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Alcohol Consumption, Smoking Urge and the Reinforcing Effects of Cigarettes: An Ecological Study

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Abstract

Smokers (N=74) who volunteered for a smoking cessation study monitored their daily experiences for up to 6 weeks prior to the quit date. Self-reports from 7,707 diary records were used to examine the associations among alcohol consumption (present in 607 diary records), situational factors, smoking, urge to smoke, and subjective consequences of smoking. Alcohol use, smoking urge, and the subjective effects of smoking were context-dependent. Momentary reports of smoking and alcohol consumption were associated with one another. Alcohol use predicted smoking even when contextual factors were covaried. Alcohol use was associated with more frequent reports of urge to smoke. Alcohol was also associated with more frequent reports that the last cigarette produced a rush/buzz, was good tasting, and reduced the urge. However, effects for rush/buzz and urge reduction were qualified by interactions between alcohol use and the latency since smoking. Rush/buzz tended to be associated with alcohol use, regardless of smoking recency. Alcohol was associated with urge reduction only when the cigarette being appraised was smoked more than 15 minutes prior to the diary entry.

Keywords

alcohol; cigarettes; electronic diary; urge/craving; subjective reinforcement

Alcohol consumption cues smoking. In laboratory investigations, smokers administered alcohol tend to increase smoking rate (cf. Griffiths, Bigelow, & Liebson, 1976;

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Henningfield, Chait & Griffiths, 1984; Mello, Mendelson, & Palmieri, 1987; Mintz, Boyd, Rose, Charavastra, & Jarvik, 1985; Mitchell, De Wit, & Zacny, 1995; Rose, Brauer, Behm, Cramblett, Calkins, & Lawhon, 2004). This cuing effect is also evident in smokers' natural environments; momentary associations between drinking and smoking have been found in ambulatory studies (Delfino, Jamner, & Whalen, 2001; Shapiro, Jamner, Davydov, & James, 2002; Shiffman, Fischer, Paty, Gnys, Hickcox, & Kassel, 1994; Shiffman, et al., 2002).

Several mechanisms have been suggested to account for the tendency for smoking to increase under the influence of alcohol (Little, 2000; Perkins, 1997; Rose, et al., 2004; Shiffman, et al., 1994; Zacny, 1990). One possibility is that cigarettes are used to offset the sedating effects of alcohol. Conversely, alcohol might reduce aversive effects of smoking such as excessive arousal or airway irritation. If smoking is habitually restrained, the disinhibiting effects of alcohol might lead to increased smoking via weakened self-regulation. Acute cross-tolerance or alcohol-related changes in the metabolic clearance of nicotine could provoke compensatory smoking escalation. Associative learning may play a role. Both drinking and smoking are subject to numerous formal and informal social controls. Contexts in which drinking is permitted (e.g., private residences, taverns) also tend to permit smoking. With repeated pairings, exteroceptive and interoceptive drinking cues might come to serve as conditioned stimuli capable of prompting urges to smoke. Disruption of cognitive resources by alcohol might lead to disproportionate focusing of attention on smoking cues (Steele & Josephs, 1990; Sayette, Martin, Wertz, Perrott, & Peters, 2005). Finally, alcohol consumption might enhance the subjective reinforcing effects of cigarettes, promoting co-use by making cigarettes more rewarding or desirable. These mechanisms could operate in concert to promote the cuing of smoking by alcohol (Shiffman & Balabanis, 1995).

Existing research most consistently supports the notion that alcohol affects cigarette-related incentive motivation. In laboratory studies, alcohol administration increases urge to smoke (Burton & Tiffany, 1997; King & Epstein, 2005; Kouri, McCarthy, Faust, & Lukas, 2004; McKee, Krishnan-Sarin, Shi, Mase, & O'Malley, 2006; Sayette, et al., 2005). Urge enhancement is most evident during the ascending limb of the blood alcohol curve (BAC), when the hedonic effects of alcohol are predominantly positive (Epstein, Sher, Young & King, 2007; King & Epstein, 2005; Kouri, et al., 2004). The association between alcohol and smoking urge is partially mediated by positively-valenced subjective intoxication effects (Epstein, et al., 2007). Notably, the ability of alcohol to increase smoking rate is limited to the first hour after drinking, a period that contains the ascending BAC limb (Mitchell, et al., 1995). Together, these observations suggest the cuing of smoking by alcohol may be more influenced by incentive processes than by a desire to counteract the sedating effects of alcohol (prominent on the falling BAC limb). Alcohol administration is also associated with increases in expectations of positive reinforcement from smoking (Kirchner & Sayette, 2007). Indeed, the subjective consequences of smoking are more hedonically positive when drinking. In laboratory studies, cigarettes smoked after alcohol have been rated as more satisfying, liked, and calming (Glautier, et al., 1996; Rose, et al., 2004).

The bulk of the evidence concerning the cuing of smoking and enhancement of smoking incentive motivation by alcohol has been derived from laboratory-based alcohol challenge

designs. The chief virtue of laboratory designs is the experimental control they afford, and these studies have permitted strong causal inferences regarding the role of alcohol in smoking promotion. However, the generalizability and descriptive value of effects seen in the laboratory are uncertain. Laboratories are novel contexts and often involve unusual drug-related manipulations (e.g., speeded consumption of a non-preferred beverage, drinking alone at an unusual time of day, smoking research cigarettes, limited cigarette availability). Contextual factors may affect reactions to both alcohol (e.g., Sher, 1985) and tobacco (Perkins, Sayette, Conklin, & Caggiula, 2003).

Field studies are vital complements to laboratory investigations of alcohol and tobacco coadministration (Istvan & Matarazzo, 1984; Perkins, 1997). When moving from the laboratory to the field, experimental control is surrendered and causal inference is weakened. However, participants assume much of the control ceded by the investigator, enhancing ecological validity. In everyday life, smokers select (within naturally prevailing constraints) the doses of alcohol and tobacco they consume, the timing of consumption, the company they keep, and the physical locations in which consumption occurs. Subjective states assessed in users' natural environments therefore reflect the impact of potent environmental cue complexes and fluctuating baseline states, factors not easily reproduced in the laboratory (Perkins, 1997). Assessments of attained states in users' ecological niches describe the typical effects of alcohol and tobacco use. Because these are the effects that presumably account for the well-known associations between drinking and smoking, it is important to determine the degree to which they articulate with laboratory findings.

It has long been recognized that observational and experimental research techniques are mutually enriching (e.g., Cronbach, 1957). Important advancements in research and theory on addictive behaviors may result from an iterative empirical strategy involving both ecological techniques and conventional laboratory approaches. Laboratory studies might be used to document, with experimental rigor and strong inference, the existence of theoretically important phenomena in substance use. Ecological techniques might then be used to assess whether these processes are evident in the natural course of drug user's daily affairs. Correspondence between the two sets of findings should bolster confidence in both the theoretical assertion and the original laboratory protocol. Divergent findings would raise a more complicated set of issues, but scrutinizing the various possibilities may prove generative. For example, the artificiality of the laboratory environment might spuriously produce an effect that, while congruent with theory, has little apparent relevance in the "real world." If this cannot be discounted, revision of the generating theory may be required. Another, perhaps more likely outcome is that ecological data – which capture variations in states and circumstances deliberately constrained by experimental designs – facilitate identification of novel correlates, moderators, or boundary conditions that expand or qualify the working understanding of a laboratory phenomenon. Such observations may refine theory and generate hypotheses worthy of more rigorous examination under laboratory conditions.

In this study, we examined associations among alcohol consumption, smoking, urge and subjective reinforcement from cigarettes using field data from smokers who monitored their daily experiences for up to 6 weeks prior to making a quit attempt. Smokers were prompted

four times per day to complete assessments that included items tapping recent smoking, alcohol consumption, urge to smoke, ratings of the last cigarette smoked, and a variety of situational descriptors.

An important preliminary question was whether ratings of the subjective reinforcing effects of the last cigarette were context-sensitive. Smoking behavior and craving to smoke have been extensively studied using ecological techniques (Shapiro, et al., 2002; Shiffman, et al., 1997; Shiffman, et al., 2002; Shiffman & Paty, 2006), but remarkably little empirical data speak to relations between the subjective reinforcing effects of cigarettes and features of smokers' natural environments. We expected subjective reinforcing effects of tobacco would vary across settings, a finding that would underscore the unique value of assessing alcohol effects in ecological context.

Based upon prior diary research (Shiffman, et al., 1994), we expected alcohol consumption itself would be strongly related to contextual factors, such as time and day, physical location, and social contacts. On the basis of prior laboratory research and field research, we expected reports of alcohol consumption would be univariately associated with cigarette use, urge to smoke and more hedonically positive ratings of cigarette effects. We also tested more stringent multivariate models assessing whether any associations between alcohol and smoking, urge, or subjective effects could be accounted for by correlated contextual factors. Because laboratory findings have suggested the pharmacologic effects of alcohol are causally related to smoking and smoking motivation, we expected unique effects of alcohol consumption in these domains, even when adjusting for contextual factors. In this study, smokers always rated the reinforcing effects of the last cigarette smoked, but smoking had not always occurred in close proximity to prompted diary recordings (smoking-contingent recording was not a feature of the design). Because drug effects change across time, and because alcohol consumption has been shown to acutely alter smoking outcome expectancies in the context of mild smoking deprivation (Kirchner & Sayette, 2007), we also tested whether the recency of smoking moderated the effects of alcohol on cigarette appraisals.

Method

Participants.

Ninety adult smokers (15 cigarettes per day at screening) were recruited through print advertisements and waiting lists for a smoking cessation study involving active or placebo nicotine patches and individual counseling. Candidates were excluded if screening assessments revealed significant psychopathology or cardiovascular disease, use of non-study cessation medication, or use of psychoactive prescription medication. Females were ineligible if they were pregnant, planning to become pregnant, or breastfeeding during the study period. Study medication was free. Participants could receive up to \$250 for completing the study: \$10 was paid for attending each of 15 study visits, \$25 was paid for providing a breath carbon monoxide sample at a follow-up 3 months after the quit date, and a \$75 bonus was paid for returning the study diary. Compensation was not directly tied to the quality or quantity of diary assessments, but diary performance was reviewed at the compensated study visits during the recording period.

Of the 90 eligible volunteers, 14 withdrew before being issued a diary. Two additional participants withdrew from the study prior to the completion of a 1-week diary training phase, leaving 74 smokers with analyzable diary data from the pre-quit period. Thirty-eight (51.4%) were male and 67 (90.5%) were White. The mean age was 40.9 (range: 20-73). At baseline, they reported smoking an average of 24.2 cigarettes per day (range: 12-60) and having smoked an average of 23.4 years (range: 5.8-60.2). The mean score on the Fagerstrom Test for Nicotine Dependence (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991) was 5.77 (range: 1-10).

Electronic Diary.

Electronic diaries were implemented on personal digital assistants (PDAs; Palm IIIe, Palm, Inc., Sunnyvale, CA) equipped with commercially-available database software (Pendragon Forms, Pendragon Software, Libertyville, IL). The interview software automatically recorded a time and date stamp for each interview administered. Participants could not review or edit completed interviews. Signaling was controlled using the PDA's calendar software. Alarms audibly prompted participants to complete an interview 4 times per day. The first prompt was scheduled to correspond with participants' self-reported typical waking time. The second prompt was randomly scheduled between wake-up and midday. The third prompt occurred at a random time between midday and one hour prior to participant's self reported typical bedtime. The final prompt was scheduled to occur at the typical bedtime. The interviews were persistently available (i.e., they did not time out if not begun immediately after the alarm sounded).

Procedure.

The present analyses focus on prequit assessments only; to conserve space, we do not describe treatment procedures or post-quit assessments here (see McCarthy, Piasecki, Fiore, & Baker, 2006, for greater detail). Participants received individual training in the use of the electronic diary. They were then issued a diary and asked to record their daily experiences for 10 weeks. The first week of diary recording was a training phase during which participants were encouraged to familiarize themselves with the use of the diary. Data collected during this phase were not analyzed.

The duration of prequit monitoring was varied across participants. Some smokers (51 of the original 90 volunteers; 57%) were assigned to a late quit date; they were asked to make diary entries prior to quitting for 7 weeks (including training phase) and carried the diaries during the first 3 weeks of the quit attempt. The remainder (n=39; 43%) were assigned a quit date after 4 weeks of diary monitoring (including training phase) and were asked to carry the diaries during the first 6 weeks of the quit attempt. Of the 74 participants included in the present analyses, 41 (55.4%) were assigned to a late quit date.

During the prequit period, participants visited the lab once per week to complete paper-pencil assessments and to upload diary data. At these visits, study staff reviewed diary recording performance, fielded technical questions, and encouraged compliance with the diary recording.

Participants were instructed to complete data entry when the diary alarm fired. They were also instructed to initiate diary recordings if they experienced a significant stressful event. User-initiated recordings were rare during the prequit phase ($n = 159$, 2.0% of all prequit records from the analyzed sample); for this reason and to avoid biasing estimates of alcohol effects by oversampling stressful moments, analyses were restricted to data reported during prompted assessments.

These 74 smokers completed a total of 7,940 prompted interviews during the prequit period. This represents an 82.2% response rate ($41 \text{ late quitters} \times 42 \text{ prequit days} \times 4 \text{ prompts per day} = 6,888 \text{ possible interviews}$; $33 \text{ early quitters} \times 21 \text{ prequit days} \times 4 \text{ prompts per day} = 2,772 \text{ possible interviews}$; total = 9,660). We discarded 233 diary records (2.9%) from 60 participants because they were completed within 30 minutes of a previous assessment (mean number of affected records per participant = 3.1, range: 0 to 28). This left 7,707 diary records for analysis. In the final sample, participants contributed an average of 104 entries (range: 9-167; median = 86).

Measures

Alcohol Consumption.

One item in the diary assessment stated “Check any of the following that you have consumed in the last hour” and was followed by a checklist with these response options: (a) coffee, (b) other caffeine beverage, (c) decaf coffee, (c) other non-caffeine beverage, (d) alcohol, (e) other intoxicating substance. The alcohol response option was recoded into a dichotomous variable (1 = past hour consumption endorsed, 0 = no consumption reported).

Urge and Cigarette Effects.

Urge to smoke was assessed in each diary interview with an item that asked “Have you had a strong temptation/urge to smoke in the last 15 minutes?” For analysis, responses of “yes” were coded as 1 and “no” were coded as 0.

Each diary interview contained an item that asked “What was your most recent cigarette like? (check all that apply)” followed by a checklist with these response options: (a) good tasting, (b) a rush/buzz (c) relaxing, (d) reduced the urge, (e) pleasant, (f) bad tasting, (g) made me feel dizzy/nauseated, (h) unpleasant. These response options were recoded into separate dichotomous variables (1 = endorsed, 0 = not endorsed). Data analyses used a subset of these cigarette effects as dependent measures. We excluded “dizzy/nauseated” and “unpleasant” because they were too rarely endorsed (1.0% and 2.2% of reports, respectively) to permit multivariate statistical modeling. We also omitted the “bad tasting” response from reported analyses as it was redundant (inversely) with the “good tasting” response option (odds ratio predicting bad tasting from concurrent reports of good tasting = 0.04, 95% CI = 0.02 – 0.08).

Recent Smoking

A diary item asked “Have you smoked in the last 15 minutes?” (1 = yes, 0 = no). We used responses to this item to test the association between alcohol consumption and smoking.

Appraisals of cigarette effects could plausibly be influenced by how recently smoking has been performed (e.g., drug effects change over time, the sensory and hedonic effects of more recent cigarettes might be more vivid or available in memory, ratings of distant cigarettes might be colored by expectancies for the next cigarette). Therefore, this item was included as a predictor of cigarette effects and urge and tested as a moderator of alcohol effects.

Situational Variables.

A number of situational factors were considered as predictors/covariates of urge and cigarette effects. Diary time stamps were used to determine the time of day each entry was made and whether the interview was completed on a weekend day. Following Shiffman, et al. (1994), we represented time of day with a set of dummy-coded intervals: 4 am – 12 pm (reference category), 12 pm – 4 pm, 4 pm -8 pm, 8 pm -12 am, and 12 am – 4 am. A report was counted as a weekend report if logged between 6 pm Friday and 6 pm Sunday.

An interview item asked “In the last 15 minutes, have you been with: (check all that apply)” followed by these checklist options: (a) no one, (b) spouse/partner, (c) other family member, (d) other person you know, (e) stranger. We recoded responses to this item to create a presence of others variable, with a score of 0 indicating “no one” and 1 indicating any other response.

The interview also asked “In the last 15 minutes, have you seen any of these people smoke? (check all that apply)” followed by the same categories used to measure the presence of others. We recoded this item to indicate the presence of others smoking, with 0 indicating “no one” and 1 indicating any other response.

Current location was assessed with an item asking where participants were when the alarm sounded. Response options were: (a) home, (b) work or school, (c) in a vehicle, (d) bar/restaurant. (e) other public place, and (f) other. We recoded responses into a series of dichotomous variables. Locations were entered as a set in all analyses, with “work or school” as the reference category.

Statistical Analyses.

Odds ratios and associated confidence intervals were computed using generalized estimating equations (GEE) analyses performed with STATA software (STATA Corp, College Station, TX). GEE was used to account for the clustering of observations within subjects. These analyses specified a binomial family and logit link function (i.e., they were extensions of logistic regression) and used an AR1 autoregressive within-cluster working correlation structure. GEE is robust to misspecification of the working correlation structure (Zeger & Liang, 1986), and supplemental analyses confirmed that results were very similar when alternative working correlation structures were specified. We used GEE in preference to mixed modeling to enhance comparability with other EMA studies of smoking and alcohol use (Delfino, et al., 2001; Shiffman, et al., 2002; Shiffman & Paty, 2006; Shiffman, Paty, Gwaltney & Dang, 2004), because there is uncertainty regarding the reliability and interpretability of mixed models for binary outcomes (Carlin, Wolfe, Brown & Gelman, 2001) and because population-averaged GEE parameter estimates tend to be more conservative (e.g., Hu, Goldberg, Hedeker, Flay & Pentz, 1998).

Prior ecological studies testing associations between smoking or smoking urge and alcohol have sometimes (e.g., Shapiro, et al., 2002; Shiffman, et al., 1994) but not always (Delfino, et al., 2001; Shiffman, et al., 2002; Shiffman, et al., 2004; Shiffman & Paty, 2006) limited analyses to participants reporting a threshold level of drinking. We elected to model the entire data set because we fit population-averaged models rather than estimating within-person effects. Additionally, foundational analyses testing associations between situational factors and tobacco motivation did not involve alcohol; the entire data set provided the most complete characterization of these effects. Empirically, the pattern of results was very similar when analyses were restricted to smokers who reported drinking.

Preliminary analyses tested whether urge to smoke, ratings of reinforcing effects, and alcohol use were predicted by situational variables. In these models, time of day (entered as a set), weekend, presence of others, presence of others smoking, location (entered as a set), and recent smoking were tested individually as predictors in separate analyses.

Two sets of models tested whether alcohol consumption was associated with smoking urge and subjective ratings of smoking reinforcement. In one set, alcohol was entered as the sole predictor of each smoking motivation measure. A second set of models included all the situational factors as covariates and also included an interaction term assessing whether recent smoking moderated alcohol effects on smoking motivation. These multivariate, interactive models were more stringent, permitting a determination of the robustness of the alcohol effects and exploration of the extent to which the passage of time or retrospection might have affected the obtained results.

Results

Descriptive Findings.

Alcohol consumption was reported in 607 diary entries (7.9%). On average, participants reported alcohol consumption in 8.2 diary records. The median number of alcohol reports was 3. At or below the median, 18 participants (24%) did not report alcohol consumption, 6 (8%) reported drinking once, another 6 (8%) reported drinking twice, and 9 (12%) reported drinking in 3 records. Thirty-five (47%) smokers reported drinking on 4 or more occasions, and the maximum number of drinking reports was 50 (n=1). Smokers contributed differing numbers of valid diary records; the within-subject ratio of alcohol reports to total records ranged from 0 to 35%, with a mean of 8% and a median of 4%. In the 56 smokers reporting at least 1 drink, the ratio ranged from 1% to 35% with a mean of 10% and a median of 6%.

Recent smoking was reported in 3,345 diary entries (43.4%). A strong urge to smoke was endorsed in 3,503 of the diary records (45.5%). Overall, the most commonly endorsed cigarette effect was “reduced the urge” (n=4,331, 56.2%), followed by “relaxing” (n=2,905, 37.7%), “good tasting” (n= 2,286, 29.7%), “pleasant” (n=2,141, 27.8%) and “rush/buzz” (n=677, 8.8%).

Predicting Urge, Cigarette Effects, and Alcohol Use from Situational Variables.

Table 1 summarizes results of analyses predicting strong temptation/urge to smoke, cigarette appraisals and alcohol use from situational variables and recent smoking. Strong urge to

smoke was more likely to be reported in the late evening (8 pm -12 am) compared to the morning (4 am to 12 pm reference category). Urge was more likely when in the presence of others and when exposed to others who were smoking. Compared to the work/school location, urge was more likely when having been in a vehicle, other location, other public place, or bar/restaurant. Urge was more likely to be reported when recent smoking (past 15 minutes) had occurred (or, conversely, smoking was more likely when a strong urge was experienced).

Subjective effects of the most recently smoked cigarette also varied significantly as a function of context. Time of day indicators tended to be negatively related to rush/buzz reports, indicating rush/buzz was most likely in the morning. The remaining 4 subjective effects (good tasting, pleasant, relaxing, urge reduction) were more likely in the afternoon than the morning, and all of these except good tasting were also reported more in the early evening. In the late evenings, when urges were common, cigarettes were more likely to be rated as being pleasant and relaxing. The presence of others influenced ratings of relaxation and pleasantness, but not taste, rush/buzz, or urge reduction. Being with someone who was smoking influenced taste as well as pleasantness and relaxation ratings. With the exception of relaxing, all subjective effects were endorsed at a higher rate when participants were at a bar or restaurant (relative to work or school). The only other relation with location observed indicated that ratings of urge reduction were less likely at home than at work or school. Finally, all 5 subjective effects were more likely to be endorsed when the last cigarette was smoked recently (in the past 15 minutes) than when a longer interval had elapsed.

Past-hour alcohol consumption was strongly related to time of day, becoming more likely at later hours. Smokers were more likely to report having consumed alcohol on the weekend, in the presence of others and when with others who were smoking. Relative to work/school, alcohol was more likely to be reported in all other locations. As might be expected, the association between alcohol use and the bar/restaurant location was particularly strong. Notably, alcohol consumption was related to recent smoking (OR = 1.81, 95% CI = 1.53 – 2.14, $p < .001$).

For descriptive purposes, we re-estimated the associations between recent smoking and alcohol consumption, treating recent smoking as the dependent measure and accounting for all situational variables in a multivariate model. Alcohol remained a predictor of recent smoking (OR = 1.23, 95% CI = 1.02 – 1.49, $p < .05$). Thus, our data replicated the event-level association between drinking and smoking, and this effect was robust to controls for correlated contextual factors.

Univariate Models of Alcohol Effects.

The left portion of Table 2 summarizes univariate analyses predicting smoking motivation variables from past-hour alcohol use. When smokers reported consuming alcohol in the past hour, they were more likely to report a strong urge to smoke and to rate their most recent cigarette as giving them a rush/buzz, being good tasting, pleasant, relaxing, and reducing the urge to smoke.

Multivariate, Interactive Models of Alcohol Effects.

In multivariate models including controls for situational variables and an alcohol \times recent smoking interaction term (right portion of Table 2), main effects for alcohol were again found for urge, rush/buzz, good tasting, and urge reduction. Main effects for recent smoking were found for all dependent measures. These main effects were qualified by significant alcohol \times recent smoking interactions for 2 outcomes: rush/buzz and urge reduction. We probed these interactions in stratified analyses¹.

First, effects of alcohol were examined separately within strata defined by the presence or absence of recent smoking. Alcohol was a significant predictor of rush/buzz within recent smoking records (OR = 1.51, 95% CI = 1.08-2.11). The parameter estimate for alcohol was similar but not statistically significant (OR = 1.49, 95% CI = 0.94 - 2.36, $p = .09$) in records in which the last cigarette had been smoked more than 15 minutes prior to reporting.

Alcohol was unrelated urge reduction ratings (OR = 0.92, 95% CI = 0.76-1.10, $p = .34$) in recent smoking records but positively related to urge reduction when the last cigarette was smoked more than 15 minutes prior to reporting (OR = 1.40, 95% CI = 1.13-1.73, $p < .01$).

Next, the data were stratified by the presence or absence of alcohol and recent smoking was examined as the predictor. Recent smoking was associated with more frequent reports of rush/buzz (OR = 1.88, 95% CI = 1.60-2.22, $p < .001$) in the absence of alcohol but did not predict rush/buzz in alcohol records (OR = 1.15, 95% CI = 0.71-1.85, $p = .57$). Recent smoking positively predicted urge reduction in the absence of alcohol (OR = 1.28, 95% CI = 1.19-1.38, $p < .001$) but was negatively associated with urge reduction (OR = 0.74, 95% CI = 0.56-0.98, $p < .05$) in alcohol records.

In sum, the stratified analyses suggested rush/buzz tended to be associated with alcohol, whether smoking was recent or more distant. In contrast, reports of alcohol-related urge reduction were most likely when the cigarette being rated had not been recently smoked.

Discussion

Using records from smokers' day-to-day experiences, we found that alcohol consumption and smoking were associated in daily life. Momentary associations between drinking and smoking have been documented in prior diary studies involving heavy smokers (cf. Delfino, et al., 2001; Shiffman, et al., 2004; Shiffman & Paty, 2006; Shiffman, et al., 1994; Shiffman, et al., 2002). Prediction of smoking from drinking remained significant when controlling for correlated situational factors. Two prior diary studies (Shiffman, et al., 1994; Shiffman, et al., 2002) found an association between drinking and smoking when setting variables were controlled. However, in one study the association was reduced to a nonsignificant trend when conservative analytic methods were adopted to account for environmental restrictions on smoking (Shiffman, et al., 2002). On balance, the existing evidence suggests the cuing of smoking by alcohol consumption is reliably observed outside the confines of the laboratory.

¹The reported effects for stratified analyses included situational covariates. However, a modified set of time of day variables was used. The strong associations between drinking and time (Table 1) translated to a paucity of observations at earlier times of day in the alcohol-restricted analyses, leading to problems with model fitting. These problems were alleviated when times between 4 am and 4 pm were combined and treated as the reference category.

We found that alcohol consumption, smoking urge, and reinforcing effects of tobacco were associated with numerous situational factors. Alcohol use, in particular, was strongly predictable from factors such as time of day and weekend, location, and presence of other smokers. Drinking occurs in particular ecological niches; laboratory arrangements frequently do not resemble these naturally-selected contexts. These findings should encourage both the further use of ecologically sensitive field designs and incorporation of contextual manipulations in laboratory research.

Many of the same contextual factors associated with drinking were associated with natural variation in smoking urge and subjective reinforcement. Indeed, some univariate alcohol effects were liquidated when situational factors were covaried. Specifically, reports that cigarettes smoked with alcohol were pleasant and relaxing appeared to be accounted for by the setting in which the coadministration occurred. Accounting for contextual covariates permits an assessment of the robustness of alcohol effects. It must be remembered, however, that smokers actively select the conditions under which co-use of alcohol and tobacco occurs. Because they reflect the impact of these selected conditions, univariate analyses of alcohol effects may more completely characterize the typically-experienced or sought-after profile of co-administration effects in daily life.

Although alcohol effects were of primary interest, the general context-dependence of craving and subjective smoking reinforcement was noteworthy. Some findings were unsurprising. For example, the strong association between recent smoking and smoking urge accords with other diary studies suggesting craving is the most consistent antecedent of smoking (Shapiro, et al., 2002; Shiffman, et al., 2002; Shiffman, et al., 2004). Exposure to others who were smoking was associated with more frequent urge to smoke, consistent with other data suggesting urge/craving is robustly responsive to smoking-related cues (e.g., Carter & Tiffany, 1999; McCarthy, et al., 2006). Other findings were novel and may deserve further research attention. The reinforcing effects of smoking were related to social settings, especially the presence of other smokers. Presence of others smoking remained associated with ratings that cigarettes were pleasant in multivariate models, even controlling for alcohol consumption (OR = 1.26, 95% CI = 1.12-1.41, $p < .001$ in multivariate interactive model, not tabled). The bar/restaurant location was associated with most measured reinforcing effects. Surprisingly, alcohol consumption did not completely account for these findings. In the multivariate interactive models (not tabled), bar/restaurant remained associated with rush/buzz (OR = 2.68, 95% CI = 1.72-4.18, $p < .001$), pleasant (OR = 1.67, 95% CI = 1.26-2.22, $p < .001$) and urge reduction (OR = 1.38, 95% CI = 1.06-1.79, $p < .05$). These effects likely arise from associative processes, but further research is needed to probe and characterize modulation of smoking reinforcement by social and physical settings. If replicable, such findings may have implications for psychosocial treatments focused on smoking triggers. They may also be relevant for understanding the psychosocial impact (to smokers) of policies prohibiting smoking in settings such as taverns, restaurants, and other convivial public venues.

Consistent with one prior diary study (Delfino, et al., 2001), we found that alcohol use was associated with more frequent reports of strong temptation or urge to smoke. The statistical association between alcohol and urge was smaller but remained significant when these

contextual factors were included in the model. Although strong causal conclusions cannot be drawn from our correlational findings, the results are congruent with laboratory research demonstrating that smoking urge is specifically influenced by the pharmacologic effects of alcohol (Burton & Tiffany, 1997; Epstein et al., 2007; King & Epstein, 2005; Kouri, et al, 2004; Sayette, et al., 2005).

To our knowledge, this is the first ecological study to examine the effects of alcohol on ratings of the reinforcing effects of cigarettes. When smokers reported having consumed alcohol, they were more likely to rate their last cigarette as producing a rush/buzz, being good tasting, pleasant, relaxing, and reducing the urge to smoke. In a multivariate interactive model incorporating situational covariates, alcohol predicted ratings of rush/buzz, good tasting, and urge reduction, but effects for rush/buzz and urge reduction were qualified by interactions between drinking and the recency of smoking. Overall, the findings corroborate laboratory-based findings that alcohol enhances the subjectively rewarding effects of smoking, but also suggest that some effects are context- and time-dependent.

Smokers were more likely to report that cigarettes were good tasting when they had consumed alcohol. Taste satisfaction has been identified as a major motive for smoking and correlates strongly with other measures of positive reinforcement (Piper, et al., 2004; Brandon & Baker, 1991). Taste may play a role in modulating drug intake; sensitivity to bitter taste appears to confer some protection against smoking (Cannon, et al., 2005; Enoch, Harris, & Goldman, 2001; Snedecor, Pomerleau, Mehringer, Ninowski, & Pomerleau, 2006) and drinking (Duffy, Peterson, & Bartoshuk, 2004). Alcohol does not inevitably cause consumables to be rated as better tasting. For example, feeding research suggests that alcohol increases food intake but this effect is not mediated by changes in the rated pleasantness of food (Caton, Marks, & Hetherington, 2005). Smokers report that many foods and beverages alter the taste of cigarettes, and alcohol is among the most frequently cited taste enhancers (McClernon, Westman, Rose & Lutz, 2007). Research into the mechanisms through which alcohol might specifically enhance the taste of cigarettes may be warranted. Rival hypotheses should also be considered. Smokers may use diverse sets of descriptors to report cigarette effects, expressing pleasure both via the language of taste and terminology associated with central effects (e.g, rush/buzz). Diary reports of good taste might have been influenced by the taste properties of the alcoholic beverage in addition to or instead of cigarette taste².

There is some evidence that rush/buzz is an especially important subjective response to tobacco. Retrospective studies suggest that experiencing a rush or buzz in response to the first few lifetime cigarettes is associated with progression to regular smoking and degree of tobacco dependence³ (DiFranza, et al., 2004; Pomerleau, Pomerleau, & Namenek, 1998; Pomerleau, Pomerleau, Namenek, & Marks, 1999) as well as a tendency to experience

²At each interview, smokers indicated the activity they were engaged in when the alarm sounded. One response option was "eating." Current eating was univariately associated with past hour alcohol consumption (OR = 1.79, 95% CI = 1.26-2.55, $p < .001$), but reports that cigarettes were good tasting were not predicted by current eating (OR = 0.93, 95% CI = 0.79-1.10, $p = .41$). All reported associations between alcohol and good tasting remained significant when eating was included as an additional covariate.

³Indeed, in this sample, the tendency to report a rush/buzz was significantly predicted by FTND scores, OR = 1.33, 95% CI = 1.24 – 1.42, $p < .001$.

euphoric effects in response to nicotine challenge after smoking deprivation (Pomerleau, Pomerleau, Mehringer, Snedecor, & Cameron, 2005). Smokers who recall experiencing a rush/buzz to their first cigarette are also more likely to report deriving a rush or buzz from their first lifetime alcoholic beverage (Pomerleau, Marks, Pomerleau, & Snedecor, 2004), suggesting that this response domain may mark a general sensitivity to the reinforcing effects of drugs (Perkins, Fonte, Ashcom, Broge, & Wilson, 2001). If rush/buzz is an important component of reinforcement, the findings may indicate that alcohol increases the reward value of smoking through its actions on central reward systems.

Among the cigarette effects we examined, rush/buzz was the least common (present in only 8.8% of all reports). If rush/buzz is a valued but rare subjective response to smoking, then the ability of alcohol to increase its likelihood may be an important mechanism that accounts for co-use of alcohol and tobacco. Rush/buzz was related to time of day, being most likely in the morning hours (Table 1). This diurnal trend may be related to repletion of nicotine when smoking after waking or morning caffeine consumption⁴. Alcohol consumption was also related to time of day (Table 1), but in the opposite direction. Alcohol may be used to increase the probability of attaining euphoric responses to smoking at times of day when they are otherwise unlikely to be experienced.

Alcohol interacted with smoking recency in predicting rush/buzz reports, an effect probed in a series of stratified analyses. The effect of alcohol in analyses limited to recent smoking records was of special interest. This analysis isolated the immediate consequences of smoking and approximated a common diary design featuring immediate, event-contingent recording of smoking. Notably, alcohol was associated with rush/buzz within the recent smoking records.

However, the effect of alcohol on rush/buzz reports was not limited to the subset of recent smoking records; the interaction suggested alcohol and rush/buzz tended to be associated, regardless of the latency since smoking. In the absence of alcohol, rush/buzz effects may be short-lived and thus normally captured only when diary reports occur soon after smoking. Alcohol might prolong euphoric sensations from smoking, increasing the likelihood of rush/buzz reports over a wider range of post-smoking intervals. Intuitively, one might expect smoking rate to decrease after drinking if alcohol prolongs pleasant or euphoric effects of smoking. However, affective/hedonic response may be only one component of reinforcement (e.g., White, 1996). If rush/buzz reports serve as readouts of activation in approach motivation systems (e.g., Stewart, de Wit & Eikelboom, 1984; Baker, Morse, & Sherman, 1987), prolonged effects might translate to behavioral activation and an increase in the rate of drug self-administration. Alternatively, the interaction effects might be secondary to the tendency for alcohol to increase smoking rate. A locally accelerated smoking rate would decrease the true temporal distinction between “recent” and “distant” cigarettes, with a corresponding reduction in the explanatory power of recent smoking. Finally, the interaction

⁴Exploratory analyses tested whether caffeine use might account for diurnal pattern in rush/buzz. Like rush/buzz, caffeine use was less likely at later times of day (12 pm-4pm, OR = 0.89, 95% CI = 0.79-1.01, p=.08; all other time intervals, ORs = 0.37-0.59, ps<.001). Caffeine was a significant univariate predictor of rush/buzz (OR = 1.23, 95% CI = 1.06-1.43, p<.01). In a model predicting rush/buzz from caffeine, alcohol, situational variables, and recent smoking, caffeine use was not significant (OR = 1.15, 95% CI = 0.98-1.35, p=.09) but alcohol was associated with rush/buzz (OR = 1.36, 95% CI = 1.02-1.82, p<.05).

may simply reflect a tendency to conflate the (more enduring) intoxicating effects of alcohol and the after-effects of smoking per se in self-reports. Controlled laboratory studies and targeted diary protocols may prove useful in distinguishing among these possibilities.

Considered alone, alcohol was associated with more frequent reports that cigarettes reduced urge to smoke. Recent smoking moderated the relation between alcohol and urge reduction. Notably, when analyses were limited to reports containing recent smoking, alcohol was unrelated to urge reduction. Instead, alcohol's effect on urge reduction appeared to be limited to cigarettes smoked more than 15 minutes prior to the diary entry. The recent smoking variable potentially discriminates between immediate and delayed drug responses. From this time course perspective, smoking urge reduction would appear to be primarily a late-arising consequence of coadministration. Because the general trend was for urge reduction to be predicted by recent smoking (Table 1) one might tentatively infer that alcohol use delays satisfaction of smoking urges. An alternative possibility is that urge reduction ratings explain the absence of recent smoking. That is, one may be most likely to resist smoking in the presence of a potent cue like alcohol if the last cigarette was especially satisfying. Finally, alcohol (or craving for cigarettes arising from alcohol use) may merely bias memory of cigarette effects, inflating incentive-based appraisals of past experience. When the rated cigarette is more distal from the diary report, ratings are more likely to be influenced by smoking deprivation and biases of retrospection. In the context of mild smoking deprivation, alcohol augments expectations of positive reinforcement from smoking (e.g., Kirchner & Sayette, 2007). The tendency to rate remembered cigarettes as especially urge-reducing may reflect the biasing of memory for the last cigarette by these kinds of immediately-experienced motivational processes. Sayette and colleagues (2005) found that compared to a placebo beverage condition, deprived smokers administered alcohol not only reported stronger craving to smoke but also displayed more positive facial expressions when exposed to smoking cues. They noted that this combination may reflect a hedonically positive "savoring" of smoking cues under alcohol. Our interaction effects may reflect this kind of savoring process. Further research is needed to determine if these urge reduction effects are replicable, as they appear at odds with some laboratory data (Rose, et al., 2004).

Several limitations should be borne in mind when interpreting the findings. The diary merely assessed whether or not alcohol had been consumed in the past hour. As a consequence, information concerning the dose of alcohol consumed was not available. Alcohol's effects on smoking motivation are likely to be dose dependent (King & Epstein, 2005; Kouri, et al., 2004). The precise latency between the drink(s) and the diary report is also not known. Because we assessed past-hour alcohol consumption, it is likely that our assessments were predominately capturing effects associated with the rising limb of the BAC curve. It is possible that, in some instances, drinking occurred slightly more than one hour prior to the assessment; these records would be counted as non-drinking occasions but ratings could be influenced by undetected alcohol. Although we used near-real time assessment, there was still some uncertainty about temporal order of key behaviors. For example, it is logically possible for a person to report both drinking in the past hour and smoking in the past 15 minutes without the cigarette having been consumed under the influence of alcohol. However, ratings should reflect the influence of alcohol when drinking was reported. Because we did not require smokers to initiate recordings each time they smoked, some

cigarette ratings were retrospective. The analyses accounted for whether or not smoking was reported in the past 15 minutes, but we did not know the duration of retrospection for cigarettes in records for which recent smoking was not reported, and so important time-based effects may have been obscured. Cigarette effects were assessed as present or absent in a checklist format. This measurement strategy was driven by a desire to manage assessment burden in the larger study of smoking cessation. Future, more focused investigations might incorporate continuously-scaled, multi-item assessments of cigarette effects that could prove more sensitive. Our sample was mostly white, composed of persons who volunteered for a smoking cessation trial, and was recruited in Wisconsin, a state that consistently ranks among the highest in per capita alcohol consumption (Lakins, Williams, & Yi, 2006). Results might differ in samples with greater racial diversity, in smokers not considering quitting, or in regions with different drinking cultures. Finally, we only assessed tobacco-related motivational variables. Nicotine affects preference for alcohol and subjective responses to alcohol (Acheson, Mahler, Chi, & de Wit, 2006; Barrett, Tichauer, Leyton, & Pihl, 2006; Kouri, et al., 2004). A complete analysis of motivational mechanisms contributing to alcohol-tobacco co-use would require attention to these processes.

Notwithstanding these limitations, our findings contribute valuable descriptive information to the growing literature linking alcohol and tobacco. The study identified a number of contextual factors that predicted both alcohol use and variation in smoking motivation. These observations may inform the design of future laboratory work; it may be profitable to systematically manipulate variables like time of day, social arrangements, physical environments, and the rate or recency of smoking when investigating alcohol effects. The findings replicate earlier research, using a variety of designs, documenting an increase in smoking behavior under the influence of alcohol. Additionally, the findings characterized the effects of alcohol on smoking motivation outside the laboratory that may account for the event-level association between drinking and smoking. In ecological context, drinking is associated with more smoking urge and a hedonically positive profile of tobacco effects. Of these, effects on cigarette taste, rush/buzz, and perceptions of urge reduction were strongest. Urge reduction was unique in that it was limited to reports on remembered cigarettes, an intriguing observation that may correspond to laboratory findings of acute modulation of smoking expectancies by alcohol. Further research, using both ecological and laboratory designs, is necessary to determine the robustness of these effects and to probe the specific pharmacologic, associative, and cognitive mechanisms that could account for them.

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Table 1.

Odds ratios from univariate analyses predicting urge to smoke, cigarette effects, and alcohol consumption from situational variables and recent smoking.

Predictor	Dependent Measure						
	Urge	Rush/Buzz	Good Tasting	Pleasant	Relaxing	Reduced Urge	Alcohol
Time of day							
12pm-4pm	1.06	0.76 **	1.15 ***	1.18 **	1.19 ***	1.16 ***	6.78 ***
4pm-8pm	1.11	0.81 *	1.10	1.23 ***	1.28 ***	1.09 *	35.53 ***
8pm-12am	1.20 ***	0.67 ***	1.01	1.31 ***	1.37 ***	1.03	64.40 ***
12am-4am	1.01	0.90	0.83	1.49	1.28	1.22	129.16 ***
Weekend	0.98	0.99	1.03	1.06	0.98	0.95	1.99 ***
Presence of others	1.21 ***	0.99	1.06	1.22 ***	1.13 *	1.02	2.16 ***
Presence of others smoking	2.06 ***	1.15	1.22 ***	1.52 ***	1.31 ***	1.04	3.92 ***
Location							
Home	0.97	1.17	0.96	1.10	1.03	0.88 **	5.97 ***
Vehicle	1.83 ***	1.25	1.01	1.13	0.89	1.01	3.17 ***
Other public place	1.54 ***	1.24	1.01	1.10	0.97	0.92	8.39 ***
Other location	1.41 ***	1.17	0.88	1.00	0.85	1.05	9.12 ***
Bar/restaurant	2.17 ***	2.74 ***	1.43 ***	2.25 ***	1.22	1.47 **	81.87 ***
Recent smoking	6.19 ***	1.75 ***	1.30 *	1.44 ***	1.48 ***	1.23 ***	1.81 ***

Note:

* p<.05,

** p<.01,

*** p<.001.

The reference category for the Time of Day variable is 4am to noon. Work/school was the reference category for the Location variables.

Odds ratios and associated confidence intervals from univariate and multivariate interactive models predicting urge to smoke and cigarette effects.

Table 2.

Dependent Measure	Univariate Model			Multivariate Interactive Model					
	Alcohol			Alcohol		Recent Smoking		Alcohol × Recent Smoking	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	
Urge	1.75 ^{***}	1.49 – 2.05	1.55 ^{**}	1.19 – 2.01	6.19 ^{***}	5.58 – 6.88	0.83	0.59 – 1.17	
Rush/Buzz	1.31 [*]	1.02 – 1.68	1.83 ^{**}	1.22 – 2.74	1.83 ^{***}	1.56 – 2.16	0.59 [*]	0.36 – 0.97	
Good Taste	1.27 ^{***}	1.13 – 1.42	1.31 ^{***}	1.09 – 1.57	1.29 ^{***}	1.20 – 1.38	0.87	0.69 – 1.09	
Pleasant	1.31 ^{***}	1.13 – 1.51	1.12	0.89 – 1.40	1.36 ^{***}	1.25 – 1.49	0.80	0.60 – 1.06	
Relaxing	1.23 ^{**}	1.06 – 1.43	0.91	0.72 – 1.16	1.44 ^{***}	1.31 – 1.58	1.17	0.87 – 1.59	
Reduced Urge	1.17 [*]	1.03 – 1.32	1.41 ^{**}	1.16 – 1.71	1.29 ^{***}	1.20 – 1.39	0.65 ^{***}	0.51 – 0.84	

Note:

* p<.05,

**

p<.01,

p<.001.

In the univariate models, alcohol consumption was the sole predictor. The multivariate interactive models controlled for situational variables listed in Table 1 (including recent smoking) and included an alcohol × recent smoking interaction term.