Measures below).

Participants then attended two counterbalanced experimental sessions that were scheduled at least 2 days apart but no more than 2 weeks apart: abstinent (for 16 hours) versus non-abstinent (instructed to smoke normally prior to the session). At the start of the abstinent session, participants were subjected to breath alcohol analysis (0.00 BAC reading required) and breath CO reading (must be ≤ 9 ppm).³² Participants next completed subjective measures of craving and withdrawal. Three selective attention tasks (not part of the current study) and the Picture Rating Task (PRT) were then administered in random order. Non-abstinent sessions were identical in structure, with the exception that participants smoked one cigarette prior to the expired CO assessment and subjective measures examined as part of preliminary analyses (see Manipulation Check section of the Results).

Measures

Baseline Measures

The Fagerström Test for Nicotine Dependence (FTND)³³ is a well-validated 6-item measure of cigarette dependence severity. Items relate to smoking heaviness and urgency, with higher total scores (range: 0–10) indicating greater cigarette dependence.

The Snaith-Hamilton Pleasure Scale (SHAPS)³⁴ was used to measure anhedonia. Using a 4-point Likert scale (1 = “strongly disagree” to 4 = “strongly agree”), participants are asked to rate the degree to which various pleasant situations (eg, “I would find pleasure in my hobbies and pastimes”) would invoke hedonic response during the past few days. For use in preliminary and primary analyses, the 14 items were reverse scored and summed to where higher total scores represent higher levels of anhedonia.^{35,36} For the purpose of further describing the sample, the 14 items instead were scored dichotomously in accord with the original SHAPS scoring formulation (0 = “agree” or “strongly agree”; 1 = “disagree” or “strongly disagree”), and then the percentage of participants scoring at or above the recommended clinical cutoff of 2 was determined.³⁴ The SHAPS exhibits high construct validity, internal consistency, and test–retest reliability.^{35,36}

The Center for Epidemiologic Studies Depression Scale (CES-D)³⁷ assesses past-week depressive symptom severity. The 20 items are answered on a 4-point symptom frequency scale (0 = “Rarely or None of the time” to 3 = “Most or All of the time”), and higher total scores indicate greater severity of depressive symptoms during the past week. The CES-D has shown high internal consistency and construct validity and adequate test–retest reliability.³⁷

The Demographic and Smoking-Related Characteristics Questionnaire is an author-constructed questionnaire that was used to assess demographic (sex, age, and race/ethnicity) and smoking-related characteristics (years of regular smoking and cigarettes smoked per day).

Experimental Measures

The Minnesota Nicotine Withdrawal Scale (MNWS)³⁸ is a widely used measure of tobacco withdrawal severity. Using a 6-point scale (0 = “None” and 5 = “Severe”), participants were instructed to rate

how much they had experienced each of 11 withdrawal symptoms so far today (average item scores provided in the Results below).

The Brief Questionnaire of Smoking Urges³⁹ is a 10-item measure of cigarette craving. Using a 6-point Likert scale (0 = “strongly disagree” to 5 = “strongly agree”), participants were instructed to respond as to their agreement with each statement indicative of cigarette craving in the current moment (average item scores provided in the Results below).

The PRT⁴⁰ is a measure of affective valence related to positive, negative, and smoking cues. Previous studies suggest that pleasantness ratings of smoking-related pictures are sensitive to smoking status⁴⁰ and abstinence²⁹ and correlate with behavioral approach responses toward smoking.⁴⁰ In addition, anhedonia has been inversely related to pleasantness ratings of positive or reward-related stimuli.^{35,41} Thus, this task may illuminate deficiencies in reward processing that may be related to anhedonia and affected by smoking abstinence.

The PRT was administered via computer, with pictures and instructions presented on a 17” monitor. After two practice trials, participants completed 72 experimental trials in which 18 positive, 18 negative, 18 smoking, and 18 neutral images were presented, one at a time, in random order at the screen center. On each trial, each picture (3.5” × 5.5”) was presented for 2000 ms, followed by a 500 ms pause, and then a rating scale. This 7-point Likert scale was anchored at left and right with labels –3 (very unpleasant) to +3 (very pleasant), respectively. Participants were instructed to rate the pleasantness of each stimulus by pressing a key on a keyboard corresponding to the rating. There was an intertrial interval of 500 ms.

Two distinct versions of the PRT were randomized across the two counterbalanced experimental sessions, and each version presented a unique set of stimuli in random order for 72 experimental trials, with a total of 144 pictures (36 positive, 36 negative, 36 smoking, and 36 neutral) used across the two experimental sessions. The positive and negative pictures were selected from the International Affective Picture System⁴² and the Emotional Image Series,⁴³ and the smoking and neutral (control) images were selected from the International Smoking Image Series with neutral counterparts; the smoking and neutral images came in sets of pairs in which the smoking image and neutral image were matched for content and stimulus parameters (complexity, color, saturation, and brightness per the stimulus set developer).⁴⁴ These smoking images have been shown to generate cognitive and motivational responses compared to neutral images in prior studies of nicotine deprivation.^{45,46} Smoking images included lit cigarettes, hands holding cigarettes, and male and female individuals of diverse racial backgrounds smoking. The neutral images showed emotionally non-expressive individuals and hands holding non-cigarette items (eg, a pen). Each version of the PRT took approximately 5 minutes to administer.

Outcomes for the PRT were affective reactivity (pleasantness difference) scores for each category (smoking, positive, and negative) calculated by subtracting the mean ratings of neutral (control) pictures from the mean ratings of respective category pictures.

Analytic Plan

Preliminary analyses involved reporting baseline descriptive statistics and correlations with anhedonia levels as well as descriptive statistics for the PRT and whether the abstinence procedure predicted changes in CO levels, tobacco withdrawal, and cigarette craving. The primary analyses used generalized estimating equations (GEE),⁴⁷ which take into account correlation of data within

subjects, with an independent correlation structure. Next, we examined the effects of anhedonia, abstinence, and anhedonia $\times$ abstinence interaction on affective reactivity to positive, negative, and smoking pictures. Unadjusted GEE models were subsequently adjusted for sex and depressive symptoms. Analyses were conducted in SAS using PROC GENMOD,⁴⁸ and results are reported as standardized parameter estimates ($\beta \pm 95\%$ CIs). Alpha (two-tailed) was set at 0.05.

Results

Preliminary Analyses

Baseline Descriptive Statistics and Correlations With Anhedonia Levels

Baseline descriptive statistics and correlations with anhedonia levels are displayed in Table 1. Approximately one-sixth of the sample surpassed the SHAPS clinical cutoff indicating clinically significant anhedonia.³⁴ Participants' mean score on the FTND was indicative of a moderate severity of cigarette dependence.⁴⁹ Anhedonia levels were significantly correlated with sex and depressive symptoms.

Manipulation Check

Participants provided decreased CO levels and reported greater subjective tobacco withdrawal symptoms and cigarette craving during the abstinent session relative to the non-abstinent session. Abstinence effects were significant for CO levels ($t_{125} = -21.7$; M non-abstinent = 27.46, $SD = 11.52$ vs. M abstinent = 5.67, $SD = 2.09$; $p < .0001$), MNWS scores ($t_{125} = 7.0$; M non-abstinent = 1.06, $SD = 0.82$ vs. M abstinent = 1.68, $SD = 0.97$; $p < .0001$), and Questionnaire of Smoking Urges scores ($t_{125} = 21.0$; M non-abstinent = 1.05, $SD = 1.19$ vs. M abstinent = 3.27, $SD = 0.98$; $p < .0001$).

Table 1. Baseline Descriptive Statistics and Correlations with Anhedonia Levels

Variable	% or M (SD)	Correlation with SHAPS (r)
SHAPS	9.66 (5.32)	
Surpass SHAPS Clinical Cutoff	15.2%	
Sex		0.19 ^{a*}
Male	73.6%	
Female	26.4%	
Race/Ethnicity		-0.10 ^b
Black	48.4%	
White	38.7%	
Asian/Pacific Islander	1.6%	
Multiracial	2.4%	
Hispanic	8.9%	
Age	43.74 (11.34)	0.14
Years of regular smoking	23.91 (12.04)	0.17
Cigarettes smoked per day	16.49 (7.28)	0.02
FTND	5.22 (1.95)	0.03
CES-D	11.98 (8.51)	0.25 ^{a*}

CES-D = Center for Epidemiologic Studies Depression Scale; FTND = Fagerström Test for Nicotine Dependence; SHAPS = Snaith-Hamilton Pleasure Scale; $N = 125$.

^aPoint biserial correlation Male = 1, Female = 0.

^bPoint biserial correlation black = 1, Non-black = 0.

* $p < .05$.

** $p < .01$.

PRT Descriptive Statistics

PRT descriptive statistics are shown in Table 2. In the abstinent and non-abstinent conditions, mean ratings for neutral (control) pictures were slightly positive; mean ratings for negative pictures were negative; mean ratings for positive pictures were positive; and mean ratings for smoking pictures were slightly positive.

Primary Analyses

A summary of GEEs examining if anhedonia levels, abstinence, and their interaction predict affective reactivity scores is shown in Table 3.

Main Effects of Anhedonia

Greater anhedonia was significantly associated with less negative affective reactivity to negative pictures and less positive affective reactivity to positive pictures. After controlling for sex and depressive symptoms, the association of anhedonia and less negative affective reactivity to negative pictures remained, while the association with less positive affective reactivity to positive pictures was reduced to a nearly significant trend. Anhedonia was also marginally predictive of greater positive affective reactivity to smoking pictures with and without adjusting for sex and depressive symptoms.

Main Effects of Abstinence

Abstinence increased positive affective reactivity to smoking pictures but did not significantly alter affective reactivity to positive or negative pictures.

Anhedonia by Abstinence Interaction

The interaction of anhedonia and abstinence was not significantly predictive of affective reactivity to positive, negative, or smoking pictures, suggesting that the extent to which anhedonia predicted affective reactivity to each picture type did not differ as a function of abstinence.

Discussion

In this laboratory study, anhedonia and overnight abstinence exhibited independent but not synergistic effects on the perceived pleasantness of (ie, affective reactivity to) varied classes of motivationally salient versus neutral pictures in moderate-to-heavy daily smokers. Averaged across abstinent and non-abstinent states, baseline anhedonia predicted lower pleasantness ratings of positive (vs. neutral) pictures. There was also suggestive evidence that averaged across abstinent and non-abstinent states, anhedonia predicted greater pleasantness ratings of smoking pictures in the form of a marginal trend. Together, these findings provide tentative evidence of a novel manifestation of the relative imbalance of the salience of drug relative to nondrug rewards that is associated with anhedonia (ie, tentative evidence that anhedonia is concomitantly associated with more pleasant responses to smoking pictures and less pleasant responses to positive pictures). Indeed, past work has documented that smokers with greater anhedonia are more likely to choose drug over nondrug rewards²⁴ and self-report prioritizing smoking over other reinforcers in the rewards they choose in their lives.¹³ Here we show that the association of anhedonia with a relative imbalance in the salience of drug versus nondrug rewards may extend to hyper-affective reactivity to smoking-related stimuli coinciding with hypo-affective reactivity to nondrug-related positive stimuli (ie, may extend to

Table 2. Picture Rating Task Descriptive Statistics

	Abstinent		Non-Abstinent	
	Average rating	Affective reactivity score ^a	Average rating	Affective reactivity score ^a
	M (SD)	M (SD)	M (SD)	M (SD)
PRT Stimulus				
Negative	-2.10 (.79)	-2.45 (1.04)	-2.14 (.81)	-2.55 (1.06)
Positive	1.93 (.80)	1.58 (.75)	2.07 (.79)	1.66 (.71)
Smoking	0.23 (1.55)	-0.12 (1.91)	0.05 (1.55)	-0.35 (1.79)
Neutral	0.35 (.66)		0.40 (.65)	

PRT 7-point Likert scale was anchored at left and right with labels -3 (very unpleasant) to +3 (very pleasant, respectively).

^aDifference score obtained by subtracting neutral score from respective category score.

Table 3. Summary of Generalized Estimated Equations Examining if Anhedonia Levels, Abstinence, and Their Interaction Predict Affective Reactivity Scores on the Picture Rating Task

Independent variables	Unadjusted Model			Adjusted Model		
	β (SE)	95% CI	p	β (SE)	95% CI	p
Dependent variable: negative affective reactivity score ^a						
SHAPS	0.33 (0.10)	0.14, 0.51	.0007	0.35 (0.12)	0.12, 0.57	.003
Abstinence	0.05 (0.03)	-0.01, 0.11	.12	0.05 (0.03)	-0.01, 0.11	.12
SHAPS $\times$ Abstinence	0.002 (0.03)	-0.06, 0.06	.94	0.002 (0.03)	-0.06, 0.06	.94
Dependent variable: positive affective reactivity score ^a						
SHAPS	-0.18 (0.09)	-0.35, -0.01	.04	-0.19 (0.10)	-0.39, 0.00	.054
Abstinence	-0.05 (0.04)	-0.14, 0.03	.22	-0.05 (0.04)	-0.14, 0.03	.22
SHAPS $\times$ Abstinence	-0.02 (0.04)	-0.10, 0.07	.67	-0.02 (0.04)	-0.10, 0.07	.66
Dependent variable: smoking affective reactivity score ^a						
SHAPS	0.19 (0.10)	-0.01, 0.39	.06	0.20 (0.11)	-0.02, 0.42	.07
Abstinence	0.06 (0.02)	0.02, 0.11	.007	0.06 (0.02)	0.02, 0.11	.007
SHAPS $\times$ Abstinence	0.02 (0.02)	-0.02, 0.07	.36	0.02 (0.02)	-0.02, 0.07	.36

PRT = Picture Rating Task. PRT 7-point Likert scale was anchored at left and right with labels -3 (very unpleasant) to +3 (very pleasant) respectively. Adjusted models controlled for sex and depressive symptoms.

^aDifference score obtained by subtracting neutral score from respective category score.

greater pleasantness ratings of smoking pictures being accompanied by lower pleasantness ratings of positive pictures).

We also unexpectedly found that anhedonia was associated with less negative affective reactivity to aversive pictures (ie, less unpleasantness of negative vs. neutral pictures), which suggests a generalized affective flattening in response to both positive and negative affective stimuli. Although anhedonia has mostly been related to positive affect and reward, a number of past studies have also associated anhedonia or disorders characterized by anhedonia (eg, posttraumatic stress disorder, major depressive disorder, and schizophrenia) with a general affective flattening in relation to both positive and negative affective intensity, expressivity, or reactivity.^{50,51} Growing evidence also suggests that anhedonia is associated with blunted cardiovascular response to both reward and punishment.^{52,53} Therefore, the possibility that anhedonia is part of a broader generalized deficit in affect and motivation warrants further study.

We did not find support for our hypothesis that there would be synergistic effects of smoking abstinence and anhedonia on subjective response to positive and smoking-related stimuli. In other words, the extent to which anhedonia predicted exaggerated and blunted affective reactivity to smoking-related and nondrug reward-associated cues, respectively, was not magnified by abstinence. This does not concord with past work documenting that anhedonia is related to blunted attentional bias toward positive stimuli⁵⁴ and

greater urge to smoke^{13,23} in abstinent (vs. non-abstinent) states. Perhaps the PRT methodology may not be well-suited for detecting abstinence-induced alterations in nondrug-related reward processing, given that abstinence did not have a main effect on blunting the pleasantness of positive cues and therefore may be insensitive to this particular abstinence effect. Because two prior studies exposing participants to pleasant film clips found abstinence-provoked blunting of subjective happiness,^{30,31} we speculate that the intensity of affect produced by pictures may not be strong enough in sated states to detect blunting during abstinence, which is an idea worth considering in future work. By contrast, abstinence did increase affective reactivity to smoking stimuli. Thus, the PRT may be sufficiently sensitive for abstinence-induced amplification of affective responses to stimuli that signal smoking; yet, this distortion may not be magnified in anhedonic smokers. Alternatively, anhedonia may magnify abstinence effects on affective responses to both positive and smoking-related stimuli, but the effects may be small in magnitude and require a larger sample to provide the necessary statistical power.

The current study has limitations. Participants were non-treatment-seeking smokers, and a 16-hour period of abstinence may be insufficient to capture the entire course of withdrawal relevant to anhedonic smokers. We also were not able to disentangle pharmacological from nonpharmacological or behavioral sources of withdrawal using the current smoking abstinence manipulation.

In addition, for methodological reasons we excluded smokers with current mood disorders and non-nicotine substance use disorders, and this may have eliminated some severely anhedonic smokers who would have shown some of the expected effects.

To summarize, current findings suggest that both anhedonia and acute abstinence increase the pleasantness (and potentially the incentive salience) of smoking-related stimuli. Though we did not find evidence that these effects were synergistic (or interactive), the two were additive, which implies that smokers who are anhedonic as well as acutely abstinent may have two independent and additive sources of influence on hyperreactivity to smoking-related stimuli. Hence, smoking cessation efforts that attempt to thwart mechanisms underlying incentive sensitization of drug cues (eg, medications like varenicline or bupropion, attentional bias modification, and stimulus control techniques) may benefit anhedonic smokers in the early stages of a quit attempt.

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Declaration of Interests

None declared.

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References

- Lawrence D, Mitrou F, Zubrick SR. Smoking and mental illness: results from population surveys in Australia and the United States. *BMC Public Health*. 2009;9:285. doi:10.1186/1471-2458-9-285.
- Schroeder SA, Morris CD. Confronting a neglected epidemic: tobacco cessation for persons with mental illnesses and substance abuse problems. *Annu Rev Public Health*. 2010;31:297–314. doi:10.1146/annurev.publhealth.012809.103701.
- Grant BF, Hasin DS, Chou SP, Stinson FS, Dawson DA. Nicotine dependence and psychiatric disorders in the United States: results from the national epidemiologic survey on alcohol and related conditions. *Arch Gen Psychiatry*. 2004;61(11):1107–1115. doi:10.1001/archpsyc.61.11.1107.
- Goodwin RD, Zvolensky MJ, Keyes KM, Hasin DS. Mental disorders and cigarette use among adults in the United States. *Am J Addict*. 2012;21(5):416–423. doi:10.1111/j.1521-0391.2012.00263.x.
- Piper ME, Smith SS, Schlam TR, et al. Psychiatric disorders in smokers seeking treatment for tobacco dependence: relations with tobacco dependence and cessation. *J Consult Clin Psychol*. 2010;78(1):13–23. doi:10.1037/a0018065.
- Rizvi SJ, Pizzagalli DA, Sproule BA, Kennedy SH. Assessing anhedonia in depression: Potentials and pitfalls. *Neurosci Biobehav Rev*. 2016;65:21–35. doi:10.1016/j.neubiorev.2016.03.004.
- Kashdan TB. The neglected relationship between social interaction anxiety and hedonic deficits: differentiation from depressive symptoms. *J Anxiety Disorders*. 2004;18(5):719–730. doi:10.1016/j.janxdis.2003.08.001.
- Nawijn L, van Zuiden M, Frijling JL, Koch SB, Veltman DJ, Olff M. Reward functioning in PTSD: a systematic review exploring the mechanisms underlying anhedonia. *Neurosci Biobehav Rev*. 2015;51:189–204. doi:10.1016/j.neubiorev.2015.01.019.
- Horan WP, Kring AM, Blanchard JJ. Anhedonia in schizophrenia: a review of assessment strategies. *Schizophr Bull*. 2006;32(2):259–273. doi:10.1093/schbul/sbj009.
- Audrain-McGovern J, Rodriguez D, Leventhal AM, Cuevas J, Rodgers K, Sass J. Where is the pleasure in that? Low hedonic capacity predicts smoking onset and escalation. *Nicotine Tob Res*. 2012;14(10):1187–1196. doi:10.1093/ntr/nts017.
- Leventhal AM, Zvolensky MJ. Anxiety, depression, and cigarette smoking: a transdiagnostic vulnerability framework to understanding emotion-smoking comorbidity. *Psychol Bull*. 2015;141(1):176–212. doi:10.1037/bul0000003.
- Leventhal AM, Kahler CW, Ray LA, Zimmerman M. Refining the depression-nicotine dependence link: patterns of depressive symptoms in psychiatric outpatients with current, past, and no history of nicotine dependence. *Addict Behav*. 2009;34(3):297–303. doi:10.1016/j.addbeh.2008.11.008.
- Leventhal AM, Waters AJ, Kahler CW, Ray LA, Sussman S. Relations between anhedonia and smoking motivation. *Nicotine Tob Res*. 2009;11(9):1047–1054. doi:10.1093/ntr/ntp098.
- Cook J, Spring B, McChargue D, Doran N. Effects of anhedonia on days to relapse among smokers with a history of depression: a brief report. *Nicotine Tob Res*. 2010;12(9):978–982. doi:10.1093/ntr/ntq118.
- Leventhal AM, Piper ME, Japuntich SJ, Baker TB, Cook JW. Anhedonia, depressed mood, and smoking cessation outcome. *J Consult Clin Psychol*. 2014;82(1):122–129. doi:10.1037/a0035046.
- Cook JW, Piper ME, Leventhal AM, Schlam TR, Fiore MC, Baker TB. Anhedonia as a component of the tobacco withdrawal syndrome. *J Abnorm Psychol*. 2015;124(1):215–225. doi:10.1037/abn0000016.
- Baskin-Sommers AR, Foti D. Abnormal reward functioning across substance use disorders and major depressive disorder: Considering reward as a transdiagnostic mechanism. *Int J Psychophysiol*. 2015;98(2 pt 2):227–239. doi:10.1016/j.ijpsycho.2015.01.011.
- Bickel WK, Johnson MW, Koffarnus MN, MacKillop J, Murphy JG. The behavioral economics of substance use disorders: reinforcement pathologies and their repair. *Annu Rev Clin Psychol*. 2014;10:641–677. doi:10.1146/annurev-clinpsy-032813-153724.
- Caggiula AR, Donny EC, Palmatier MI, Liu X, Chaudhri N, Sved AF. The role of nicotine in smoking: a dual-reinforcement model. *Nebr Symp Motiv*. 2009;55:91–109.
- Guillot CR, Stone MD, Geary BA, et al. Pharmacological, sensorimotor, and expectancy effects on tobacco withdrawal: a preliminary study. *Hum Psychopharmacol*. 2015;30(5):364–371. doi:10.1002/hup.2484.
- Dawkins L, Powell JH, West R, Powell J, Pickering A. A double-blind placebo controlled experimental study of nicotine: I—effects on incentive motivation. *Psychopharmacology*. 2006;189(3):355–367. doi:10.1007/s00213-006-0588-8.
- Langdon KJ, Leventhal AM, Stewart S, Rosenfield D, Steeves D, Zvolensky MJ. Anhedonia and anxiety sensitivity: prospective relationships to nicotine withdrawal symptoms during smoking cessation. *J Stud Alcohol Drugs*. 2013;74(3):469–478. doi:10.15288/jsad.2013.74.469.
- Cook JW, Spring B, McChargue D, Hedeker D. Hedonic capacity, cigarette craving, and diminished positive mood. *Nicotine Tob Res*. 2004;6(1):39–47. doi:10.1080/14622200310001656849.
- Leventhal AM, Trujillo M, Ameringer KJ, Tidey JW, Sussman S, Kahler CW. Anhedonia and the relative reward value of drug and nondrug reinforcers in cigarette smokers. *J Abnorm Psychol*. 2014;123(2):375–386. doi:10.1037/a0036384.
- Robinson TE, Berridge KC. The neural basis of drug craving: an incentive-sensitization theory of addiction. *Brain Res Brain Res Rev*. 1993;18(3):247–291.
- Kuhn S, Gallinat J. The neural correlates of subjective pleasantness. *Neuroimage*. 2012;61(1):289–294. doi:10.1016/j.neuroimage.2012.02.065.
- Bradley BP, Field M, Healy H, Mogg K. Do the affective properties of smoking-related cues influence attentional and approach biases in cigarette smokers? *J Psychopharmacol*. 2008;22(7):737–745. doi:10.1177/0269881107083844.
- Waters AJ, Feyerabend C. Determinants and effects of attentional bias in smokers. *Psychol Addict Behav*. 2000;14(2):111–120. doi:10.1037/0893-164X.14.2.111.

29. Field M, Mogg K, Bradley BP. Eye movements to smoking-related cues: effects of nicotine deprivation. *Psychopharmacology*. 2004;173(1–2):116–123. doi:10.1007/s00213-003-1689-2.
30. Dawkins L, Acaster S, Powell JH. The effects of smoking and abstinence on experience of happiness and sadness in response to positively valenced, negatively valenced, and neutral film clips. *Addict Behav*. 2007;32(2):425–431. doi:10.1016/j.addbeh.2006.05.010.
31. Dawkins L, Powell J. Effects of nicotine and alcohol on affective responses to emotionally toned film clips. *Psychopharmacology*. 2011;216(2):197–205. doi:10.1007/s00213-011-2197-4.
32. SRNT Subcommittee on Biochemical Verification. Biochemical verification of tobacco use and cessation. *Nicotine Tob Res*. 2002;4(2):149–159. doi:10.1080/14622200210123581.
33. Heatherton TF, Kozlowski LT, Frecker RC, Fagerstrom KO. The Fagerstrom Test for Nicotine Dependence: a revision of the Fagerstrom Tolerance Questionnaire. *Br J Addict*. 1991;86(9):1119–1127. doi:10.1111/j.1360-0443.1991.tb01879.x.
34. Snaith RP, Hamilton M, Morley S, Humayan A, Hargreaves D, Trigwell P. A scale for the assessment of hedonic tone the Snaith-Hamilton Pleasure Scale. *Br J Psychiatry*. 1995;167(1):99–103. doi:10.1192/bjp.167.1.99.
35. Leventhal AM, Chasson GS, Tapia E, Miller EK, Pettit JW. Measuring hedonic capacity in depression: a psychometric analysis of three anhedonia scales. *J Clin Psychol*. 2006;62(12):1545–1558. doi:10.1002/jclp.20327.
36. Franken IH, Rassin E, Muris P. The assessment of anhedonia in clinical and non-clinical populations: further validation of the Snaith-Hamilton Pleasure Scale (SHAPS). *J Affect Disord*. 2007;99(1–3):83–89. doi:10.1016/j.jad.2006.08.020.
37. Radloff LS. The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Meas*. 1977;1(3):385–401. doi:10.1177/014662167700100306.
38. Hughes JR, Hatsukami D. Signs and symptoms of tobacco withdrawal. *Arch Gen Psychiatry*. 1986;43(3):289–294.
39. Cox LS, Tiffany ST, Christen AG. Evaluation of the brief questionnaire of smoking urges (QSU-brief) in laboratory and clinical settings. *Nicotine Tob Res*. 2001;3(1):7–16. doi:10.1080/14622200020032051.
40. Mogg K, Bradley BP, Field M, De Houwer J. Eye movements to smoking-related pictures in smokers: relationship between attentional biases and implicit and explicit measures of stimulus valence. *Addiction*. 2003;98(6):825–836. doi:10.1046/j.1360-0443.2003.00392.x.
41. Keller J, Young CB, Kelley E, Prater K, Levitin DJ, Menon V. Trait anhedonia is associated with reduced reactivity and connectivity of mesolimbic and paralimbic reward pathways. *J Psychiatr Res*. 2013;47(10):1319–1328. doi:10.1016/j.jpsychires.2013.05.015.
42. Lang PJ, Bradley MM, Cuthbert BN. *International Affective Picture System (IAPS): Affective Ratings of Pictures and Instruction Manual. Technical Report A-8*. Gainesville, FL: University of Florida; 2008.
43. Gilbert DG, Rabinovich NE. *The Emotional Image Series, Version 1.1 [manual]*. Carbondale, IL: Department of Psychology, Southern Illinois University; 2003.
44. Gilbert DG, Rabinovich NE. *Manual of norms for the International Smoking Image Series (with neutral counterparts), Version 1.2*. Carbondale, IL: Department of Psychology, Southern Illinois University; 2005.
45. Gilbert DG, Sugai C, Zuo Y, Rabinovich NE, McClernon FJ, Froeliger B. Brain indices of nicotine's effects on attentional bias to smoking and emotional pictures and to task-relevant targets. *Nicotine Tob Res*. 2007;9(3):351–363. doi:10.1080/14622200701188810.
46. Gilbert DG, Sugai C, Zuo Y, et al. Effects of nicotine on brain responses to emotional pictures. *Nicotine Tob Res*. 2004;6(6):985–996. doi:10.1080/14622200412331324947.
47. Zeger SL, Liang KY, Albert PS. Models for longitudinal data: a generalized estimating equation approach. *Biometrics*. 1988;44(4):1049–1060. doi:10.2307/2531734.
48. SAS Institute. *SAS/STAT® 9.2 User's Guide*, Second Edition. Cary, NC: SAS Institute; 2009.
49. Fagerstrom KO, Heatherton TF, Kozlowski LT. Nicotine addiction and its assessment. *Ear Nose Throat J*. 1990;69(11):763–765.
50. Germans MK, Kring AM. Hedonic deficit in anhedonia: support for the role of approach motivation. *Pers Individ Dif*. 2000;28(4):659–672. doi:10.1016/S0191-8869(99)00129-4.
51. Shankman SA, Katz AC, DeLizza AA, Sarapas C, Gorka SM, Campbell ML. The different facets of anhedonia and their associations with different psychopathologies. In: Ritsner MS, ed. *Anhedonia: A Comprehensive Handbook Volume I*. New York, NY: Springer; 2014:3–22.
52. Brinkmann K, Schupbach L, Joye IA, Gendolla GH. Anhedonia and effort mobilization in dysphoria: reduced cardiovascular response to reward and punishment. *Int J Psychophysiol*. 2009;74(3):250–258. doi:10.1016/j.ijpsycho.2009.09.009.
53. Franzen J, Brinkmann K. Blunted cardiovascular reactivity in dysphoria during reward and punishment anticipation. *Int J Psychophysiol*. 2015;95(3):270–277. doi:10.1016/j.ijpsycho.2014.11.007.
54. Leventhal AM, Munafo M, Tidey JW, et al. Anhedonia predicts altered processing of happy faces in abstinent cigarette smokers. *Psychopharmacology*. 2012;222(2):343–351. doi:10.1007/s00213-012-2649-5.