

# Sex differences in the subjective and reinforcing effects of visual and olfactory cigarette smoke stimuli

Kenneth A. Perkins, Debra Gerlach, Josh Vender, James Grobe, Jennifer Meeker, Shari Hutchison

Although nicotine intake clearly reinforces cigarette smoking behavior, non-nicotine smoke stimuli may become conditioned reinforcers of smoking. In Study 1, we compared the acute subjective and reinforcing effects of cigarette smoking in men and women under two conditions: blockade of visual and olfactory/taste smoke stimuli vs. no blockade. Subjective hedonic ratings of 'like puffs' and 'satisfying', but not 'strength', 'high in nicotine', or CO boost, were significantly reduced under the blockade vs. no blockade conditions. During subsequent *ad lib* puffing, significantly fewer puffs were self-administered under the blockade condition, particularly among women. In Study 2, we examined the influences of these stimuli separately and found that olfactory/taste stimuli, but not visual stimuli, reduced hedonic ratings and puff self-administration in women but not in men. In Study 3, procedures similar to those in Study 1 were used to examine whether this sex difference in responses to conditioned stimuli generalizes to a non-drug consummatory behavior, eating (pizza). However, hedonic ratings and *ad lib* consumption of pizza were substantially reduced in both men and women following blockade of visual and olfactory/taste food stimuli. These results indicate that the presumably conditioned stimuli of olfactory/taste from cigarette smoke may influence subjective hedonic ratings and reinforcement from smoking more in women than in men. However, this sex difference may not generalize beyond smoking or other drug reinforcement.

## Introduction

Aside from its delivery of nicotine, cigarette smoking behavior likely is reinforced by non-nicotine, presumably conditioned, stimuli associated with smoking (Rose & Levin, 1991; Rose, Behm, & Levin, 1993; Shahan, Bickel, Madden, & Badger, 1999). For example, denicotinized cigarettes can produce acute subjective and reinforcing effects in smokers that are similar to effects of regular nicotine cigarettes (Butschky, Bailey, Hen-

ningfield, & Pickworth, 1995; Shahan *et al.*, 1999; Westman, Behm, & Rose, 1996a). On the other hand, nicotine administered in novel forms, such as by nasal spray (Perkins, Sexton, Reynolds, Grobe, Fonte, & Stiller, 1994) or intravenous infusion (Westman *et al.*, 1996a), may produce less subjectively pleasurable effects than equal amounts of nicotine via cigarette smoking. Pharmacokinetic and other differences between nicotine administration via smoking vs. novel means may help explain some of these differences in effects, but added reinforcement from the conditioned stimuli that typically accompany nicotine during smoking also may be key. Recent research in neurobiology suggests that conditioned reinforcement may be a stronger influence on cigarette smoking than on other drug dependencies (Balfour, Wright, Benwell, & Birrell, 2000). A few studies have shown modest conditioned responses to novel environmental stimuli paired with smoking

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(Mucha, Pauli, & Angrilli, 1998; Lazev, Herzog, & Brandon, 1999), further suggesting that conditioned stimuli may influence smoking reinforcement.

Nevertheless, the study of reinforcement of human drug use by drug-associated stimuli largely has been ignored by researchers, including those in the smoking field. Only two studies, to our knowledge, specifically blocked peripheral sensory smoking stimuli to determine their effects on subjective responses to smoking. Rose and colleagues (Rose, Tashkin, Ertle, Zinser, & Lafer, 1985) anesthetized the respiratory airway with lidocaine and found reduced subjective smoking 'satisfaction' in six men and two women. Baldinger, Hasenfratz, and Battig (1995) blocked olfactory cues with noseclips and showed reduced taste and enjoyment of smoking in 12 women. Notably, neither study directly assessed smoking reinforcement (i.e., self-administration) to address the very important question of whether changes in these subjective responses are relevant to actual smoking behavior. Demonstration of the influence of non-nicotine stimuli on smoking reinforcement could have important implications for improving smoking cessation treatment (Rose & Levin, 1991). In addition, neither study directly compared results between men and women. Women tend to have greater difficulty than men quitting smoking (Perkins, 1996; Wetter, Kenford, Smith, Fiore, Jorenby, & Baker, 1999). Some of this difficulty could arise from the failure of most treatments to extinguish or otherwise address conditioned reinforcing effects of smoking, which may be greater in women than men (Perkins, Donny, & Caggiula, 1999).

In Study 1, we compared the acute subjective and reinforcing effects of cigarette smoking in men and women under two conditions: blockade of visual and olfactory/taste stimuli vs. no blockade. Blockade of these stimuli was selected because of previous research suggesting that visual smoke stimuli may influence smoking reinforcement (Perkins, Epstein, Grobe, & Fonte, 1994) and that olfactory smoke stimuli may influence subjective responses to smoking (Baldinger *et al.*, 1995). In Study 2, we wanted to determine which of the two types of sensory stimuli was more important in influencing subjective and reinforcing effects of smoking behavior of men and women. Thus, we examined the influence of four blockade conditions: visual stimuli alone, olfactory/taste alone, both, or neither. Finally, because there is no *a priori* reason to think that blockade of these stimuli should specifically influence smoking behavior and not other consummatory behaviors, Study 3 examined whether blockade of visual and olfactory/taste stimuli would similarly influence responses of men and women to a consummatory reinforcer other than smoking, that of food intake.

## Study 1

Study 1 examined the influence of blocking both visual and olfactory/taste smoke stimuli on the subjective and

reinforcing effects of cigarette smoking in men and women.

## Method

**Participants.** Participants in Study 1 were 63 healthy young nicotine-dependent smokers, 32 men and 31 women comparable on age ( $\text{mean} \pm \text{SE} = 25.9 \pm 1.1$  vs.  $23.7 \pm 0.9$ , respectively) and on smoking history characteristics of number of cigarettes per day ( $20.3 \pm 1.2$  vs.  $18.3 \pm 1.0$ ), number of years smoking ( $9.7 \pm 1.2$  vs.  $7.9 \pm 0.9$ ), and Fagerström Test of Nicotine Dependence (FTND) score ( $4.9 \pm 0.4$  vs.  $5.3 \pm 0.3$ ; Heatherston, Kozlowski, Frecker, & Fagerström 1991). They were recruited from flyers posted in the nearby community and from ads placed in a university newspaper.

**Subjective measures.** Subjective responses to smoking were assessed primarily using the Rose Sensory Questionnaire (see Westman *et al.*, 1996a). This questionnaire assesses hedonic ratings of 'like puffs' and 'satisfying', as well as items asking 'how high in nicotine' were the smoke puffs and assessing 'strength' of puffs on the tongue, nose, back of mouth/throat, windpipe, and chest. 'Strength' items were averaged to provide an overall rating of cigarette 'strength'. Each item in the Rose Questionnaire is rated on a 1 ('not at all') to 7 ('extremely') scale. Participants were also asked the following: 'How much would you pay to smoke another of the same type of cigarette the same way?' (in US cents) and 'How similar to your own brand were the puffs?' (rated on a 0–100 visual analog scale, with 0='not at all' and 100='extremely').

**Procedure.** Subjects participated in two sessions following *ad lib* smoking throughout the day prior to each session. Subjects brought an unopened pack of their preferred brand of cigarettes to the first session, and only these cigarettes were presented to subjects for smoking during each session. However, subjects were told that the purpose of the study was to 'test different kinds of cigarettes' and that they might receive their preferred or another brand of cigarettes to smoke.

Upon arrival at each session, subjects first smoked one of their preferred cigarettes *ad lib* (baseline cigarette) and completed the Rose Sensory Questionnaire for that cigarette. They were told that this questionnaire would be administered after each cigarette during the session, and so they should focus on the different items and think about how they will rate each item while they are smoking the particular cigarette. Subjects then rested in the lab for 1 h to ensure equal deprivation from smoking across subjects and between sessions.

Subjects then were instructed to smoke eight puffs on a cigarette ('cig 1'), followed 30 min later by *ad lib* puffing on another cigarette ('cig 2'). Each was a cigarette of their preferred brand, but identifying marks on the cigarettes were covered over to blind subjects to brand. The number of puffs was fixed for cig 1 in order

to gauge subjective responses to a specific amount of smoke exposure between conditions and between men and women. Thus, subjective measures were obtained after the baseline cigarette and cig 1. The number of puffs taken on cig 2 was allowed to be *ad lib* so that this puff self-administration could be used as the measure of smoking reinforcement. However, because the number of puffs from cig 2 was variable and could be confounded with subjective responses, subjective responses to this cigarette were not analyzed. Expired-air carbon monoxide (CO) was obtained after each cigarette and at the end of the 1-h abstinence prior to cig 1 to gauge smoke exposure (i.e., to verify equal exposure after cig 1 and to provide another measure of smoke self-administration during cig 2).

During one of these sessions (sensory 'blockade'), subjects wore light-blocking swimming goggles and noseclips that blocked the nostrils while smoking cig 1 and cig 2 in order to eliminate visual and olfactory/taste stimuli from smoking. (Because taste is highly dependent on olfaction, any blockade of olfaction necessarily reduces ability to taste. Thus, obstruction of olfactory stimuli is viewed here as producing blockade of both olfaction and taste.) During the other session (no blockade), subjects wore very similar but clear goggles and noseclips that did not block the nostrils while smoking cig 1 and cig 2, so that visual and olfactory/taste stimuli from smoking would not be obstructed. This procedure controlled for the impact of the novelty of wearing goggles and noseclips while smoking. Order of blockade vs. no blockade conditions across days was counter-balanced.

Finally, because wearing the light-blocking goggles or obstructive noseclips could non-specifically reduce subjective liking and reinforcement of any reinforcer, such as by increasing feelings of annoyance or discomfort, subjects were also asked to rate the hedonics and perception of short musical pieces. Wearing goggles or noseclips would not be expected to specifically influence subjective responses to auditory stimuli such as music. On each day, subjects listened to two different 90-s interludes from a classical music piece (Beethoven's Sixth symphony, the 'Pastorale') once during baseline rest before cig 1 without any goggles or noseclips and again after cig 2 while wearing the goggles and noseclips designated for that session. After listening to each, subjects rated the music for 'liking', 'pleasant', and 'loudness' on 1–7 scales identical to those used in the Rose Sensory Questionnaire (see Subjective measures, above).

Subjects in all three studies provided informed consent to participate after the nature and consequences of the research were explained. This research was approved by the Institutional Review Board of the University of Pittsburgh.

**Data analysis.** Subjective responses to smoking were analyzed by analyses of variance (ANOVAs) of the responses to cig 1, in which the number of puffs was

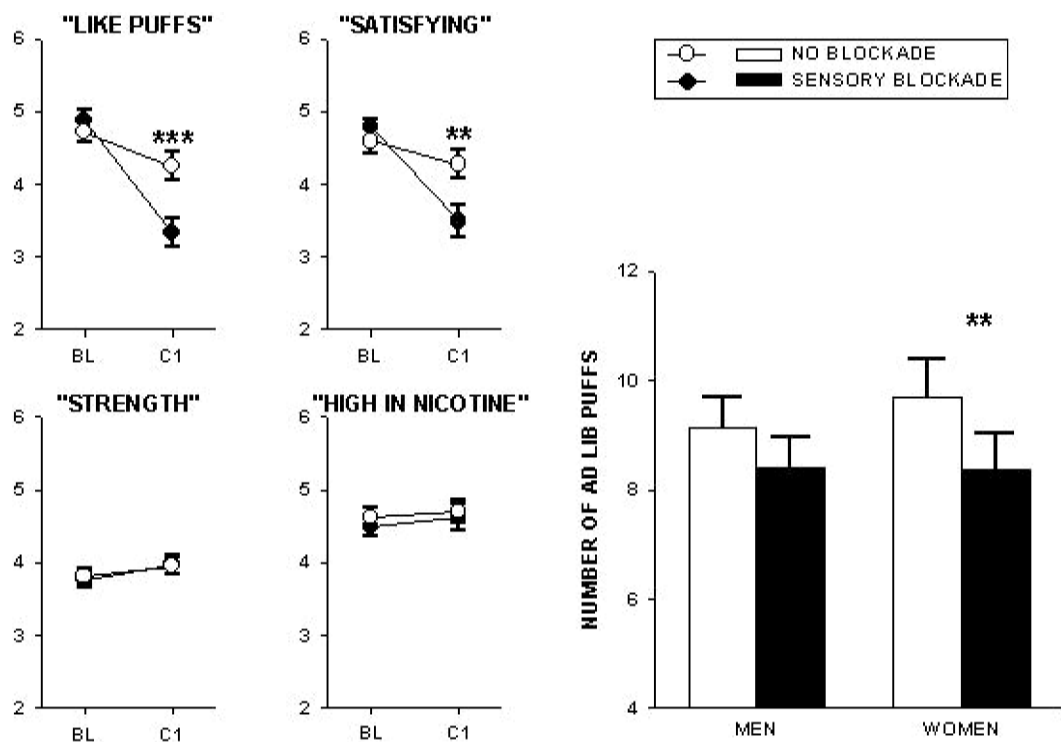
fixed (eight puffs). Sensory condition (blockade vs. no blockade) was the within-subjects factor and subject sex was the between-subjects factor. (Because of the non-normal distribution of amount of money subjects would pay for a cigarette, ANOVA of that measure was done after log-transformation of values.) Music ratings at post-cig 2 were analyzed by similar ANOVAs. The number of *ad lib* puffs on cig 2, the measure of smoking reinforcement, was analyzed by a similar ANOVA. Subjective hedonic ratings for cig 1 ('like puffs', 'satisfying') were related to number of *ad lib* puffs on cig 2 by Pearson correlation. Smoke exposure was analyzed by ANOVA of CO values, with time (three points; following the 1-h abstinence before the session and after cig 1 and cig 2) and sensory condition as within-subjects factors and sex as the between-subjects factor. All follow-up comparisons were made using Fisher's least significant difference (LSD) *t*-test (Huitema, 1980).

## Results

As expected, there were no differences between the two experimental days in subjective measures and CO following the baseline cigarette, prior to the 1-h verified abstinence. Importantly, expired-air CO before and after the eight puffs from cig 1 also was not different between the sensory blockade (from 22.2 to 26.3 ppm) and no blockade (from 23.2 to 27.7 ppm) conditions, nor between men and women. This observation verified that smoke exposure from cig 1 was equal between conditions, and that the blockade manipulation did not interfere with subjects' ability to take in smoke while puffing.

**Subjective responses ('cig 1').** Subjective ratings of 'like puffs' in response to the eight puffs from cig 1 was significantly reduced under the sensory blockade vs. no blockade condition,  $F(1,61)=18.04$ ,  $p<0.001$ , as shown in Figure 1. Virtually identical results were found for 'satisfying',  $F(1,61)=12.87$ ,  $p<0.01$  (see Figure 1). Sensory blockade also significantly lowered the amount of money subjects would pay for another cigarette under those conditions ( $\$0.18\pm0.04$  vs.  $\$0.34\pm0.08$ ;  $F(1,60)=4.15$ ,  $p<0.05$ ) and reduced subjective 'similarity to own brand' ( $50.9\pm3.5$  vs.  $63.9\pm3.1$ ;  $F(1,59)=10.14$ ,  $p<0.01$ ). However, significant main or interaction effects involving subject sex were not observed with any of these measures.

In contrast with these 'hedonic' ratings, sensory blockade had no effects on perceived overall 'strength' or 'nicotine content' of cigarette (see Figure 1). However, not surprisingly (due to the noseclips), the individual item of perceived strength of the cigarette in the nose was significantly reduced by blockade ( $1.7\pm0.2$  vs.  $2.8\pm0.2$ ;  $F(1,61)=10.71$ ,  $p<0.01$ ). Finally, no main or interaction effects of blockade condition or sex were observed on any of the music ratings, indicating specificity of the blockade condition on hedonic ratings of smoking only and no generalized reduction in hedonic value of all stimuli (due to discomfort of goggles and



**Figure 1.** Mean ± SEM subjective hedonic ('like puffs', 'satisfying') and perceptual ('strength', 'high in nicotine') ratings of smoking and *ad lib* puff self-administration (i.e., smoke reinforcement) in Study 1. Subjective measures (left) were obtained at baseline (BL, 1 h before session) and following fixed intake of eight puffs under sensory blockade of visual and olfactory/taste stimuli or no blockade (C1). *Ad lib* puffs (right) were taken 30 min later under the same blockade condition. \*\* $p < 0.01$ ; \*\*\* $p < 0.001$  for differences between blockade conditions.

clips, etc.). For example, 'liking' of music on the 1–7 scale was rated  $4.6 \pm 0.3$  under the blockade condition vs.  $4.6 \pm 0.2$  under the no blockade condition.

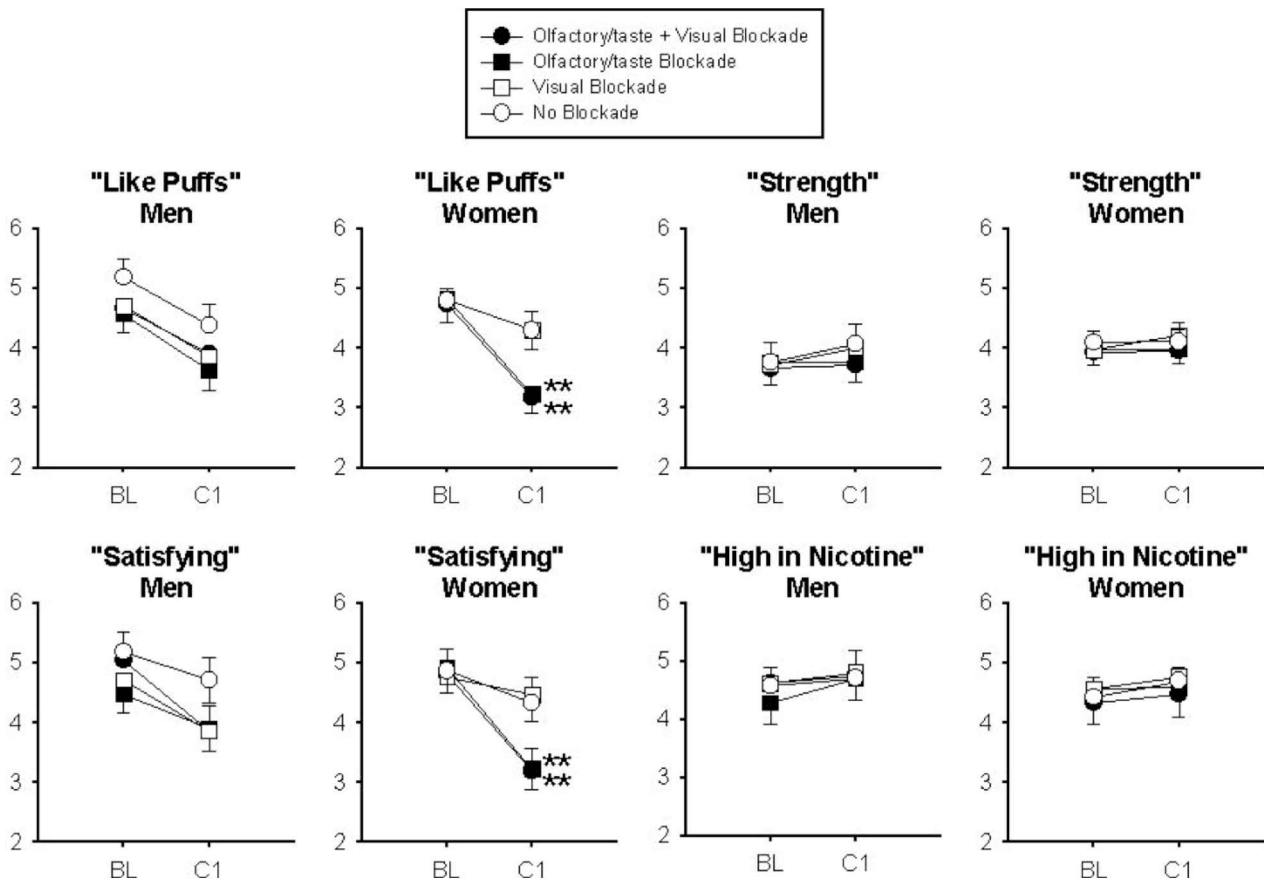
**Smoke self-administration ('cig 2').** During *ad lib* puffing of cig 2, subjects took significantly fewer puffs under the blockade vs. no blockade condition ( $8.4 \pm 0.4$  vs.  $9.4 \pm 0.5$  puffs, respectively;  $F(1,61) = 9.28$ ,  $p < 0.01$ ). Although the interaction of sex by condition was not significant, the decrease in puff number due to sensory blockade was significant in women but not in men, as also shown in Figure 1. Consistent with the reduction in number of *ad lib* puffs from cig 2 due to sensory blockade, the CO boost from cig 1 to cig 2 also was significantly reduced by sensory blockade ( $1.7 \pm 0.3$  vs.  $2.9 \pm 0.3$  ppm,  $F(1,60) = 13.22$ ,  $p = 0.001$ ). Reduced CO boost from cig 2, which was smoked *ad lib*, but not from cig 1 (as noted above), in which a fixed number of puffs was smoked, confirms that subjects self-administered less smoke under sensory blockade and did not compensate by smoking each of the fewer puffs more intensely.

Finally, the number of *ad lib* puffs on cig 2 was significantly correlated with the subjective hedonic ratings to cig 1 of 'like puffs' ( $r = 0.23$ ,  $p < 0.01$ ) and 'satisfying' ( $r = 0.29$ ,  $p = 0.001$ ). Thus, the influence of sensory blockade on smoking reinforcement (*ad lib* puffs) may relate to its attenuation of hedonic ratings of smoking. However, when correlations were done sepa-

rately by sex, *ad lib* puffs on cig 2 were related to cig 1 'like puffs' and 'satisfying' only for women ( $r$  values of 0.31 and 0.36, respectively, both  $p < 0.01$ ) and not men ( $r$  values of 0.12, n.s., and 0.17,  $p < 0.10$ , respectively).

Discussion

Results of Study 1 showed that subjective hedonic ratings ('liking', 'satisfaction', and money they would pay for another cigarette following cig1) and reinforcement (puff self-administration and CO boost following cig 2) from smoking were sharply reduced when smokers were unable to see or smell/taste the cigarette smoke due to blockade of these stimuli. Yet, the perceptual ratings of subjective 'strength' and 'nicotine content' of cigarettes were unaffected by sensory blockade, indicating that the influence of the blockade was specific to the hedonic and reinforcing effects of smoking. Specificity of the sensory blockade's influence was further demonstrated by the absence of blockade effects on hedonics or perception of music. Moreover, expired-air CO following fixed puffing from cig 1 was not different between conditions, ruling out reduced ability to obtain smoke during the blockade condition as an explanation for the reduced hedonic responses to cig 1. These results also suggested that women may be more sensitive than men to blockade of sensory smoke stimuli. Although the interaction of sensory blockade condition and sex was not significant for any dependent measure, exploratory



**Figure 2.** Mean+SEM subjective hedonic and perceptual ratings of smoking under olfactory/taste and/or visual blockade conditions in Study 2, presented separately for men and women. Other details as in Figure 1. \*\* $p < 0.01$  for differences between either olfactory/taste blockade condition vs. the no blockade condition in change from baseline rating.

analyses indicated that the influence of blocking visual and olfactory/taste smoke stimuli on puff self-administration, as well as the relationship between hedonic ratings and puff self-administration, were significant in women but not in men (Figure 1).

## Study 2

Study 2 determined whether the visual or the olfactory/taste stimuli had a greater influence on subjective and reinforcing effects of smoking. Baldinger *et al.* (1995) found that blocking olfactory/taste stimuli alone with noseclips was sufficient to reduce subjective 'enjoyment', suggesting that these stimuli may be more important than visual stimuli as a conditioned reinforcer of smoking. We also sought to determine any sex differences in the influence of these stimuli.

## Method

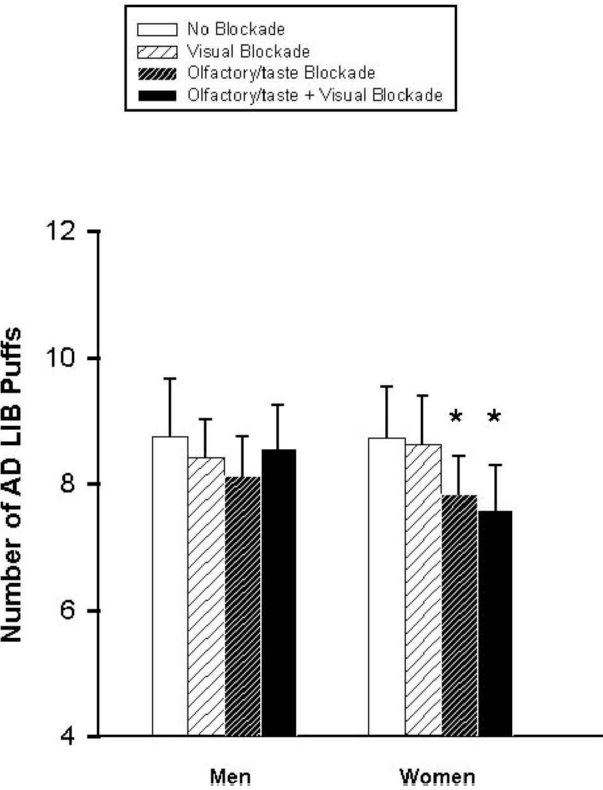
**Participants and procedures.** Participants were 51 healthy young nicotine-dependent smokers recruited in the same manner as those in Study 1. The 21 men and 30 women were comparable on age (mean $\pm$ SE=28.2 $\pm$ 1.7 vs. 25.2 $\pm$ 1.2, respectively) and on smoking history characteristics of number of cigarettes per day (18.1 $\pm$ 1.1 vs.

17.7 $\pm$ 1.2), number of years smoking (10.8 $\pm$ 1.7 vs. 8.9 $\pm$ 1.2), and FTND score (5.1 $\pm$ 0.4 vs. 4.8 $\pm$ 0.5).

Procedures were virtually identical to those of Study 1 but involved independent manipulation of the two types of stimuli in a 2 $\times$ 2 within-subject design. Thus, the four conditions were: blockade of olfactory/taste alone, blockade of visual stimuli alone, blockade of both, no blockade. Subjects participated in four sessions, one for each condition, following *ad lib* smoking throughout the day prior to each session, as in Study 1. Order of the four blockade/no blockade conditions across days was counter-balanced.

## Results

**Subjective responses to 'cig 1'.** Subjective ratings of 'like puffs' in response to the eight puffs from cig 1 was significantly reduced by the main effect of olfactory/taste blockade,  $F(1,49) = 7.79$ ,  $p < 0.01$ , but not by the visual blockade,  $F(1,49) < 1$ . Moreover, as shown in Figure 2, the interaction of olfactory/taste blockade by sex was significant,  $F(1,49) = 7.13$ ,  $p = 0.01$ , as the decline in 'like puffs' due to this blockade condition was greater in women than in men. No other main or interaction effects, including the interaction of olfactory/taste by visual blockade, were significant. Virtually identical results



**Figure 3.** Mean±SEM *ad lib* puff self-administration under olfactory/taste and/or visual blockade conditions in Study 2, presented separately for men and women. \**p*<0.05 for difference between either olfactory/taste blockade condition vs. the no blockade condition.

were found for ‘satisfying’, as significant effects were found for olfactory/taste blockade,  $F(1,49)=12.54$ ,  $p=0.001$ , and the interaction of olfactory/taste blockade by sex,  $F(1,49)=6.21$ ,  $p<0.05$ , but for no other factors. The main effect of olfactory/taste blockade,  $F(1,47)=6.35$ ,  $p<0.05$ , and its interaction with sex,  $F(1,47)=4.05$ ,  $p=0.05$ , were also significant for ratings of ‘similarity with own brand’, as this blockade condition lowered ratings more in women ( $45.0\pm5.3$  vs.  $61.7\pm4.8$  under the no olfactory/taste blockade conditions) than in men ( $50.9\pm6.9$  vs.  $52.7\pm7.4$ ). No effects were significant for amount they would pay for another cigarette. As in Study 1, neither blockade condition had any effects on perceived overall ‘strength’ or ‘nicotine content’ of cigarette (Figure 2). Blockade conditions also had no effect on ratings of the music.

**Puff self-administration from ‘cig 2’.** As with the subjective hedonic ratings of cig 1, *ad lib* puffing of cig 2 was significantly reduced by blockade of olfactory/taste,  $F(1,49)=7.86$ ,  $p<0.01$ , but not visual stimuli,  $F(1,49)<1$ . The interaction of sex by olfactory/taste blockade approached significance,  $F(1,49)=2.87$ ,  $p<0.10$ . As in Study 1, exploratory comparisons showed that *ad lib* puffing was significantly reduced by the olfactory/taste blockade conditions in women but not in men, as shown in Figure 3. No other main or interaction effects on *ad lib* puffing were significant. A similar

interaction of olfactory/taste blockade with sex was seen for expired-air CO boost following the *ad lib* puffs,  $F(1,45)=9.84$ ,  $p<0.01$ . CO boost was reduced by olfactory/taste blockade in women (1.8 vs. 3.0 ppm) but not in men (2.7 vs. 2.8 ppm), consistent with the results for *ad lib* puffs. The hedonic ratings of ‘like puffs’ and ‘satisfying’ of cig 1 were each significantly correlated with *ad lib* puffs on cig 2 (*r* values of 0.28 and 0.29, respectively, both  $p<0.01$ ). Unlike in Study 1, these correlations were significant for both men and women.

Discussion

Results of Study 2 showed that blockade of olfactory/taste, but not visual, stimuli reduced subjective hedonic ratings (‘like puffs’, ‘satisfying’) and reinforcement (puff self-administration) from smoking. Furthermore, interactions involving sex indicated that this blockade tended to influence smoking hedonics and reinforcement in women more than in men. Therefore, the olfactory/taste stimuli that typically accompany nicotine intake via cigarette smoking may provide conditioned reinforcement of smoking behavior in women, but less so in men. Visual stimuli accompanying smoking may not be a source of conditioned reinforcement in women or men, at least under the procedures of this study.

Study 3

Among the questions this research now raises is the degree to which these sex differences generalize across other consummatory behaviors. Drug consumption may share some key characteristics with food intake and other consummatory behaviors (Wise, 1997), including the degree to which they are influenced by conditioned stimuli. Food intake can be influenced by ‘non-metabolic’ and perhaps conditioned factors, such as the appearance and taste or smell of the food (Cornell, Rodin, & Weingarten, 1989; Fedoroff, Polivy, & Herman, 1997; Jansen & van den Hout, 1991; Maes & Vossen, 1993). Men and women may differ in the degree to which these non-metabolic factors influence food consumption (Guarino, Fridrich, & Sitton, 1994; Rolls, Fedoroff, & Guthrie, 1991; Zylan, 1996).

Study 3 examined whether removal of visual and taste/olfactory food stimuli would reduce subjective and reinforcing (*ad lib* consumption) effects of food, and whether these effects would differ between men and women. Methods were designed to be as similar as possible to Study 1.

Method

**Participants.** Participants were healthy young men and women ( $n=10$  each) comparable in age (mean±SE=21.6±0.7 vs. 20.2±0.5, respectively) and body mass index (BMI; 23.8±0.8 vs. 23.5±0.9, respectively). Men and women also did not differ in scores on the Three-Factor Eating Questionnaire (TFEQ; Stunkard

& Messick, 1985) scales of hunger ( $17.7 \pm 0.5$  vs.  $17.4 \pm 0.7$ ), disinhibition ( $22.0 \pm 0.7$  vs.  $20.7 \pm 0.4$ ), and restraint ( $20.7 \pm 0.5$  vs.  $20.2 \pm 0.8$ ). Participants were recruited from flyers posted in the nearby university community. They were first screened by telephone for health problems, medications, or psychiatric problems that might influence appetite or taste. Exclusionary criteria included obesity ( $\text{BMI} > 30$ ), tobacco dependence (to eliminate the influence of recent smoking or abstinence from smoking on eating), other drug dependence, and treatment within the past year for depression, anxiety, or an eating disorder. Participants also had to indicate a liking of cheese pizza, the food used in this study, by rating it at 7 or higher on a 0–10 scale (0 = 'not at all liked'; 10 = 'extremely liked'), and had to report eating pizza at least once a month.

**Subjective measures.** Subjective responses to pizza were assessed using a series of seven-point Likert scale items adapted from the Rose Sensory Questionnaire used to assess subjective responses to cigarette smoking in Studies 1 and 2. Items were anchored by 1 ('not at all') and 7 ('extremely') and included: 'liking', 'tasty', 'crispy', 'greasy'. The first two items were designed to assess the hedonics and taste of pizza intake, which we hypothesized would be reduced by blocking the visual and olfactory/taste food stimuli. The last two items were designed to assess the non-hedonic 'perceptual' characteristics of the pizza, which we hypothesized would not be affected by blocking these stimuli. Subjects also indicated how much money (in US cents) they would pay for another portion (two small pieces) of the pizza.

**Procedure.** Overview. Participants attended two sessions differing in the sensory 'blockade' condition administered during assessment of the subjective and reinforcing effects of food. Each session involved initial taste and rating of pizza under normal conditions (baseline ratings following no manipulation), then again under the sensory blockade condition assigned for that session (blockade of visual and olfactory/taste vs. no blockade). Subjects then consumed pieces of pizza *ad lib* under the same blockade condition. The primary comparisons were differences in subjective ratings and amount of pizza intake between the blockade and no blockade conditions. The order of blockade vs. no blockade conditions was counter-balanced between participants.

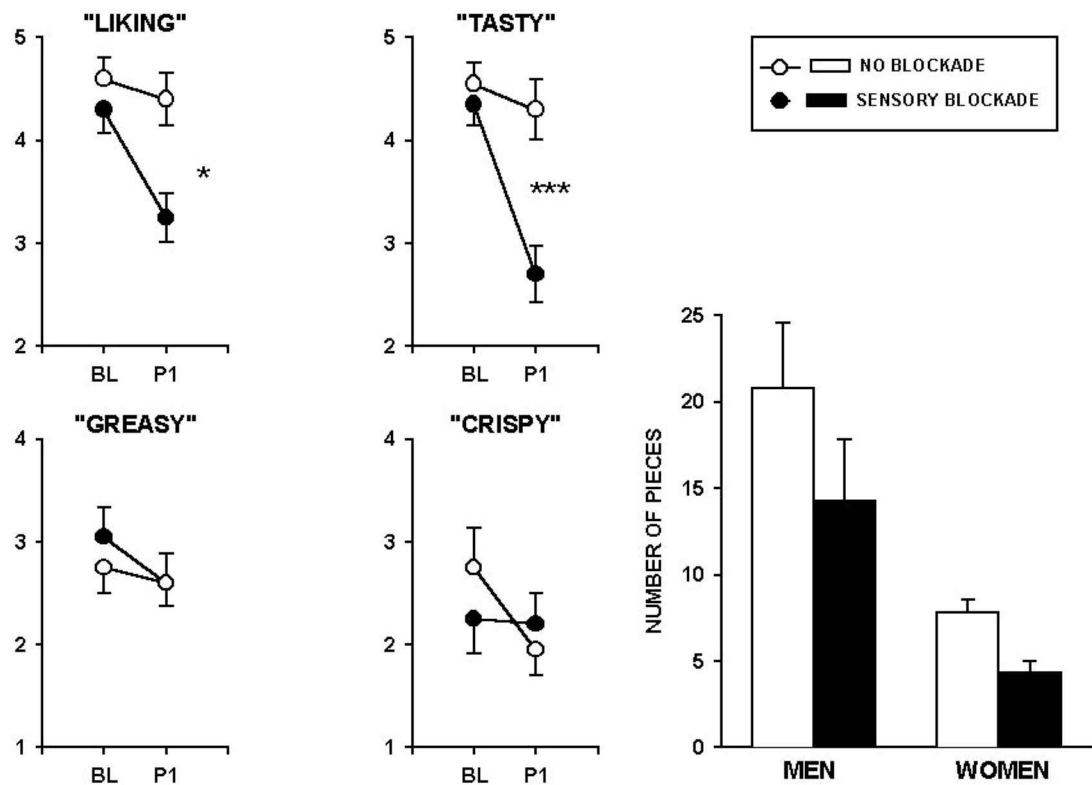
**Specific procedures.** Participants were instructed to abstain from food for 4 h before each session. The study was described as a taste test of different brands of snacks, including pizza. They were told that they would be given a variety of brands of pizza to taste and rate for hedonic and sensory characteristics and would be able to consume as much as they want at the end of the session. On each session, participants received two  $1 \times 1.5$ " pieces of Stouffer's French bread cheese pizza (Nestle USA-Food Group Inc, Solon OH; approximately 10.5 g or 26 kcals per piece). Pizza was heated by microwave oven

before presentation. Participants were instructed to eat and then rate (baseline rating) the pizza for hedonics ('liking', 'tasty') and perceptual characteristics ('greasy', 'crispy'), as well as the other subjective measures (how much they would pay for another portion of two pieces, etc.).

Participants were then introduced to the goggles and noseclips corresponding to the blockade condition assigned for their session (blockade vs. no blockade). Subjects were told that these procedures were designed to blind them to the external characteristics (appearance and smell) of known brands of pizza. While wearing the goggles and noseclips for the assigned blockade condition, subjects consumed another portion of two  $1 \times 1.5$ " pieces of pizza (post-blockade rating). Immediately after finishing the pieces, they completed the subjective Likert measures orally while still wearing the goggles and noseclips. Subjects rested quietly for 15 min without goggles and noseclips before putting them back on prior to the opportunity to consume *ad lib* as many  $1 \times 1.5$ " pieces of pizza as they wished. This *ad lib* consumption was used as the measure of the reinforcing value of pizza under the blockade condition. A plate with 15 pieces, each  $1 \times 1.5$ ", was put in front of the participant. The weight of pizza consumed was determined by the difference in weight of the plate before and after consumption. If all 15 pieces were consumed, an additional eight pieces were prepared and presented to the participant (and eight more if those eight were consumed). The *ad lib* consumption period ended when participants had eaten to satiety, defined as verbal report of not wanting to eat any more despite the presence of at least one pizza piece on the plate in front of them. Because Studies 1 and 2 showed no non-specific effects of the goggles and noseclips, as determined by hedonic and perceptual ratings of music, music ratings were not obtained in Study 3.

## Results

**Subjective responses to pizza.** As expected, there was no difference in any subjective response to the first pieces of pizza at baseline, under normal conditions (i.e., no goggles or noseclips). Subjective 'liking' of pizza was significantly reduced under the sensory blockade vs. no blockade condition (i.e., rating period by condition interaction;  $F(1,18) = 5.41$ ,  $p < 0.05$ ), as shown in Figure 4. Virtually identical results were found for 'tasty',  $F(1,18) = 15.01$ ,  $p < 0.001$ . Sensory blockade also significantly lowered the amount of money subjects would pay to eat another portion of pizza under that blockade condition ( $\$0.31 \pm 0.08$  vs.  $\$0.54 \pm 0.14$ ;  $F(1,18) = 7.10$ ,  $p < 0.05$ ). However, significant interaction effects of blockade condition by subject sex were not observed with any of these measures, contrary to expectations. No significant results were observed for 'greasy' or 'crispy' (Figure 1), the non-hedonic 'perceptual' responses to pizza consumption, suggesting that the blockade manipulation was specific to hedonics of food intake.



**Figure 4.** Mean(±SEM) subjective hedonic ('liking', 'tasty') and perceptual ('crispy', 'greasy') ratings of pizza and *ad lib* pizza intake (i.e., food reinforcement) in Study 3. Subjective measures (left) were obtained at baseline (BL) and 15 min later under sensory blockade of visual and olfactory/taste stimuli or no blockade (P1). *Ad lib* intake (right), 15 min after P1, was significantly and equally reduced due to blockade in both men and women (see text). \* $p<0.05$ ; \*\*\* $p<0.001$  for difference between blockade conditions in change from baseline rating.

**Food reinforcement.** During subsequent *ad lib* consumption of the pizza pieces, subjects ate significantly fewer pieces under the blockade vs. no blockade condition,  $F(1,18)=17.38$ ,  $p<0.001$ . As with subjective hedonic ratings, the interaction of sex by condition was not significant,  $F(1,18)=1.63$ ,  $p>0.20$ , suggesting equal reduction in pizza consumption between men and women, as also shown in Figure 4. However, women ate significantly fewer pieces overall than did men (i.e., main effect of sex),  $F(1,18)=10.23$ ,  $p<0.01$ . Similar to the previous studies, the subjective hedonic ratings of 'liking' and 'tasty' of the first pizza pieces were significantly correlated with subsequent *ad lib* consumption of pizza ( $r$  values of 0.34 and 0.36, respectively, both  $p<0.02$ ). Correlations were similar and significant for both men and women.

Discussion

As in Studies 1 and 2 with smoking, results of Study 3 showed that subjective hedonic ratings ('liking', 'tasty') and reinforcement (*ad lib* pizza consumption) of food intake were sharply reduced when participants were unable to see or smell/taste the pizza due to blockade of these stimuli. The non-hedonic, perceptual ratings of subjective 'crispy' and 'greasy' of pizza were unaffected by sensory blockade, indicating that the influence of the

blockade was specific to the hedonic and reinforcing effects of food intake.

However, there was no difference between men and women in the effects of sensory blockade on subjective and reinforcing effects of food consumption, contrary to Study 2 results with smoking and to the trend for greater effects of blockade on smoking reinforcement in women in Study 1. Therefore, sex differences in conditioned reinforcement of consummatory behavior may be specific to smoking or drugs of abuse and not generalizable across all such behavior. Alternatively, sex differences in conditioned food reinforcement may be observed with foods other than pizza, which was used here because of its popularity with young adults and because of its use in similar research (e.g., Cornell *et al.*, 1991). Olfactory/taste, and perhaps visual, stimuli may be much more important conditioned reinforcers for pizza, in which these stimuli are quite salient, compared to foods where these stimuli may be more subtle. Moreover, more substantial influences of conditioned food stimuli may be seen in women high in dietary restraint characteristics (Fedoroff *et al.*, 1997; Jansen & van den Hout, 1991), rather than in women in general. Only women and men with normal eating patterns (i.e., normal TFEQ scores) were included here to rule out factors other than subject sex as explanations for any differences between men and women. Finally, the smaller sample size in Study 3,



relative to Studies 1 and 2, may not have been sufficient to provide statistical power to observe an interaction involving subject sex. However, we saw absolutely no trend for such an interaction (Figure 4), suggesting that even very large samples would result in a similar finding.

## General discussion

Studies 1 and 2 showed that subjective hedonic and reinforcing effects of smoking behavior are influenced by olfactory/taste stimuli, but not visual stimuli, particularly in women. The pattern of our subjective results is very consistent with work by Rose *et al.* (1985), showing that local anesthesia of the respiratory airway reduced the hedonic rating of smoking 'satisfaction' but not the perceptual ratings of 'strength' or 'harshness'. Similarly, Baldinger *et al.* (1995) found reduced ratings of 'taste' and 'enjoyment' after smoking with vs. without nose-clips that blocked olfactory cues. The current studies extend those findings by examining the separate and combined influences of visual and olfactory/taste stimuli on the reinforcing, as well as subjective, effects of smoking and by directly comparing the influence of these smoke stimuli between men and women.

These results suggest the need for more research on sex differences in the influence of conditioned reinforcers of smoking. Although the interaction of sensory blockade condition and sex was not significant for *ad lib* puff self-administration in either study, exploratory analyses suggested that the influence of olfactory/taste stimuli on puff self-administration was significant in women but not in men. Subjective hedonic ratings of smoking also were reduced by olfactory/taste blockade in women but not in men in Study 2. These observations are consistent with other evidence that non-nicotine, perhaps conditioned, smoke stimuli are more reinforcing in women than in men (Perkins *et al.*, 1999; see also Eissenberg, Adams, Riggins, & Likness, 1999). Because cocaine research has shown that women exhibit greater subjective responses than men to drug-paired environmental stimuli (Robbins, Ehrman, Childress, & O'Brien, 1999), differences between men and women in the degree to which conditioned stimuli may reinforce smoking behavior could generalize to factors that reinforce other psychoactive drug use. However, any such differences are unlikely to generalize to consummatory behaviors other than drug use, such as food intake, based on the results of Study 3.

Although it is possible that the olfactory/taste smoke stimuli examined here may have unconditioned reinforcing effects, their influence on subjective and reinforcing effects of smoking more likely reflect conditioned responses to these stimuli, which accompany nicotine intake during each instance of cigarette smoking (Rose & Levin, 1991). Because the typical smoker of a pack per day smokes more than 7000 cigarettes per year, the pairing of olfactory/taste smoke stimuli with nicotine intake is certainly one of the most common conditioned

associations between stimuli experienced by humans. Thus, the possibility of robust conditioned effects of these stimuli on responses to smoking should not be surprising.

In addition, it is interesting to note that 'similarity to own brand' ratings were rather low in both studies when olfactory/taste stimuli were blocked; mean ratings were at or just below 50, the midpoint of the scale. Recognition that the cigarette indeed was their own preferred brand was poor even though we did not provide instructions that would create strong expectations of receiving novel brand cigarettes. (Subjects brought their own cigarettes to the session and were merely told they might receive their own or another brand.) Even under the no blockade conditions of Studies 1 and 2, where only the brand markings were covered and the taste and smell of the smoke were unaltered, 'similarity' ratings were well below the top of the scale (means of 63.9 in Study 1 and 59.6 in Study 2). Smokers therefore appear to be rather poor at identifying their own brand of cigarettes when peripheral sensory characteristics, or even merely the brand markings, of the cigarette are removed. Thus, while the visual stimuli examined here (sight of smoke from unmarked cigarette) did not influence responses to smoking, other visual stimuli, such as brand markings and packaging, may be important conditioned reinforcers of smoking behavior. Aside from visual and olfactory/taste smoke stimuli, many other non-nicotine stimuli may provide conditioned reinforcement of smoking behavior. For example, 'hand-mouth' activity (i.e., sensorimotor stimulation), menthol flavoring, and airway sensations may serve as conditioned reinforcers for some smokers (Rose *et al.*, 1985; Sidney, Tekawa, & Friedman, 1989; Parrott & Craig, 1995). Furthermore, environmental contexts and other drug consumption commonly associated with smoking also may serve as conditioned reinforcers of smoking behavior, such as socializing with smoking friends or consuming alcohol or caffeine (Burger & Gochfield, 1989; Zavela, Barnett, Smedi, Istvan, & Matarazzo, 1990). Greater investigation of these potentially conditioned reinforcing stimuli could substantially improve our understanding of factors that promote persistent smoking behavior in the face of its serious health risks, particularly in women.

Similarly, the findings from this study suggest that interventions to help smokers quit smoking may benefit from greater focus on extinguishing conditioned reinforcing effects of non-nicotine smoke stimuli. This approach could be particularly beneficial for women smokers, who tend to have less success in quitting smoking, as previously noted. Alternatively, given the likely difficulty of extinguishing strongly conditioned responses in humans, development of sensory substitutes (e.g., Sayette & Parrott, 1999; Westman, Behm, & Rose, 1996b) may be a more practical strategy for addressing conditioned reinforcement from non-nicotine smoke stimuli during a quit attempt. For example, Sayette and Parrott (1999) recently showed that sniffing either a pleasant or unpleasant, but not a neutral, odor in the

presence of smoking cues (holding a lit cigarette) reduced self-reported urge to smoke. In addition to implications for treatment, the possibility of a strong role for sensory smoke stimuli in promoting onset of smoking behavior in teens (particularly girls) warrants some research attention. Identification of such an influence could assist in the development of improved smoking prevention efforts.

## Acknowledgments

This research was supported by Grants DA08578 and DA12655 from the National Institute on Drug Abuse. The research was also conducted in part at the Obesity/Nutrition Research Center of the University of Pittsburgh. The authors thank Michelle Broge, Kris Barnett, and Jacquelyn Ashcom for their assistance.

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